FINAL

Monitoring Plan for Big Thompson and Fourmile Watershed Flood Recovery Projects

Larimer and Boulder Counties
Colorado

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Prepared for:

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1.0 INTRODUCTION

In September 2013, heavy rains fell on the Front Range of Colorado for five consecutive days, causing catastrophic flooding and significant damage to public and private property and infrastructure. Rivers and streams throughout the region overtopped their banks, reclaimed historic floodplains, transported tons of water and sediment, carried homes and cars downstream, and left much of the landscape denuded of vegetation. Boulder and Larimer Counties were among 18 counties that were part of the Presidential Disaster Declaration on September 24, 2013. Nearly all of the watersheds along the Front Range were impacted by the devastating floods, including the Big Thompson River Watershed in Larimer County and the Fourmile Creek Watershed in Boulder County.

Along with several other coalitions, the Big Thompson Watershed Coalition (BTWC) and the Fourmile Watershed Coalition (FWC) formed in the wake of the flood to spearhead recovery efforts in their watersheds. In the span of five years, these coalitions brought communities and local stakeholders together; created master plans to identify and prioritize needs; secured federal, state, and local funding to complete flood recovery projects; and implemented dozens of river rehabilitation projects within their watersheds.

Careful and consistent monitoring of these projects can be useful in evaluating whether the flood recovery projects have achieved their stated goals and led to reach-scale improvements. Monitoring can also help to determine whether interim actions may be taken to adaptively manage these projects toward meeting their objectives and positively impacting their river corridors. This document is designed to support the BTWC and FWC in their efforts to monitor the effectiveness of flood recovery projects implemented in their respective watersheds in response to the September 2013 Front Range floods.

2.0 MONITORING PLAN GOALS AND METHODS

The Big Thompson Watershed Coalition and the Fourmile Watershed Coalition share a vision of watershed health and resilience for their respective watersheds. This monitoring plan is meant to help guide the coalitions in assessing areas of improvement and ecological lift within their watersheds.

The primary goals of this monitoring plan are:

(1) To monitor the long-term effectiveness of flood recovery projects by tracking changes to stream health factors and key watershed functions over time; and

(2) To inform adaptive management decisions so that if needed, actions can be taken to keep project areas on a trajectory toward watershed health and resilience.

Because flood recovery projects were conceived, designed, permitted, and implemented in extremely short timeframes, limited post-flood and pre-project monitoring data were collected. In addition, project design reports often lacked detailed information about project goals and objectives. While retrospective interviews may be conducted with project designers and engineers to gather more information about specific project goals, this monitoring plan will not assume any specific project objectives or create quantitative performance standards or management triggers. Rather, it will guide the coalitions in assessing positive, neutral, or negative trends in stream health factors as a way to determine whether reaches are on a trajectory toward watershed health and resilience, and to assess whether identified project-specific objectives are being met. Recommendations made in this monitoring plan also consider the limited resources of the coalition to conduct monitoring activities at multiple project sites.

2.1 LEFT HAND WATERSHED CONCEPTUAL MODEL AND KEY WATERSHED FUNCTIONS

The Left Hand Watershed Center's (LHWC, formerly Lefthand Watershed Oversight Group) adaptive management guide (Building Watershed Resilience through Adaptive Management, Appendix A) provides a useful and relatively detailed conceptual model that can be used as a resource to understand and define their vision of watershed health and resilience. The conceptual model includes illustrations and descriptions of different watershed zones (canyons, alluvial fan, high plains) through time (pre-flood, post-flood, restoration, desired potential future condition), depicting how the watershed has changed over time and illustrating a trajectory toward resilience. The model proposes to track the trajectory toward resilience through monitoring of key watershed functions, identified in LHWC's monitoring documents as:

- Flow Regime (water quantity, timing, and floodplain connection);
- Stream Form (physical stream channel, including channel dimensions, gradient, and lateral and bank stability);
- Sediment Regime (sediment, including bed structure, sources, and transport); and
- Ecological Community (aquatic and riparian habitat and biological communities).

Performance standards and management triggers are listed in LHWC's documents and may be used by BTWC and FWC to help quantify or determine whether adaptive management actions are warranted at a particular time. While many of these triggers are qualitative, they can still be used to assess trends and trajectories toward watershed health and resilience.

2.2 CWCB FLOOD RECOVERY MONITORING PROGRAM

A number of the project sites in both the Big Thompson and Fourmile watersheds are part of the Colorado Water Conservation Board's (CWCB) flood recovery monitoring program. The CWCB prioritized 27 of more than 100 flood recovery projects as high-priority reaches where detailed baseline data were collected in 2017 and 2018 (as soon as practicable after project completion) to track changes and future progress. In particular, 4 projects in the Big Thompson watershed sponsored by BTWC (West Creek, Fox Creek, North Fork, and Jasper Lake), and 2 projects in the Fourmile watershed sponsored by FWC (Wall Street and Ingram Gulch), or almost 30 percent of projects from each watershed, are included in the CWCB monitoring program.

The CWCB flood recovery monitoring program uses baseline and future monitoring data to understand stream health trends and to evaluate the goal of enhancing watersheds and stream corridors. The program applied the Colorado Stream Health Assessment Framework (COSHAF), a Colorado-specific tool that uses 11 variables to evaluate the key factors that determine the health and resilience of a stream reach, to ensure that all relevant aspects of stream health are considered, and to serve as a guide for determining which monitoring parameters are most relevant. Upward or downward trends in stream health factors are tracked using selected parameters, indicators, and observations made during future monitoring efforts. COSHAF identifies the following 11 variables as key factors that determine the health and resilience of a stream reach:

- Flow Regime (amount and timing of water supply);
- Sediment Regime (amount, timing, and type of sediment supply);
- Water Quality (physicochemical properties of water);
- Landscape (buffer capacity and aquatic and terrestrial habitat connectivity);
- Floodplain Connectivity (frequency, extent, and duration of floodplain saturation or inundation);
- Riparian Condition (riparian habitat condition, including vegetation structure and diversity);
- Organic Materials (supply of wood and detritus to the reach);
- Morphology (reach morphology including stream evolutionary state, planform, dimension, and profile);
- Stability (ability of the reach to maintain form via resistance, dynamic equilibrium, and resilience);
- Physical Structure (physical habitat including water depth, velocity, structural components, and substrate); and
- Biotic Structure (community and trophic structure of the organisms in the reach).

Of the 11 variables, the first 4 are watershed-scale and the remaining 7 are reach-scale. Because rehabilitation and recovery projects were completed at a reach scale, monitoring activities and selected parameters focus largely on the 7 reach-scale factors. Methods used in the CWCB flood recovery monitoring program are described in detail in their Flood Recovery Monitoring Methods report (Appendix B).

2.3 BTWC/FWC PROJECTS AND MONITORING METHODS

This document serves as a plan for monitoring 14 flood recovery projects in the Big Thompson Watershed and 7 flood recovery projects in the Fourmile Watershed. The projects addressed in this plan are listed in Table 1.

Table 1. BTWC and FWC Flood Recovery Projects

Project Name	Waterbody	Included in CWCB Monitoring Program?
Big Thompson River Watershed		
West Creek	West Creek	Yes
Fox Creek	Fox Creek	Yes
North Fork	North Fork Big Thompson	Yes
Waltonia	Big Thompson River	
Mountain Shadows 1	Big Thompson River	
Mountain Shadows 2	Big Thompson River	
Moodie	Big Thompson River	
Cedar Cove	Big Thompson River	
Jasper Lake	Big Thompson River	Yes
Sylvan Dale Ranch	Big Thompson River	
City of Loveland Water Treatment Plant	Big Thompson River	
Wild Natural Area (& Neighbors)/Reach 28	Big Thompson River	
Rossum-Wilson	Big Thompson River	
Rist-Goss Diversion	Big Thompson River	
Fourmile Creek Watershed		
Sunset Pond	Fourmile Creek	
Wall Street	Fourmile Creek	Yes
Ingram Gulch	Ingram Gulch	Yes
Upper Ingram	Ingram Gulch and gullies	
Black Swan	Fourmile Creek	
Logan Mill	Fourmile Creek	
Lower Fourmile Bank Protection Projects	Fourmile Creek	

Building from the LHWC and CWCB monitoring frameworks, this monitoring plan will provide a guide for monitoring each of the projects listed in Table 1. Section 3 of this monitoring plan will identify and describe a range of monitoring parameters and methods that are useful for assessing stream health. Parameters are grouped into physical, chemical, biological, and “other” categories. These parameters relate directly to the key watershed functions identified by LHWC, as well as the stream health factors used in the COSHAF model.

Sections 4 (Big Thompson Watershed) and 5 (Fourmile Watershed) of the monitoring plan will contain a sub-section for each of the projects listed in Table 1. These sections will describe each flood recovery project, list its stated goals and objectives, and inventory and document project details. Based on that information, the plan will identify the parameters and methods from Section 3 that may be useful in assessing the condition of the project reach, including recommended frequencies and specific locations to the extent possible.

For projects included in the CWCB monitoring program, baseline information from those monitoring efforts should be used to assess trends. For projects not included in the CWCB's program, limited baseline data will be available, but data should still be evaluated regularly to assess whether positive, neutral, or negative trends are being observed for stream health factors and/or key watershed functions.

While this monitoring plan is designed to track improvements or declines in reach-scale stream corridor health and resilience over time, particularly as they relate to specific project goals, the plan also intends to serve as a tool to inform adaptive management decisions. If data and observations show that parameters related to a particular stream health factor or watershed function are worsening over time, watershed coalitions can intervene and initiate actions to alleviate those conditions. For example:

- If cross-section surveys show incision and disconnection of the primary channel from the floodplain, the constructed bankfull benches may not be inundated every 1.5 to 2 years as intended. Floodplain wetness, inundation levels, riparian plant species, and cross-sectional channel dimensions would then be checked, and adaptive management treatments related to reconnecting the floodplain may be initiated to remedy the condition.

- If photo points and SVAP assessments show dry-up points or extremely shallow sections of the main channel where flow is spread out across the channel and water depths are too shallow to support aquatic life during times of low flow, cross-sectional channel dimensions would be checked and adaptive management treatments, including channel shaping, installation of a low-flow channel, or thalweg definition may be implemented.

The monitoring plan can also produce information that will prove helpful to project designers. For example, if design engineers or geomorphologists expected a component of their design to function a certain way and monitoring illustrates that something different is occurring, useful information for the design of future projects may be gleaned. Some examples include expectations about plant survival, floodplain bench or overflow channel activation (i.e., at what flow or recurrence interval is an area expected to be wet), success and persistence of pool scour mechanisms, and functionality of installed structures. This type of information can be shared with project designers, and may also be used to inform adaptive management decisions and actions.

3.0 MONITORING PARAMETERS

This section describes the suite of potential physical, chemical, biological, and other monitoring parameters available for use at the flood recovery project sites. Links to applicable existing methods, approaches, and/or Standard Operating Procedures (SOP) are provided to the extent possible. In the appropriate section, each parameter is described, potential reasons for its use are identified, and links or suggestions for suitable methods are provided.

3.1 PHYSICAL PARAMETERS

Physical surveys are conducted to document how the physical project area moves, shifts, and changes over time. Physical parameters that may be monitored include cross-section and longitudinal profile surveys, substrate surveys, surveys of installed structures, and surveys of aquatic habitat features. Each survey type is described in more detail below**.**

3.1.1 Cross-Section Surveys

Cross-section (XS) surveys are linear arrays of station-elevation data measured perpendicular to the channel across the stream, riparian area, and floodplain. Elevations are plotted at stations (particularly grade breaks) across specific project cross-sections to see how ground height has changed over time as a result of aggradation, degradation, and other geomorphic processes.

Repeat cross-section surveys with a common datum and coordinate system are a powerful tool for tracking changes at a project site over time. They enable detection of geomorphic change that might occur as a result of flood scour, bed-material aggradation, or lateral channel migration (USGS 2015, CWCB 2013), and allow for tracking changes in channel dimensional shape and size, migration, bank erosion, lateral accretion, bed scour, incision, deposition, and other processes. Cross-section surveys can also be used to calculate channel dimension parameters (e.g., cross-sectional area, width, depth, width-to-depth ratio, bank height) (Beardsley and Johnson 2018).

To collect cross-section data, the elevation at each station across the XS is recorded relative to control points on the site. Established control points have a set location and elevation, and therefore increase the accuracy of the survey and allow for survey work to be relocated by future parties despite changes that may have occurred to the channel, banks, or floodplain. XS surveys may be conducted using any appropriate survey gear, including tape and rod, laser level, survey-grade Global Positioning System (GPS), and total station. Where possible, XS end points should be marked with capped rebar pins, and their locations should be recorded on a GPS device so that they can be located in the future. A detailed SOP produced by the CWCB that may be referenced when completing cross-section surveys is provided in Appendix C.

The ideal time to conduct cross-section surveys is during fall when water levels are low and significant geomorphic change is unlikely. Unless a major spring runoff event or flood has occurred, it may not be cost-effective or a good use of time to conduct cross-section surveys annually. Photo points (discussed in Section 3.4.1) are an effective way to document changes from year to year and can be reviewed to decide whether investing in cross-section surveys is worthwhile. If flows stay near bankfull even during spring runoff, cross-section surveys are only recommended every 3-5 years. If flows are higher, these surveys may be conducted more frequently. At least one member of the survey team should have technical training or experience to ensure accurate surveys that include an appropriate level of detail.

3.1.2 Longitudinal Profiles

Longitudinal profile surveys are elevation profiles measured along the project area from upstream to downstream in order to track changes in bed elevation and grade breaks. Elevations are plotted at stations (particularly grade breaks) along the vertical profile of a project area to see how the local topography has changed over time as a result of geomorphic processes.

The purpose of the longitudinal profile survey is to capture the topographic variability of the streambed and floodplain, as well as significant channel-formed features (CWCB 2013, USGS 2015). These surveys are useful in characterizing the average slopes and depths of bed features such as riffles, pools, glides, runs, step-pools, and cascades. They show the range of channel gradients, spacing and length of channel features, type and distribution of grade controls, and pool scour depths. Longitudinal profile surveys are particularly useful in assessing whether a headcut is moving up a channel, whether the channel is becoming incised, how the size of habitat features (e.g., riffles, pools) is changing, whether habitat features are migrating, whether pools are being appropriately scoured or filling in, and other related questions.

Longitudinal surveys define the downstream slope or grade, and are typically measured at the thalweg (i.e., deepest part of the channel), but may also include the left and right edge of water, left and right banks, tops of gravel bars, levees, and terrace scarps (CWCB 2013). Data should be recorded at locations where changes in elevation occur (e.g., riffle crest, riffle tail, pool, pool tailout, headcut), and can also be documented at other areas of interest (e.g., bars, islands, side channels, eroding banks, berms, in-channel structures). As with cross-section surveys, the elevation at each station is recorded relative to established control points at the site. A detailed SOP produced by CWCB that may be referenced when completing longitudinal profile surveys is provided in Appendix C.

Longitudinal profiles may be conducted to measure vertical stability as time and budget allow. They can be particularly useful in areas where conveyance, sedimentation, or pool depth are concerns. Gathering longitudinal profile data may also be warranted in canyon locations where room for cross-section surveys is especially limited. In general, these are recommended on a case-by-case basis to answer particular questions or evaluate specific project goals. If conducted, they only need be repeated every 3-5 years or during the low-flow period following a significant flow event. As with XS surveys, at least one individual involved in the longitudinal profile survey should have technical training or experience to ensure accurate and appropriately detailed surveys.

3.1.3 Thalweg Depth Measurement

A well-defined thalweg, or deepest portion of the channel, is important for survival of aquatic biota during times of low flow. A common objective of many flood recovery rehabilitation projects is definition of a low-flow channel for the benefit of resident aquatic species. Repeating measurements of thalweg depth provide an indication of the quality of low-flow habitat provided by the project, and indirectly measure of the stability of the constructed low-flow channel.

A thalweg survey consists of measuring the depth of the thalweg at regular intervals throughout a project reach and computing the average depth. Specifically, thalweg depth should be measured using a range pole, stadia rod, or similar measuring stick at regular intervals depending on the length of the project reach (a total of approximately 50 measurements should be targeted). Depths measurements should be recorded, and an average thalweg depth computed. Comparison of average depths over time will provide information on habitat, stability, and persistence of a well-defined low-flow channel. Performing thalweg surveys is recommended during low flows, and these surveys must be conducted during comparable flows from year to year (e.g., every fall).

3.1.4 Substrate Surveys

Substrate surveys are conducted to characterize the composition of the streambed and banks by quantifying the size of bed material, and are generally done using a standard Wolman pebble count procedure (Wolman 1954). Pebble counts are used as a monitoring tool particularly in areas where fine sediment loading and fish spawning habitat availability are primary concerns. These data are relatively easy to collect, and provide information about gross changes to streambed composition.

Procedures for conducting Wolman pebble counts are provided in Appendix D. In general, bed substrates are sampled at riffle features on regular intervals (e.g., heel-toe or short steps) across the active stream bed in a zig-zag pattern. The diameters of the intermediate axis of at least 100 particles along the transect are measured using a standard ruler or gravelometer, and classified into Wentworth class sizes (gradations of sand, gravel, cobbles, and boulders) to yield a grain-size distribution for the sampled riffle.

Substrate samples can also be conducted on point bars to provide information about newly deposited material. Recording the median (D50) and maximum (Dmax or D100) particle sizes can provide useful information about stream power, competency, and the relative size of material being transported and deposited. A rapid method for point bar assessments developed by TJ Burr at NRCS is outlined in Appendix E (Rapid Point Bar Assessment Method). This method involves visually assessing the downstream third of the selected point bar; measuring the intermediate axis of at least ten particles that represent the average particle size on the point bar and averaging those measurements to determine the D50; measuring the intermediate axis of the largest 3 particles on the point bar and identifying the largest one as the D100/Dmax; and documenting the site.

At flood recovery project sites, pebble counts are recommended in areas where sedimentation is a concern, or at locations where project designers were intending to achieve a specific average bed material size. Point bar samples are useful in areas where project designs were driven significantly by sediment transport, or where project designers seek to verify their substrate sizing. Pebble counts and point bar assessments can easily be conducted by capable volunteers, landowners, or citizen scientists with little training. They are most effectively performed in low-flow conditions.

3.1.5 Structure Surveys

Structures installed as components of each flood recovery project may be monitored to ensure that the feature or structure is serving its intended function. However, it is important to note that while the qualitative and quantitative surveys of installed structures described in this section can be used as a tool to inform adaptive management decisions and actions, they are not a component of monitoring overall stream health. Conditions related to key watershed functions or stream health factors should be assessed independent of whether the installation of specific structures was meant to improve these conditions.

Structure surveys do not provide or substitute for an assessment of basic stream health factors to determine whether a project reach or stream segment is on a trajectory toward watershed health and resilience. Approaches to assessing and monitoring river health generally do not include assessments of specific installed structures. Rather, information gathered about the structure and function of a particular reach may provide insight into whether the intended goals of the structures (and of the overall project) are being met. A failing “structure” in and of itself is not detrimental if its intended functions are still being met, or if overall watershed health is still on a positive trajectory. Structures are often intended or expected to degrade over time, and the stream is expected to adjust naturally. The intention of many restoration actions is to “kick-start” or set the system up for recovery, rather than installing features that persist through time or are meant to be final products.

Photo points (discussed in Section 3.4.1) are useful tools for documenting changes in structures over time, but some more quantitative methods can also be employed. The CWCB’s Measurable Results Program (MRP) provides an in-channel structure assessment field form that allows an evaluator to rank the relative stability of the area surrounding the installed structure and to assess the condition of the structure itself (CWCB 2016a). The form also helps the evaluator determine the causes of impairment by listing and defining possible causes. This procedure may be used to assess constructed in-channel structures such as cross vanes and J-hooks. This SOP for Assessment of In-Channel Structures is provided in Appendix F.

In general, walking a project site and visually inspecting the installed grade control, bank protection, and other structures, specifically looking for items such as significant movement of structural components, signs of erosion, other divergences from post-construction appearance, or potential for unintended consequences, is recommended if resources are available. In lieu of filling out a formal form or checklist, photo documentation and/or narrative descriptions could be shared with project designers to obtain their input on whether adaptive management actions may be warranted.

Structure surveys should be performed in low-flow conditions where as much of the structure is as exposed as possible, but observing them at high flows can also be useful because more substantial flows have the greatest impacts on geomorphic change and stream form. Structures can be documented by citizen scientists, volunteers, or local landowners, but documentation should be reviewed and structures should be formally assessed by coalition staff or landowners who are familiar with the particular structure and its intended functions.

3.1.6 Aquatic Habitat Feature Surveys

Aquatic habitat features, or facet types, are combinations of water depth and velocity that define different habitat features in a stream during low-flow conditions. The four facets are:

- Riffle (fast, shallow) (or cascade, defined as very fast and shallow);
- Run (fast, deep);
- Pool (slow, deep); and
- Glide (slow, shallow).

Occurrence of varying depth and velocity patterns is an important feature of habitat diversity and quality. The presence of all four of these patterns in a high-gradient stream relates to the stream's ability to support and maintain a stable aquatic environment for resident aquatic species through all their life stages (Barbour et al. 1999). Furthermore, hydraulic diversity interacts with bedforms to influence bed material sorting processes that contribute to diversity in benthic habitat as well (Cluer and Thorne 2013). Aquatic habitat feature surveys are a useful and relatively easy tool for monitoring habitat variability, and are recommended for reaches where enhanced aquatic habitat was a primary or secondary objective.

The frequently cited and implemented EPA Rapid Bioassessment Protocol, Barbour et al. (1999), recommends 0.5 m (1.64 ft) as the depth criterion (less than 1.6 ft is considered shallow, greater than 1.6 ft is considered deep) and 0.3 m/sec (0.98 ft/sec) as the velocity criterion (less than 1 ft/sec is considered slow, greater than 1 ft/sec is considered fast) for all high-gradient streams. CWCB's monitoring team used 1 ft as the depth criterion and 1 ft/sec as the velocity criterion (Beardsley and Johnson 2018). For consistency and ease of implementation, CWCB criteria are recommended for flood recovery projects, but the depth criterion of 1 ft may be reduced for Fourmile Creek, Fox Creek, or other small tributaries.

In the detailed method used by CWCB and described in Appendix B, reaches were delineated into segments by walking the reach during low-flow conditions and marking transition points with a GPS. Stream segments are generalized across their width to allow for a coarse delineation that represents the dominant facet type for each segment. Depths and velocities may be measured using a stadia rod and current meter, respectively, but the experience of the CWCB monitoring team allowed them to visually estimate these parameters (classifications can be verified if needed). At project locations where baseline facet delineations have been completed, the CWCB monitoring team recommends that future surveyors look for obvious changes to baseline delineations to detect change rather than remapping project reaches in order to reduce error from different observers (Beardsley and Johnson 2018). Revisiting these facet delineations can be useful in tracking changes to habitat feature sizes and locations over time or seeing if the percentages of these features change significantly over time. This level of detail is useful for comparing reaches or for documenting major geomorphic changes.

A simpler, but still quantitative, method for surveying aquatic habitat involves recording the number of each facet type present within the project reach. This may be the preferred option in reaches that are especially long or non-wadeable, or if a sub-meter GPS unit is not available. Revisiting the site in the future and repeating the feature count will still provide a coarse assessment of aquatic habitat and help check to ensure that aquatic habitat diversity is being maintained over time. When using this method, the observer should consider making notes about the locations or attributes of certain features that might be useful to reference during future surveys (e.g., largest pool approximately 50 ft upstream of downstream end of site, longest riffle approximately 100 ft long under bridge). This simple method is referred to as the "rapid" method for aquatic habitat feature surveys in the project-specific monitoring sections (Sections 4 and 5).

Finally, the USFS Stream Inventory Handbook contains a method for inventorying aquatic ecosystems by channel unit (USFS 2016, provided in Appendix G). Using this method for a project reach or sub-reach can provide useful and detailed information about habitat types including size and depth. It is particularly applicable in small streams like Fourmile Creek, where the depth criteria specified above may not be met. The method involves parsing the channel into channel units based on velocity and turbulence, and measuring the length, wetted width, average depth, and maximum depth of each channel unit. This is a relatively precise way to track changes to pool habitat in small streams, and will also verify whether aquatic habitat diversity is being maintained over time. A modified field form to use when applying this method is provided in Appendix H.

Regardless of method, aquatic habitat surveys are easier and safer during low-flow periods. For comparability across years, they should also be conducted during similar flow rates (i.e., similar timing) each year. Experienced observers can conduct these surveys more efficiently, but citizen scientists or volunteers can also perform the surveys with some training.

3.1.7 Pool Area Mapping

Pool area is an important limiting factor for fish habitat. Therefore, if habitat is a primary project objective, pool area mapping may be the best and most objective tool for assessing aquatic habitat (as opposed to measuring the deepest location in a pool or tracking the size of individual pools). Using a handheld GPS during low-flow conditions, the CWCB monitoring team quantified pool area by delineating the pool perimeter (areas that are deeper than 1.5 ft plus the depth of the nearest downstream grade control feature are located within the perimeter of the pool) (Beardsley and Johnson 2018). This objective depth measurement is called the "residual pool depth" (RPD) and can be repeated in future surveys. More details for this method, as well as example mapping products, are provided in Appendix B. Pool area in small streams can also be quantified when the USFS channel inventory method (Appendix G) is applied. RPD and pool area are best delineated during low-flow conditions.

3.2 CHEMICAL PARAMETERS

Aquatic organism and stream substrate chemistry monitoring are beyond the scope of this monitoring plan and are not typical components of river restoration project monitoring. However, information about water quality is pertinent to the characterization of stream habitat. A combination of information about physical characteristics and water quality provide insight into a stream's capacity to support a healthy aquatic community, and about the presence of stressors (both chemical and non-chemical) to the aquatic ecosystem (Barbour et al. 1999). The sub-sections below discuss water quality monitoring at flood recovery sites.

3.2.1 Water Quality Parameters

Certain water quality measurements can be important for assessing stream health, particularly some standard parameters that can be measured *in situ* with a handheld water quality instrument that provides instantaneous results. Water quality meters should always be calibrated per manufacturer's instructions for reliable readings. Relevant water quality parameters include:

- Temperature: Water temperature can be recorded using a standard water quality meter or a thermometer. The ranges of many aquatic species are limited by temperature, so this parameter is important to measure from a habitat perspective. Shading from the riparian canopy, good hyporheic exchange with local groundwater, and seepage from spring-fed tributaries (in some cases) contribute to lower temperatures that support the cool- and cold-water fish species present in Colorado streams and rivers. Water temperature is recorded in degrees Celsius or Fahrenheit.

- Turbidity: Water clarity can be limited as a result of high levels of total suspended solids (TSS) in the water column. High TSS can be associated with reach-scale channel instability that produces elevated levels of fine sediment from bed scour and bank erosion (Cluer and Thorne 2013). Streams often show some turbidity after storm events, so prior weather conditions should be noted, especially if turbidity readings are high. Turbidity is generally recorded in NTU (Nephelometric Turbidity Unit).

- Dissolved Oxygen (DO): Dissolved oxygen is the amount of free oxygen present in the water column, and is important for the survival of fish and other aquatic species. To ensure accurate readings when using a water quality meter to record DO, the meter must be suspended in the water column and out of direct contact with the stream bed, which is sometimes difficult in shallow streams. DO is typically measured in micrograms per liter (µg/L).

- Conductivity: Conductivity is a measure of water's capability to pass electrical flow, which is related to the number of ions (i.e., dissolved salts) in the water. The ranges of some aquatic species, including fish and benthic macroinvertebrates, are limited by conductivity. This parameter is particularly important to record in areas with a history of mining. Conductivity is typically measured in micromhos per centimeter (µmhos/cm) or micro Siemens per centimeter (µS/cm).

- pH: pH measurements indicate the level of acidity in the water. On a scale from 0 to 14, lower numbers indicate high acidity, pH 7 is neutral, and higher numbers indicate water that is more basic. Like conductivity, the ranges of many aquatic species are limited by pH, and this measurement is important in areas with a history of mining. pH is unitless.

In addition to recording water quality parameters using a meter, the water's appearance should also be documented. A visual assessment can be made to assess turbidity if a meter is not available. Oily sheens or odd smells should be recorded as well, although these may be natural. Water that is discolored or cloudy should be noted also, as different hues may be visual indicators of low pH (e.g., metal precipitates in acidic streams such as iron (orange), manganese (black), or aluminum (white)).

3.2.2 Water Chemistry Monitoring

Water chemistry is important to watershed health and resilience, particularly in locations with legacy mining, but water chemistry monitoring and recommendations are beyond the scope of this monitoring plan. However, both the Fourmile and Big Thompson watersheds have some water quality data available that may be reviewed and used to supplement other monitoring activities.

The Fourmile Watershed Coalition has partnered with Trout Unlimited (TU) to sample water chemistry at several locations on Fourmile Creek and its tributaries, some of which are proximal to flood recovery project sites. This information should be used where available to provide additional information about stream health at or near project locations. Sites were sampled in summer 2017 and 2018 for a suite of metals, and water quality parameters were recorded as well. TU produced reports summarizing sampling results, with more detailed information regarding parameters that exceeded water quality standards.

Similarly, the Big Thompson Watershed Forum regularly collects water quality data, including metals, nutrients, and water quality parameters, on the Big Thompson River and some of its tributaries. Some of their sites are near or within flood recovery project boundaries, and data may be used where locations coincide to provide additional information about stream health at or near project locations. The Forum produces an Annual Water Quality Report summarizing the results of their data collection efforts each year. They also recently installed a temporary real-time USGS monitoring station in the Jasper Lake project reach to measure temperature, conductivity, pH, and turbidity at 15-minute intervals during winter 2017-2018.

3.3 BIOLOGICAL PARAMETERS

Biological monitoring is important for documenting the ecological condition of the project area (in-stream, riparian, and upland regions). The most critical component of biological monitoring at all flood recovery project sites is vegetation monitoring, as vegetation is important for both the structural and ecological integrity of a stream corridor. Benthic macroinvertebrate and fish species and populations may also be assessed and tracked over time to provide additional information about the health of resident aquatic communities, and as indicators for overall stream condition.

3.3.1 Vegetation Monitoring

The importance of healthy and functional riparian areas cannot be overstated, particularly to kick-start recovery of flood-affected areas. Riparian areas provide many critical functions for maintaining healthy and resilient stream ecosystems, including providing physical roughness that slows water velocities and mitigates the impacts of flood flows; increasing bank stability through root system cohesiveness; hosting a diversity of riparian plants, animals, and microbes though provision of moisture, micro- and macro-topography, micro-climates, and healthy soil conditions; filtering surface runoff; shading the stream corridor to lower water temperatures for the benefit of aquatic species; contributing large wood to stream channels, which provides habitat, in-stream cover, pool creation, and sediment trapping; adding organic matter to the stream corridor; and creating off-channel habitats like backwaters, wetlands, and side channels that act as refugia for fish and other aquatic species. Well-established and connected riparian areas also link stream corridor and upland ecological processes.

The ideal time for vegetation monitoring is in late summer or early fall during the peak growing season, before the onset of senescence. Numerous methodologies exist for monitoring riparian (and upland) vegetation, and most are contingent upon the evaluator's ability to correctly identify native and non-native plant species. In an effort to provide some quantitative vegetation monitoring options while still allowing for evaluators who may not have in-depth knowledge of plant identification, three different methods are described in the sub-sections below.

CWCB's monitoring team has implemented a guild-based approach to vegetation monitoring, meaning that herbaceous plants were grouped by functional guild (e.g., grasses, sedges, forbs, mixed ruderal species) instead of by species, and shrubs were identified to either genus or species. LHWC's monitoring approach is a modified version of the CWCB methodology, where dominant and non-native vegetation are recorded by species, and several additional companion measurements are made for each plot. AlpineEco's approach also considers the CWCB methodology, but focuses on quantitative assessments of vegetative cover and qualitative assessments of other variables that may affect the overall success of the site.

3.3.1.1 CWCB Vegetation Transect Surveys

The CWCB vegetation monitoring method consists of evaluating plots placed along transects (Beardsley and Johnson 2018). Depending on the site layout, plots are either placed perpendicular to the stream channel (coincident with XS transects) or parallel to the channel (at locations with only a narrow riparian bench). Details about the monitoring method are provided in Appendix B and summarized here.

Transect endpoints are marked with capped rebar pins and locations are recorded with a GPS. A tape measure is stretched between the end pins, and monitoring occurs from the landward extent of the floodplain to the edge of water during baseflow conditions. At sites with a narrow riparian bench, monitoring occurs from upstream to downstream. The tape measure defines the center of the plot, with 2 meters on each side of the tape creating the plot (so that plots are 4 meters wide). The length of the plots along the transect vary, and are determined by breaks in vegetation composition. The following data are recorded at each plot: dominant and subdominant herbaceous functional "guild" (e.g., grasses, sedges, forbs, mixed ruderal species); percent herbaceous coverage; dominant and subdominant shrub genus (e.g., willow) or species (e.g., coyote willow); percent shrub coverage; and number and type of individual shrubs.

The CWCB method for monitoring riparian and upland vegetation is useful for evaluators with limited plant identification knowledge. It is adaptable to many different site configurations, and is worth repeating at sites that are already part of the CWCB monitoring program. Creating plots that are coincident with XS transects allows for vegetation composition and development to be analyzed in relation to floodplain position and elevation.

3.3.1.2 LHWC Riparian Condition Monitoring

LHWC's riparian condition monitoring procedures are a modification of CWCB's vegetation transect survey methods described in the preceding sub-section (LWOG 2018). The complete methodology is provided in Appendix I and summarized here.

Transects are placed perpendicular to the channel, with transect endpoints extending beyond project boundaries, marked with capped rebar pins, and GPS coordinates recorded. Approximately 3 plots measuring 6 feet by 12 feet should be placed along the transect on each side of the channel (for a total of 6 plots). Zones will likely be channel edge, floodplain, and upland, with potential additions such as terrace or vegetated island. The center point on the transect tape should be recorded, with the plot boundaries extending 6 feet upstream and downstream of the tape, and 3 feet toward and away from the channel. Placing removable pin flags on plot corners is recommended for visualizing plot boundaries. The following parameters should be measured at each plot: dominant species (≥20% cover, species identification); native biodiversity (number of native species); woody species age class diversity (number of age classes, e.g., seedling, sapling, mature, dead); percent cover of herbaceous species; percent cover of woody species; non-native species (species identification, percent cover, and instances of State-listed noxious weeds); and percent cover of bare ground.

The LHWC methodology has several important components for monitoring flood recovery projects that may be incorporated even if the CWCB method is selected. The methodology includes success criteria for each of the parameters recorded, which may be helpful to document trends and trajectories for watershed health. This methodology specifies monitoring similar transects and plots at an unmodified control location and a restoration project location. For the purposes of this monitoring plan, transects may be placed only at flood recovery project locations.

3.3.1.3 AlpineEco Flood Recovery Vegetation Monitoring

AlpineEco's flood recovery vegetation monitoring procedures consider CWCB's vegetation transect survey methods described in the preceding sub-section, but focus on quantitatively measuring vegetative cover and qualitatively assessing other variables that may affect the overall success of the site. The complete methodology is provided in Appendix J and summarized here. A field form to use when applying this method is provided as Appendix K.

Transects are established perpendicular to the channel, and two methodologies are implemented to estimate overall vegetation and overall ground cover: a modified Daubenmire method (BLM 1999) to estimate herbaceous vegetation cover using 0.5 x 0.5 meter quadrats at 5-ft intervals on the downstream side of the transect, and the line-intercept method (BLM 1999) to estimate woody plant cover (shrubs and trees) along the transect. Information about the general ecological condition of the site is recorded during a general site reconnaissance, or "wandering transect." The wandering transect qualitatively assesses other variables that may affect the overall success of the site, such as presence of volunteer plants, problem bare areas, insect infestations, human or animal use, formation of problem rills or gullies.

3.3.2 Benthic Macroinvertebrate Community Monitoring

Benthic macroinvertebrates are excellent indicators of the condition of lotic aquatic systems because macroinvertebrates are found in almost all freshwater environments, have a small home range, are relatively easy to sample and identify, and the different taxonomic groups show varying degrees of sensitivity to pollution and other stressors (CDPHE 2016a, Barbour et al. 1999).

The Colorado Department of Public Health and Environment (CDPHE) monitors streams throughout the state for assessment and protection of water resource quality. Their principal indicator is a multi-metric index (MMI) based on direct benthic macroinvertebrate sample data. By using five to six equally weighted metrics, the MMI combines measures of diversity, abundance, pollution tolerance, community structure, and other factors to generate a normalized score of 0-100 for each sample. Scores may then be compared to reference threshold scores for one of three generalized Colorado biotypes (mountains, transition, plains). The SOP used by CDPHE for benthic macroinvertebrate sampling (CDPHE 2016a) is provided in Appendix L. Detailed procedures for sample collection, processing, and preservation are provided in the SOP, and sending the samples to a reputable laboratory for taxonomic identification is recommended.

Other indicators used to supplement the MMI in assessing the health of the benthic community are the Shannon-Wiener Diversity Index (SDI) and the Hilsenhoff Biotic Index (HBI). The SDI is a mathematical measure of species diversity within a given community. For benthic macroinvertebrates, values range from 0-5, and higher values indicate higher species diversity (MacArthur 1965). The HBI reveals the relative abundance of pollution-tolerant species. Scores range from 0-10, where a higher value indicates more pollution-tolerant species are present (Hilsenhoff 1987). In "grey" areas where the MMI alone is not sufficient, the SDI and HBI can also be compared to attainment and impairment threshold values.

Benthic macroinvertebrate community monitoring is a useful tool for monitoring flood recovery project sites, particularly if pre-project data are available. Macroinvertebrates can be monitored at any time of year, but low-flow conditions are preferred for ease of sample collection using a kick-net in wadeable streams. Macroinvertebrate community samples should ideally be collected and analyzed every 1-2 years if possible. Sampling can be conducted by coalition staff, or staff can train responsible and dedicated citizen scientists, volunteers, or landowners to collect samples.

3.3.3 Fish Population Monitoring

Fish population monitoring, typically conducted via electrofishing surveys, are used to determine fish species types, population estimates, relative species and age class distribution, abundance, size, and other metrics related to the health of the fishery. Existing data collected by Colorado Parks and Wildlife (CPW) should be used where available to supplement other available biological data (refer to CPW's website for a brief summary of fish survey methods: CPW Fishery Management).

CPW has been conducting electrofishing surveys at several locations on the Big Thompson River since before the 2013 flood, and has continued to collect data annually in the years following the flood event. Some of the survey locations are near flood recovery project sites, and those data can be used to inform reach-scale stream health assessments.

Aside from anecdotal information stating healthy populations of brook trout and brown trout in the upper canyon, limited fish species and population data are currently available for Fourmile Creek. However, fish population data were collected for the first time in summer 2019 at several locations, and will useful in assessing the aquatic condition of Fourmile Creek.

3.4 OTHER PARAMETERS

In addition to the monitoring parameters listed in previous sections, several other tools can be used to gather important data about the effectiveness of flood recovery projects and help evaluate reach-scale stream health and resilience. These include detailed photographic documentation, qualitative visual assessments and observations (particularly the Stream Visual Assessment Protocol developed by the NRCS), and discharge data. These parameters are described in more detail in the sub-sections below.

3.4.1 Photo Points

A “photo point” is a photograph taken at an established location and direction with the intention of recapturing the image from the same place repeatedly over time. Photo point documentation is arguably one of the most valuable tools available for long-term monitoring. Photo points provide a qualitative record of changes to stream and riparian parameters, and can also be used to verify mapped parameters and make quantitative measurements (Beardsley and Johnson 2018). Locations should be selected to capture features of interest in the stream, floodplain, and riparian area. Professional judgement based on project goals and objectives, as well as site-specific information in Sections 4 and 5 of this monitoring plan, should be used to establish photo point locations in the field (CWCB 2016b).

Detailed documentation of exact photo point location and direction is essential to capturing adequate information for resurveying each photo station. Several ways to accomplish this are listed below, and application of more than one of these techniques is recommended:

- Indicating photo point locations on a field map (ideally a high resolution, large scale, aerial orthophotograph printed on waterproof or laminated paper);
- Marking the location with an accurate GPS device;
- Recording the direction that the camera was pointed for the photograph in relation to true north;
- Installing wooden or metal stakes or other physical monuments, if possible;
- Taking detailed notes regarding photo point locations;
- Including an obvious landmark or permanent reference point in the photo (e.g., building, bridge, highway mile marker, road sign, large tree, or other permanent landscape features);
- Avoiding locations that will soon be obscured by growing vegetation; and
- Bringing historical photos along to the site when recapturing the image for as close a directional and locational replica as possible.

Additional professional tips regarding effective photo point documentation provided by the CWCB's monitoring team (Beardsley and Johnson 2018) include:

- Broader photos from high vantage points are usually most valuable for long-term monitoring, unless the photo's purpose is to track a specific feature (e.g., particular pool, bank line, installed structure);
- Panoramic photos can be effective, but beware of automatic image distortions on cameras and smart phones;
- Take photos in decent lighting conditions to eliminate glare and shadowing (optimal conditions are usually high noon on a clear day); and
- Consider repeating photos at various times of year to capture different project elements and seasonally dependent attributes of the reach (e.g., phenology, vegetation development, stream stage, floodplain or overflow channel activation).

Some additional notes regarding file management and photo documentation are provided below:

- Labeling photos either within their file names or in a companion photo log spreadsheet (as soon after taking photos as possible) is a good way to accurately document photo locations;
- Using a white board or similar signage to document photo locations is another common way to ensure accurate documentation and attribution; and
- Cellular phone or iPad applications also have documentation features (in particular, the "Context Camera" app on the iPhone records site name, location, date, time, and bearing).

For reference, a detailed SOP for collection of stream restoration monitoring photographs developed by the CWCB's MRP is provided in Appendix M (CWCB 2016b). Another valuable resource is the CWCB's monitoring methods report (Beardsley and Johnson 2018, Appendix B).

3.4.2 Qualitative Visual Assessments

Numerous qualitative rapid visual assessment tools exist for ranking observations of stream and floodplain features and condition. Because many of the flood recovery projects in the Big Thompson and Fourmile watersheds that are part of this monitoring plan were funded by the NRCS EWP Program, the Stream Visual Assessment Protocol developed by the NRCS and adapted for Colorado streams and rivers is recommended for use here. In addition, pre-project SVAP assessments have been conducted for many of these projects.

The SVAP2 uses 16 stream assessment elements to derive a comprehensive score for stream health based on this rapid qualitative tool. Elements are scored based on descriptions in the guidance document, available here: Stream Visual Assessment Protocol (SVAP2) and provided as Appendix N (NRCS 2017). Guidance document descriptions are summarized in the field form developed by Alba Watershed Consulting (Appendix O), but the guidance document should accompany observers in the field and should be consulted for clarifications or when questions arise. It provides definitions of terms and details about items to look for when conducting the assessment, and helps different evaluators reach more similar conclusions. The 16 stream assessment elements addressed in the SVAP2 are:

- Channel condition (stream shape and channel evolution model (CEM) stage);
- Hydrologic alteration (degree to which hydrology and stream flow conditions differ from natural or unregulated flow patterns);
- Bank condition (level of streambank stability);
- Riparian area quantity (amount of natural vegetation coverage along the assessment reach and associated floodplain);
- Riparian area quality (health of riparian community in terms of composition, diversity, age structure, and native species);
- Canopy cover and stream shading (percentage of shading by vegetation);
- Water appearance (degree of water clarity or turbidity);
- Nutrient enrichment (level of algal growth in the channel);
- Manure or human waste presence (livestock access or presence of waste discharge pipes);
- Pools (assessment of pool quantity and quality for aquatic habitat);
- Barriers to aquatic species movement (classification of barriers to movement of aquatic organisms);
- Fish habitat complexity (quantification of available habitat features for fish);
- Aquatic invertebrate habitat complexity (quantification of available habitat features for macroinvertebrates);
- Aquatic invertebrate community (ranking of diversity and tolerance level of resident macroinvertebrate species);
- Riffle embeddedness (degree to which gravel and cobble substrates are surrounded by fine sediment); and
- Salinity (level of salts in the water, scored only in cases of suspected elevated salinity levels).

NRCS recommends that the SVAP2 assessment be conducted during low-flow conditions when habitat features are most likely to be visible. Conducting the assessment during or within 5 days after a precipitation event should be avoided. Because rankings are somewhat subjective and can vary based on the observations and conclusions of different evaluators, completing the assessment in groups of two people and/or having the same evaluator(s) repeat the assessment in future years is suggested when possible.

Annual inspections are required for projects funded by the NRCS EWP Program to assess flood recovery project status. The EWP inspection form templates and supporting information are provided in Appendix P.

3.4.3 Flow Data

Discharge data are useful for flood recovery monitoring to determine whether designed low-flow and bankfull cross-sectional channel dimensions are appropriate, and whether expected floodplain bench and side/overflow channel activation flow rates and recurrence intervals are accurate or need to be reassessed.

The best site-specific flow data are derived from direct use of a current meter (e.g., Marsh McBirney, Hach 950, SonTek FlowTracker) and wading rod at the project site. An SOP for measuring stream discharge using a current meter developed by CDPHE’s Water Quality Control

Division (CDPHE 2016b) is provided in Appendix Q. However, USGS, Colorado Division of Water Resources (DWR), or other gauging stations can be used as a proxy if they are located in close proximity to project reaches, with no tributaries, inflows, or diversions between the gauging station and the project location. If no gauging station exists in relatively close proximity, a staff gauge may be installed to develop a stage-discharge rating curve, where discharge rates are associated with stream height. With enough points on the curve (i.e., enough direct discharge measurements associated with staff gauge height), a staff gauge reading alone can be used to estimate discharge rates. A field form for recording flow measurements is provided as Appendix R.

To determine flow rates for floodplain inundation and overflow or side channel activation, flow should be measured or recorded during spring runoff or other periods of high flow. At locations close to stream gauges, pin flags or photographs can be used to record high water marks, and those marks can then be associated with peak discharge rates for the season. Wetted width of the channel during high flow at discrete locations can also be measured. At locations for which stage-discharge rating curves have been developed, the height of water at the staff gauge should be recorded during peak flow for the season. If inundation of floodplain benches or overflow channels is observed, flow should be measured or recorded to associate discharge rates with recurrence intervals for inundation. Where possible, flagging, photo documentation, wetted width, and other observations should be recorded at or near as-built cross-section locations so that inundation levels may be tied to modeling results by the project engineer.

Several stream gauges operated by USGS, Colorado DWR, Bureau of Reclamation (BOR), and Northern Water (NCWCD) exist in the Big Thompson watershed that can provide discharge data in close proximity to project locations. However, the tributary streams West Creek and Fox Creek do not have associated stream gauges. The following existing gauges provide discharge data for the remaining project locations in the Big Thompson watershed:

- North Fork Big Thompson River at Drake (operated jointly by BOR and NCWCD) – North Fork project;
- Big Thompson River Below Lake Estes (operated jointly by BOR and NCWCD) – Waltonia, Mountain Shadows 1, and Mountain Shadows 2 projects;
- Big Thompson River Above Canyon Mouth at Cedar Cove (operated by DWR) – Moodie, Cedar Cove, Jasper Lake, Sylvan Dale Ranch, and City of Loveland WTP projects; and
- Big Thompson River at Loveland (operated by USGS) – Wild Natural Area (& Neighbors)/Reach 28, Rossum-Wilson, and Rist-Goss diversion projects.

Fourmile Canyon has one existing stream gauge, Fourmile Creek at Orodell (operated by USGS), that can provide discharge data for projects in the lower canyon (Lower Fourmile Bank Protection projects). Two additional gauges expected to be installed in 2020 by the Pine Brook Water District near the Poorman Fire Station, and by USGS at the Logan Mill Road bridge.

If resources are available, discharge can be measured at or near project locations that lack established stream gauges, and stage-discharge rating curves can be developed over time. Recommendations for measuring or estimating discharge rates at or near specific project locations are provided in the project-specific sub-sections in Sections 4 and 5 of this monitoring plan.

4.0 BIG THOMPSON WATERSHED FLOOD RECOVERY PROJECTS

The Big Thompson watershed sustained considerable damage as a result of extreme flooding in the past 50 years, with the catastrophic flood of 1976 in the Big Thompson Canyon and the more recent Front Range flood in 2013 across the watershed. Federal, state, and local funding was secured by the Big Thompson Watershed Coalition after the 2013 flood to complete 14 flood recovery projects in the years following the flood: Glen Haven (West Creek and Fox Creek), North Fork, Waltonia, Mountain Shadows 1, Mountain Shadows 2, Moodie, Cedar Cove, Jasper Lake, Sylvan Dale Ranch, City of Loveland Water Treatment Plant, Wild and Natural Area (& Neighbors)/Reach 28, Rossum-Wilson, and Rist-Goss Diversion. Monitoring plans for each of the coalition projects are provided in the sections that follow. A summary of monitoring parameters by project is provided in Table 2. While this matrix may be used for reference, it should not supplement the details provided in the monitoring plan sections of this report.

Colorado Department of Transportation (CDOT), Central Federal Lands (CFL), and other entities also completed several additional flood recovery projects within the watershed, mainly involving roadway reconstruction and restoration of adjacent river reaches. Although project-specific monitoring plans were not developed for those projects as part of this effort, similar monitoring parameters may be used to evaluate those project areas as desired.

In addition, although “unrestored” sites are not identified in this plan, it is recommended that if possible, similar monitoring parameters be applied to such areas in both the canyon section and the plains section of the Big Thompson watershed in order to collect comparable data from sites that were impacted by flooding, but left untreated.

4.1 WEST CREEK

The West Creek project rehabilitated approximately 1.5 miles of damaged stream corridor along West Creek outside the town of Glen Haven. Three streams converge near Glen Haven: West Creek, Fox Creek, and the North Fork of the Big Thompson River. The 2013 flood resulted in extensive damage along these tributaries and at their confluence, where massive amounts of water and sediment were transported through narrow constricted canyons.

On West Creek, major portions of adjacent CR 43 were damaged or destroyed, along with many access bridges and culvert crossings. Several homes and summer cabins were compromised as well, as much of the infrastructure in this area was built on the floodplain in the river’s natural path. The channel and floodplain experienced widening, channel migration, bank erosion, removal of riparian vegetation, and deposition of sediment at locations along the West Creek corridor. Following the flood, state and federal agencies initiated emergency measures to rebuild the impacted communities and regain home access, but did not address many of the long-term issues. The West Creek project sought to re-establish a functional stream corridor to repair the damage caused by the flood and ensuing emergency efforts. The project removed sediment and debris, stabilized failing streambanks, re-established and revegetated floodplains, and redirected the creek away from critical structures.

4.1.1 Site Details

This section provides details about the Glen Haven West Creek site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and Larimer County)
- **Design engineer(s)** – TJ Burr, NRCS
- **Construction oversight engineer(s)** – TJ Burr, NRCS
- **Construction contractor** – American Civil Constructors and Dietzler Construction
- **Vegetation designer** – NRCS with technical assistance from Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – October 6, 2016 – January 27, 2017 (planting completed May 31, 2017)
- **Select design flow(s)** – Bankfull flow (130 cfs – upper reach; 140 cfs – lower reach)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – none upstream of project; CR43 road/river construction downstream of project (downstream of confluence with Fox Creek)
- **Fish passage barriers** – Multiple private culverts within the project area may pose fish barriers
- **Diversion structures** – No diversion structures upstream or downstream
- **Nearest flow gauge** – None on West Creek, but stage-discharge rating curve is available for use by measuring stage height at the Silver Horn Springs Court culvert

Restoration Methods:

- **Seeding methods** – 3 zones (bankfull bench, floodplain, upland), broadcast and hand-raked (refer to schematic diagram in Appendix S for more information)
- **Planting zones** – 3 zones (linear on creek side of bankfull bench, floodplain, and upland), (refer to schematic diagram in Appendix S for more information)
- **Willow installation method(s)** – Willows and cottonwoods installed by hand using rebar and mallet. Willows installed after heavy construction/grading activities
- **Topsoil** – Topsoil was expected to be generated on Fox Creek for use on West Creek, but this never materialized so no topsoil was added
- **Erosion control** – Used a combination of coir fabric, coconut matting, hydromulch, and wood straw. Hydromluch did not work well, so woodstraw was reapplied in late May 2017 to areas with no grass emergence that had been previously hydromulched.
- **Irrigation** – None

Stakeholder Information:

- **Percent public/private land** – 5% public, 95% private
- **Number of private landowners** – 50 (approximate)
- **Public land agencies** – Some parcels owned by Larimer County; USFS land located in surrounding areas but not within project boundaries

Post-Construction Inspections/Site Visits:

- The CWCB monitoring team visited the West Creek project site on October 24, 2017, after the project had already experienced one spring runoff event, to collect baseline data at the site. Data collection efforts were focused in 2 project sub-sections: approximately Station 28+00 to 32+00 (Pod 1, 4 transects), and approximately Station 64+00 to 70+00 (Pod 2, 3 transects). At each pod, the team conducted cross-section surveys, vegetation transect surveys, aquatic habitat facet delineation, pool area mapping (where applicable), photo points, wood counts, and test banks.
- The CWCB monitoring team returned to West Creek on October 4, 2018 and collected vegetation transect and photo point data at the baseline locations.
- TJ Burr conducted several post-construction follow-up visits (5/4/2017, 8/30/2018, 10/4/2018). He conducted cross-section surveys from Station 51+30 to 56+21 on May 4, 2017. He summarized observations from his visit on August 30, 2018 in an email to Rob Molacek on 8/31/2018. He also visited the site on October 4, 2018 to repeat cross-section surveys from Station 51+30 to 56+21.
- BTWC visited the site for annual inspection visits in August 2017 and July 2018, and summarized findings in a memorandum and PowerPoint document submitted to the State on January 25, 2019.
- Great Ecology completed an assessment of vegetation survivorship in May 2018 on behalf of the State. Findings for West Creek are as follows: willow survivorship (88%), cottonwood survivorship (35%), container survivorship (79%), seed cover river left (45%), seed cover river right (55%). The accompanying report noted that there was a difference between seed cover on river left and river right and noticeable difference between cover within Zone 2 and Zone 3 areas, with Zone 3 cover generally higher on both sides of the stream. Cottonwood mortality may be due to its installation in Zones 1 and 2.
- Larimer County Department of Natural Resources visited the site in 2018 to assess and manage noxious weeds. Refer to Appendix T for details regarding weed presence and management at West Creek.
- The CWCB monitoring team visited West Creek on June 15, 2019 to collect photo point data at the baseline locations.
- The CWCB monitoring team returned to West Creek on September 5, 2019 and used a drone to collect aerial imagery and generate a digital terrain model (DTM) via photogrammetry. They also collected vegetation transect, photo point, and wood count data at the baseline locations. Photo points were revisited on September 27, 2019.

4.1.2 Project Goals and Monitoring Questions

The West Creek project's Basis of Design Report lists the following primary objectives:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land;
(3) Reduce threats to life or property; and
(4) Restore the discharge capacity of the stream to pre-flood levels where feasible and possible.

Anticipated ancillary benefits from the project were also listed in the Basis of Design Report, as follows:

(5) Improve water quality from the reduction of sediment loading caused by bank erosion;
(6) Enhance riparian habitat from planting, revegetation, and reconnection of stream to floodplain;
(7) Improve fish habitat from additional vegetation, improved water quality, and better habitat complexity; and
(8) Lower the base flood level.

Finally, additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(9) Improve fish habitat with deeper pools, more pools, riparian vegetation, and increased refugia from summer heat and winter ice;
(10) Increase the quantity and size of fish;
(11) Restore natural stream "landscape" for aesthetics to be enjoyed by landowners and visitors;
(12) Restore natural variability with habitat boulders, toe wood, in-stream structures, meander patterns, etc.; and
(13) Track point bar development and measure particle size in point bars to gain information about sediment transport.

4.1.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.1.2, the following monitoring parameters are recommended for the West Creek flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Measuring discharge during high flows and associating discharge measurements with inundation levels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are being conducted by the CWCB monitoring team and the design engineer at several sub-reaches along this project reach. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional physical surveys are recommended at the West Creek project site. For completeness, the approximate locations of existing surveys are listed here:

- Approximately Station 28+00 to 32+00 (CWCB monitoring team Pod 1, 4 transects)
- Station 51+30 to 56+21 (NRCS design engineer)
- Approximately Station 64+00 to 70+00 (CWCB monitoring team Pod 2, 3 transects)

Surveying cross-sections at these locations addresses project/monitoring goals (1), (4), (6), and (8).

Substrate surveys – To ensure that excessive sedimentation is not occurring at the project site, substrate surveys are suggested but not required if resources are available. If conducted, pebble counts should be performed at 2-4 riffles within the project site (1-2 in the reach upstream of Station 22+67 and 1-2 in the reach downstream of Station 22+67) to address project/monitoring goal (5). In addition, point bar assessments should be conducted at 2 representative point bars to address project/monitoring goal (13). For reference, Tables 4 and 5 of the project's Basis of Design Report lists the following pre-construction substrate sizes: lower reach D50 (128 mm), D84 (249 mm); upper reach D50 (100 mm), D84 (195 mm).

Structure surveys – Because individual installed structures do not relate directly to project or monitoring goals, no formal structure surveys are recommended at the West Creek site. However, structures can be opportunistically documented during annual inspections and/or regular site visits. The log bank structure on river left at approximately Station 31+00 was noted in the BTWC inspection report and should be documented on subsequent site visits (no formal structure survey needs to be followed). The bank protection function was being maintained by the structure, but significant deposition was noted, so the habitat function may be compromised if sediment is not flushed by future flows.

Aquatic habitat feature surveys – Baseline aquatic habitat feature surveys were conducted by the CWCB monitoring team at Pod 1 and Pod 2 in 2017, and will be revisited as needed in future years. These surveys address project/monitoring goals (7) and (9). Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. Because the CWCB monitoring team is conducting these surveys at select sub-reaches, additional monitoring by the coalition is not necessary at this time.

Pool area mapping – The CWCB monitoring team conducted an RPD survey within both study areas in 2017, and the pool near Station 31+00 was the only one that met the depth criteria (greater than 1.5 feet). They will continue to revisit this measurement as needed. In addition to this survey, counting pools and measuring their maximum depth over time can be a simple yet quantitative way to address project/monitoring goal (9). Therefore, the number of pools at the site should be recorded and the deepest point in each pool in the project area should be measured using a range pole, stadia rod, or similar measurement device to evaluate the effectiveness of natural and constructed scour mechanisms for maintaining pools. If resources are limited, a subset of reaches can be designated for this parameter. For consistency in temporal comparisons, depth measurements should always be conducted at approximately the same time of year and relative flow (e.g., summer baseflow in August/September). Observations of excessive sedimentation in the pools should be noted at each site visit as well.

Water quality parameters – Another way to address the project/monitoring goals (5), (7), and (9) related to enhanced fish habitat is by measuring select water quality parameters. At West Creek, temperature, dissolved oxygen, and turbidity are of the greatest interest. If DO and turbidity meters are not available, measure temperature only. Water quality parameters should be measured at a minimum of two locations, one in the upper reach and one in the lower reach (boundary is at Station 22+67).

Vegetation surveys – Vegetation transect surveys are being conducted by the CWCB monitoring team at Pod 1 and Pod 2. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional vegetation surveys are recommended at the West Creek project site. Vegetation monitoring addresses project/monitoring goals (2), (6), (7), and (9).

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goals (7) and (9) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would address project/monitoring goal (10). However, CPW does not currently have any fish or macroinvertebrate monitoring sites on West Creek. Biological data collection at West Creek may be cost- or resource-prohibitive, so project/monitoring goals (7) and (9) can serve as proxy for goal (10), and all three goals can be addressed by other parameters (e.g., aquatic habitat feature surveys, pool area mapping, water quality parameters). If CPW begins to collect data at West Creek, these data should be used to supplement the other sources.

Photo points – Photo points should be established for monitoring at the West Creek project site. Consider occupying some of the NRCS (TJ Burr) and BTWC/CWCB (Shayna Jones/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (3), (6), (11), and (12).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (5), (6), (7), (9), and (12). Annual EWP inspections should also be completed at the West Creek project site.

Flow – Discharge should be measured or estimated at the West Creek project because no established stream gauges exist in relative proximity to the project site. If possible, installation of a staff gauge and periodic measurement of discharge at a range of flows using a flow meter to develop a stage-discharge rating curve is recommended. An alternative or complement to installing a staff gauge is to measure the height of water at the center of the upstream side of the CMP culvert at Silver Horn Springs Court. Discharge was measured at this location during project design and construction, and a rating curve has been developed to associate water height with discharge at that location. Flow should be measured during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations, particularly at as-built or monitoring cross-sections where possible. These activities will address project/monitoring goals (4), (6), and (8).

4.2 FOX CREEK

The Fox Creek project rehabilitated approximately 1.5 miles of damaged stream corridor along Fox Creek outside the town of Glen Haven. The steep, narrow canyon containing Fox Creek was inundated with floodwaters and sediment during the 2013 flood. Much of the infrastructure in the canyon was damaged or destroyed, including homes, cabins, roadways, and culverts. Most of the development in this canyon exists on the floodplain in the river’s natural path, including 13 stream crossings that provide access to private property. These crossings quickly became clogged during the flood, redirecting and amplifying flood flows and causing damage within the canyon, including significant erosion. Following the flood, state and federal agencies initiated emergency measures to rebuild the impacted communities and regain home access, but did not address many of the long-term issues.

The Fox Creek project attempted to accelerate the natural stream stabilization process during the most frequent flow events by creating the long-term geomorphic and riparian conditions expected for Fox Creek. It also eliminated two of the constricting stream crossings and redesigned another two in an effort to reduce flood risks in the canyon.

4.2.1 Site Details

This section provides details about the Glen Haven Fox Creek site, project, and surroundings for reference during future monitoring events.

Project Details:
- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and Larimer County)
- **Design engineer(s)** – Rob Molacek, NRCS
- **Construction oversight engineer(s)** – Rob Molacek, NRCS
- **Construction contractor** – American Civil Constructors
- **Vegetation designer** – NRCS with technical assistance from Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – December 5, 2016 – April 3, 2017
- **Select design flow(s)** – Bankfull flow (55 cfs); 25-year flow (180 cfs)
- **Select activation flow(s)** – NA

River System Information:
- **Position in watershed** – Canyon
- **Adjacent restoration projects** – none upstream of project; several downstream of the confluence with the North Fork of the Big Thompson River in Glen Haven
- **Fish passage barriers** – Multiple private culverts within the project area may pose fish barriers
- **Diversion structures** – No diversion structures upstream or downstream
- **Nearest flow gauge** – None on Fox Creek

Restoration Methods:
- **Seeding methods** – 2 zones (riparian and upland), broadcast and hand-raked
- **Planting zones** – 3 zones (linear on creek side of bankfull bench, floodplain, and upland)
- **Willow installation method(s)** – Installed by hand after heavy construction/grading activities
- **Topsoil** – Yes (220 cubic yards generated from an onsite cut at Youth United property)
- **Erosion control** – Coconut matting with hydromulch
- **Irrigation** – None

Stakeholder Information:
- **Percent public/private land** – 100% private
- **Number of private landowners** – 50 (approximate)
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:
- The CWCB monitoring team visited the Fox Creek project site on October 24, 2017, after the project had already experienced one spring runoff event, to collect baseline data at the site. Data collection efforts were focused in 2 project sub-sections: approximately Station 15+00 to 18+00 (Pod 1, 2 transects), and approximately Station 28+00 to 31+00 (Pod 2, 2 transects). At each pod, the team conducted cross-section surveys, vegetation

transect surveys, aquatic habitat facet delineation, pool area mapping (although no locations met the depth criteria), photo points, wood counts, and test banks.

- The CWCB monitoring team returned to Fox Creek on October 4, 2018 and collected vegetation transect and photo point data at the baseline locations.
- Rob Molacek conducted a post-construction follow-up visit on June 25, 2018, and TJ Burr visited on August 30, 2018 (observations summarized in an email to Rob Molacek on August 31, 2018).
- BTWC visited the site for annual inspection visits in July 2017 and August 2018, and summarized findings in a memorandum and PowerPoint document submitted to the State on January 25, 2019.
- Great Ecology completed an assessment of vegetation survivorship in May 2018 on behalf of the State. Findings for Fox Creek are as follows: willow survivorship (68%), container survivorship (82%), seed cover (60%). The accompanying report noted that vegetation throughout the site was robust, although willow stake survival was lower compared to West Creek. Cottonwood stake survivorship was not observed during the site visit.
- Larimer County Department of Natural Resources visited the site in 2018 to assess and manage noxious weeds. Refer to Appendix T for details regarding weed presence and management at Fox Creek.
- The CWCB monitoring team visited Fox Creek on September 5, 2019 to collect vegetation transect, photo point, and pool area (although no locations met the depth criteria) data at the baseline locations. Photo points were revisited on September 27, 2019.

4.2.2 Project Goals and Monitoring Questions

The project's Basis of Design Report states that the primary goal of the Glen Haven Fox Creek project was to decrease the flood, ecological, and geomorphic risk resulting from the 2013 flood event. Specific project objectives were listed in the report as follows:

(1) Create a stable step-pool channel section;
(2) Remove debris and extensive sediment deposition to regain floodplain capacity;
(3) Increase in-stream habitat complexity;
(4) Rehabilitate vegetation that typically exists adjacent to the river and in the floodplain; and
(5) Reduce erosion along unstable creek banks.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(6) Accelerate the establishment of a new floodplain (with abandoned floodplain acting as a terrace);
(7) Continually evaluate the size and alignment of existing stream crossings to determine if/how they increase/decrease floodwater elevations, improve/constrict passage of debris, and support/inhibit aquatic passage and habitat;
(8) Monitor large wood during a range of flow events to check for potential increase in flood risk, particularly near stream crossings;

(9) Track point bar development and measure particle size in point bars to gain information about sediment transport;
(10) Measure water surface elevations near homes and other assets during high flow periods and associate inundation levels with discharge rates;
(11) Monitor evidence of erosion through photo documentation to determine whether the project reduced erosive conditions; and
(12) Evaluate the upper watershed above the project area to determine how it is recovering relative to the project area and whether the large amount of debris in that area is mobilizing.

4.2.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.2.2, the following monitoring parameters are recommended for the Fox Creek flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Measuring discharge during high flows and associating discharge measurements with inundation levels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

<u>Physical surveys</u> – Cross-section surveys are being conducted by the CWCB monitoring team at two sub-reaches along this project reach. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional physical surveys are recommended at the Fox Creek project site. For completeness, the approximate locations of existing surveys are listed here:

- Approximately Station 15+00 to 18+00 (CWCB monitoring team Pod 1, 2 transects)
- Approximately Station 28+00 to 31+00 (CWCB monitoring team Pod 2, 2 transects)

Surveying cross-sections at these locations addresses project/monitoring goals (1), (2), (5), (6), and (9).

<u>Substrate surveys</u> – Substrate surveys are recommended to ensure that excessive sedimentation is not occurring in this reach. Pebble counts should be conducted at 2-3 riffles within the project site to address project/monitoring goals (2) and (5). In addition, any new point bars that have been created should be noted, and point bar assessments should be conducted at 2 representative point bars to address project/monitoring goal (9). For reference, the "Project Area Morphological Characteristics" table on page 8 of the project's Basis of Design Report lists the following expected substrate sizes: active bed D50 (51 mm), active bed D84 (113 mm), point bar D50 (24 mm), point bar D84 (99 mm), largest particle size to be moved (127 mm).

<u>Structure surveys</u> – Surveying the installed structures that contain woody material would address project/monitoring goal (8). Key project structures, including woody bank stabilization structures near Stations 9+49, 37+11, and 82+66, should be evaluated to determine whether they are fulfilling their intended functions (to reduce water velocities and dissipate energy; stabilize banks; provide cover; and direct flow away from the bank). In addition, these structures should be inspected and documented to make sure they are intact, stable, and not in danger of becoming dislodged or undermined in order to alleviate concerns of large wood blocking downstream crossings.

Aquatic habitat feature surveys – Baseline aquatic habitat feature surveys were conducted by the CWCB monitoring team at Pod 1 and Pod 2 in 2017, and will be revisited as needed in future years. These surveys address project/monitoring goals (1) and (3). Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. Because the CWCB monitoring team is conducting these surveys at select sub-reaches, additional monitoring by the coalition is not necessary at this time.

Vegetation surveys – Vegetation transect surveys are being conducted by the CWCB monitoring team at Pod 1 and Pod 2. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional vegetation surveys are recommended at the Fox Creek project site. Vegetation monitoring addresses project/monitoring goal (4).

Photo points – Photo points should be established for monitoring at the Fox Creek project site, particularly at stream crossings and locations that were heavily eroded as a result of the 2013 flood. Consider occupying some of the NRCS (Rob Molacek) and BTWC/CWCB (Shayna Jones/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (3), (4), (5), (6), (7), and (11).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (3), (4), and (7). In conjunction with photo documentation, visual assessments should be made at each of the stream crossings as well, particularly noting concerns about sedimentation, debris blockage, or fish passage at a range of flows. To address project/monitoring goal (11) if time and budget allow, the upper watershed above the Fox Creek project should be visited and assessed to evaluate its recovery compared to the project area and to determine whether the large amount of debris in that area is mobilizing downstream. Annual EWP inspections should also be completed at the Fox Creek project site.

Flow – Discharge should be measured or estimated at the Fox Creek project because no established stream gauges exist in relative proximity to the project site. Installation of a staff gauge and periodic measurement of discharge at a range of flows using a flow meter to develop a stage-discharge rating curve is recommended, and staff gauge installation was completed on June 3, 2019. The gauge was installed on the Youth United property just upstream of the new NRCS-installed culvert at approximately Station 36+60. A rating curve is being developed to associate water height with discharge at that location. Flow should be measured during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations, particularly at as-built or monitoring cross-sections where possible. Water levels near homes and other assets are particularly important to document as well. These activities will address project/monitoring goals (2), (6), (7), and (10).

4.3 NORTH FORK

The North Fork project is located at the confluence of the North Fork and main stem of the Big Thompson River near the Town of Drake. Set in a natural canyon opening, the North Fork of the Big Thompson River reclaimed historic channel pathways and deposited large quantities of sediment during the 2013 flood. Storm Mountain Bridge, at the upper end of the project, was flanked by flood flows as floodwaters occupied the northern and southern overbanks, burying an old truck, filling buildings with sediment, and damaging or destroying other public and private infrastructure such as campground buildings, private residences, a hotel, and a roadway embankment. The Highway 34 bridge at the downstream end of the project was completely blocked by sediment and debris. Restoring roads and bridges were the highest priority immediately after the flood, but emergency measures executed without a holistic vision left the reach severely degraded and in need of significant additional investment to repair.

The North Fork project sought to reduce the impacts of future moderate flood events on public infrastructure, private properties, and businesses at this dynamic river confluence. Through the approximately 2,100-foot project reach, sediment and debris were removed to improve flood conveyance, streambanks were stabilized using innovative engineering techniques, and river corridor restoration was attempted through native riparian revegetation and reintroduction of large wood.

4.3.1 Site Details

This section provides details about the North Fork site, project, and surroundings for reference during future monitoring events.

<u>Project Details:</u>

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and Larimer County)
- **Design engineer(s)** – Joe Juergensen, Muller Engineering
- **Construction oversight engineer(s)** – Michael Blazewicz, Round River Design, and Katie Jagt, Watershed Science and Design
- **Construction contractor** – Connell Resources
- **Vegetation designer** – Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – February 1 – April 28, 2017
- **Select design flow(s)** – Bankfull flow (250 cfs), winter baseflow (8 cfs), summer baseflow (60 cfs), 10-year flow (1,540 cfs)
- **Select activation flow(s)** – Overbank channel on river left just downstream of Storm Mountain Bridge (designed to take 10% of flow (158 cfs) in a 10-year event)

<u>River System Information</u>:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – CR43 road/river construction upstream of project; Drake project (completed by CDOT) on the main stem of the Big Thompson River just downstream of the project (at the confluence of the North Fork and main stem)
- **Fish passage barriers** – No known barriers
- **Diversion structures** – No diversion structures upstream or downstream
- **Nearest flow gauge** – North Fork Big Thompson River at Drake (BTNFDRCO), at Storm Mountain Bridge at upstream end of project area, jointly operated by Northern Water and Bureau of Reclamation

<u>Restoration Methods</u>:

- **Seeding methods** – 4 zones (channel margin, bankfull bench, floodplain, upland), broadcast and hand-raked
- **Planting zones** – 4 zones plus 3 additional zones in upland areas for guidebanks/berms
- **Willow installation method(s)** – several methods including fascines, staking by hand, and staking with heavy equipment during grading work
- **Topsoil** – Yes, generated from secondary channel onsite and amended
- **Erosion control** – Coir fabric, coconut matting, and wood straw
- **Irrigation** – None

Stakeholder Information:
- **Percent public/private land** – 100% private
- **Number of private landowners** – 4
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:
- The CWCB monitoring team visited the North Fork project site on October 4, 2017, after the project had already experienced one spring runoff event, to collect baseline data at the site. Data collection efforts were focused in 4 project sub-sections: approximately Station 20+00 to 18+00 (Pod 1, 4 transects), approximately Station 14+50 to 13+80 (Pod 2, 2 transects), approximately Station 9+00 to 7+60 (Pod 3, 2 transects), and approximately Station 5+00 to 2+60 (Pod 4, 4 transects). At each pod, the team conducted cross-section surveys, vegetation transect surveys, aquatic habitat facet delineation, pool area mapping (where applicable), photo points, and wood counts.
- The CWCB monitoring team returned to the North Fork on October 4, 2018 and collected vegetation transect and photo point data at the baseline locations.
- BTWC visited the site for annual inspection visits in early summer 2017 and 2018, and summarized findings in a memorandum and PowerPoint document submitted to the State on January 25, 2019.
- Great Ecology completed an assessment of vegetation survivorship in May 2018 on behalf of the State. Findings for North Fork are as follows: willow stakes survivorship (83%), willow fascine survivorship (85%), container survivorship (89%), seed cover (50%). The accompanying report noted that vegetation was robust and survivorship was exceptional across all treatments; no differences on river right/left or between zones. Some willow stakes had been removed from the project site by those using the campsites, and noxious weeds were present.
- Larimer County Department of Natural Resources visited the site in 2018 to assess and manage noxious weeds. Refer to Appendix T for details regarding weed presence and management at North Fork.
- The CWCB monitoring team visited the North Fork on June 15, 2019 to collect photo point data at the baseline locations.
- The CWCB monitoring team returned to the North Fork on September 7, 2019 and used a drone to collect aerial imagery and generate a digital terrain model (DTM) via photogrammetry. They also collected vegetation transect and photo point data at the baseline locations. Photo points were revisited on October 21, 2019.

4.3.2 Project Goals and Monitoring Questions

The North Fork project's Basis of Design Report lists the following primary objectives:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land; and
(3) Restore the discharge capacity of the stream to pre-flood levels to the maximum extent practical where feasible and possible.

Anticipated ancillary benefits from the project were also listed in the Basis of Design Report, as follows:

(4) Improve water quality from the reduction of sediment loading caused by bank erosion;
(5) Enhance riparian habitat from the addition of vegetation; and
(6) Improve fish habitat from additional vegetation, improved water quality, and better habitat complexity.

Finally, additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(7) Track depths of constructed pools in relation to their scour mechanism (size, width, feature type) to provide information about the effectiveness of different control features;
(8) Measure vegetation type and density at or near log revetments and track the erosion and vegetation response as the logs degrade over time;
(9) Track sediment accumulation, as this confluence reach is susceptible to sediment deposition;
(10) Note any signs of erosion and possible sources of sediment into the channel; and
(11) Verify design flows for floodplain benches and overflow channel.

4.3.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.3.2, the following monitoring parameters are recommended for the North Fork flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches and in the overflow channel, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

<u>Physical surveys</u> – Cross-section surveys are being conducted by the CWCB monitoring team at four sub-reaches within the project area, with sufficient coverage across the project. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional physical surveys are recommended at the North Fork project site. For completeness, the approximate locations of existing surveys are listed here:

- Approximately Station 20+00 to 18+00 (CWCB monitoring team Pod 1, 4 transects)
- Approximately Station 14+50 to 13+80 (CWCB monitoring team Pod 2, 2 transects)
- Approximately Station 9+00 to 7+60 (CWCB monitoring team Pod 3, 2 transects)
- Approximately Station 5+00 to 2+60 (CWCB monitoring team Pod 4, 4 transects)

Surveying cross-sections at these locations addresses project/monitoring goals (1), (3), (7), and (9).

Substrate surveys – Substrate surveys are recommended to provide a measure of sedimentation in this reach. Pebble counts should be conducted at 2-3 riffles within the project site to address project/monitoring goals (9) and (10). Possible sources of any accumulating sediment that is observed should be noted.

Structure surveys – Surveying the installed log revetments at the downstream end of the project (approximately Station 1+00 to 4+20 on river left) addresses project/monitoring goal (8). These woody bank stabilization structures should be evaluated to determine whether they are fulfilling their intended functions, and vegetation type and density in the vicinity of the structures should be recorded. The intended functions of these log revetments are to reduce water velocities and dissipate energy; stabilize banks; create pools; provide cover; and direct flow away from the bank. In addition, these structures should be inspected and documented to assess how they degrade over time and associated vegetation and erosion responses. The live crib wall at approximately Station 14+00 to 15+20 on river left should also be evaluated to address project/monitoring goals (1), (2), (4), and (10). Prior to the project, this area was one of the most severely eroded slopes in the area. The intended functions of the live crib wall with boulder toe are to stabilize the bank, establish vegetation, and reduce erosion.

Aquatic habitat feature surveys – A baseline aquatic habitat feature survey for the entire project area was conducted by the CWCB monitoring team in 2017, and will be revisited as needed in future years. This survey addresses project/monitoring goal (6). Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. Because the CWCB monitoring team is conducting this survey at the North Fork project, additional monitoring by the coalition is not necessary at this time.

Pool area mapping – The CWCB monitoring team conducted a residual pool depth (RPD) survey for the entire project site in 2017 for pools with a RPD greater than 1.5 feet, and mapped 14 pools within the project extent. They will continue to revisit this survey as needed. The RPD survey addresses project/monitoring goal (7). In addition to pool area mapping, notes about the size and type of scour mechanisms directly upstream of pools (size, type) should be recorded by the coalition to provide information about the relative width of control features and their impact on scour depth in the resulting pool at various flow rates. Because the CWCB monitoring team is conducting these surveys throughout the project site, additional monitoring by the coalition is not necessary at this time.

Water quality and chemistry – Measuring select water quality parameters addresses project/monitoring goals (4) and (6). At the North Fork site, temperature, dissolved oxygen, and turbidity are of the greatest interest because water quality goals relate to improved fish habitat and reduced sedimentation. The Big Thompson Watershed Forum (BTWF) has an established water quality monitoring location on the North Fork (site T10), and data including water quality parameters, certain metals, and nutrients are collected by BTWF at least every other year at this site. Review data collected by BTWF at this location to provide information about water quality at the North Fork.

Vegetation surveys – Vegetation transect surveys are being conducted by the CWCB monitoring team at all 12 cross-sections. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional vegetation surveys are recommended at the

North Fork project site. Vegetation monitoring addresses project/monitoring goals (2), (5), and (6).

Benthic macroinvertebrate and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goal (6) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (6). While CPW does not currently have any fish or macroinvertebrate monitoring sites on the North Fork, they collect data at the confluence of the North Fork and the main stem at Drake. These data should be reviewed and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the North Fork project site. Consider occupying some of the BTWC/CWCB (Shayna Jones/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Note that the CWCB monitoring team has established photo point locations as well beginning in October 2017. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), (6), (8), and (10).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (4), (5), and (6). Annual EWP inspections should also be completed at the North Fork project site.

Flow – A stream gauge maintained cooperatively by Northern Water and the Bureau of Reclamation, North Fork Big Thompson River at Drake (BTNFDRCO), is located at the Storm Mountain Bridge at the upstream end of the project area. Floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations during high flow periods such as spring runoff, particularly at as-built or monitoring cross sections where possible. Suggested cross sections for inundation level monitoring are located at Stations 3+58 (P4XSC), 8+73 (P3XSA) 14+56 (P2XSA), 17+85 (P1XSD), and 20+85 (refer to Appendix U for a map of the suggested cross-section locations). The parenthetical cross section notations (e.g., P4XSC) are established CWCB long-term monitoring cross sections marked with capped rebar pins. These activities will address project/monitoring goals (3) and (11).

4.4 WALTONIA

The Waltonia community experienced a catastrophic flood in 1976, and again in 2013, causing the Big Thompson River to overflow and flood. Damage from the 2013 flood included erosion along the main channel and erosion and deposition in the isolated small floodplains that exist through the upper canyon, including the Waltonia neighborhood. The area also experienced damage from channel widening, bank erosion, channel shifting, and areas of sediment deposition. As a result, large sections of roads were destroyed, bridges quickly clogged with flood debris, and homes were lost or severely damaged. In the immediate aftermath of the flood, restoring roads and bridges were high priorities. Some of the work completed in that effort further impaired the river corridor by straightening and homogenizing the channel, removing material from the channel to be used as fill and embankment armor for the road, and armoring the banks with rock, absent of soil and vegetation.

The Waltonia project rehabilitated approximately 2,250 feet of river corridor by re-establishing a low-flow channel, reconnecting the floodplain, protecting and stabilizing streambanks, excavating flood deposits, and revegetating the project area with native species. The project aimed to provide a sustainable floodplain design to protect the safety of neighborhood residents while enhancing habitat and improving river function and resilience.

4.4.1 Site Details

This section provides details about the Waltonia site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program)
- **Design engineer(s)** – Brad Florentin, Muller Engineering
- **Construction oversight engineer(s)** – Brad Florentin, Muller Engineering
- **Construction contractor** – Kiewit Infrastructure Company, Iron Woman Construction, and FlyWater
- **Vegetation designer** – Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – October 2, 2017 – May 11, 2018
- **Select design flow(s)** – winter baseflow (25 cfs), summer baseflow (125 cfs), bankfull flow (550 cfs), 10-year (960 cfs), 25-year (2,280 cfs), 50-year (3,960 cfs), 100-year (6,450 cfs), 500-year (15,690 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Mountain Shadows 1 and 2 downstream of project; CDOT reconstruction of US 34 within project boundaries
- **Fish passage barriers** – Olympus tunnel upstream
- **Diversion structures** – Olympus Tunnel (part of C-BT project) is located approximately 9 miles upstream; no other diversions until Dille Tunnel approximately 7.5 miles downstream
- **Nearest flow gauge** – Big Thompson River Below Lake Estes (BTBLESCO) approximately 9 miles upstream of project area, jointly operated by Northern Water and Bureau of Reclamation

Restoration Methods:

- **Seeding methods** – 4 zones (channel margin, bankfull bench, floodplain, upland), broadcast seeding
- **Planting zones** – 4 zones
- **Willow installation method(s)** – Installed by hand with rebar and jackhammer for especially difficult installation areas after heavy construction/grading was completed
- **Topsoil added?** – Approximately 2090 CY of imported topsoil added to project area
- **Erosion control** – Coir mat and hydromulch primarily, with small amount of coconut blanket near power poles used as shown in as-builts

- **Irrigation** – Western States conducted hand watering of container stock during one-year warranty period

Stakeholder Information:

- **Percent public/private land** – 100% private (with small amount of CDOT right-of-way at Waltonia Bridge)
- **Number of private landowners** – 12
- **Public land agencies** – CDOT

Post-Construction Inspections/Site Visits:

- BTWC visited the site in June and September 2018 to repeat photo points and conduct an SVAP assessment. BTWC visited again in June 2019 for high-water inundation monitoring.

4.4.2 Project Goals and Monitoring Questions

The Waltonia project's Basis of Design Report lists the following primary objectives:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land; and
(3) Restore the discharge capacity of the stream to pre-flood levels to the maximum extent practical where feasible and possible.

Anticipated ancillary benefits from the project were also listed in the Basis of Design Report, as follows:

(4) Improve water quality from the reduction of sediment loading caused by bank erosion;
(5) Enhance riparian habitat from the addition of vegetation; and
(6) Improve fish habitat from additional vegetation, improved water quality, and better habitat complexity.

Finally, additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(7) Verify design flows for floodplain benches.

4.4.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.4.2, the following monitoring parameters are recommended for the Waltonia flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1) and (3). Suggested cross-section locations are Stations 915+58, 904+70, and 898+94 (refer to Appendix U for a map of the suggested locations).

Structure surveys – Formal surveys of particular structures are not required at Waltonia. However, walking the site and visually inspecting the installed bank protection structures, cobble bar stabilization structures, and boulder cascades, specifically looking for significant shifting of structural components or signs of erosion, is recommended if resources are available. In cases of uncertainty, photo documentation and/or narrative descriptions may be shared with project designers to obtain input on whether adaptive management actions may be warranted.

Water quality and chemistry – Measuring select water quality parameters addresses project/monitoring goals (4) and (6). At the Waltonia site, temperature, dissolved oxygen, and turbidity are of the greatest interest because water quality goals relate to improved fish habitat and reduced sedimentation. The Big Thompson Watershed Forum (BTWF) has an established water quality monitoring location approximately 9 miles upstream of Waltonia just below Olympus Dam (site M50), and another site approximately 2 miles downstream of Waltonia just above Drake (site M60). Data including water quality parameters, certain metals, and nutrients are collected by BTWF at these locations at least every other year. Review these data to provide information about water quality at Waltonia; if water quality results at the two BTWF monitoring locations are substantially different, efforts may be pursued to determine the location and potential source(s) of changes in water quality along the Big Thompson corridor.

Vegetation surveys – To address project/monitoring goals (2), (5), and (6), vegetation transect surveys should be conducted. These transects should be co-located with the three recommended cross-section survey transects. The LHWC monitoring method is suggested here, likely with fewer zones due to the narrow canyon setting, and with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Fish population monitoring – Monitoring fish quantity, size, and distribution would address project/monitoring goal (6). CPW conducts repeat electrofishing surveys at their Waltonia site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout (> 150mm) per mile almost returning to pre-flood numbers by 2016. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the Waltonia project site. Consider occupying some of the BTWC/CWCB (Tracy Wendt/Kim Lennberg) or Muller Engineering (Brad Florentin/Joe Juergensen) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), and (6).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (4), (5), and (6). Annual EWP inspections should also be completed at the Waltonia project site.

Flow – A stream gauge maintained cooperatively by Northern Water and the Bureau of Reclamation, Big Thompson River Below Lake Estes (BTBLESCO), is located approximately 9 miles upstream of project area. Floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations during high flow periods such as spring runoff, particularly at useful hydraulic cross sections where possible (refer to Appendix U for a map of the suggested cross-section locations). Measuring inundation levels during high flow at Stations 915+58, 904+70, and 898+94 will address project/monitoring goals (3) and (7).

4.5 MOUNTAIN SHADOWS 1

The Mountain Shadows community experienced a catastrophic flood in 1976, and again in 2013, causing the Big Thompson River to overflow and flood. Damage from the 2013 flood included erosion along the main channel and erosion and deposition in the isolated small floodplains that exist through the upper canyon, including the Mountain Shadows 1 neighborhood (in the vicinity of the Mountain Shadow Lane bridge and the Linger Longer cabin). The area also experienced damage from channel widening, bank erosion, channel shifting, and areas of sediment deposition. As a result, large sections of roads were destroyed, bridges quickly clogged with flood debris, and homes were lost or severely damaged. In the immediate aftermath of the flood, restoring roads and bridges were high priorities. Some of the work completed in that effort further impaired the river corridor by straightening and homogenizing the channel, removing material from the channel to be used as fill and embankment armor for the road, and armoring the banks with rock, absent of soil and vegetation.

The Mountain Shadows 1 project rehabilitated approximately 2,050 feet of river corridor by re-establishing a low-flow channel, reconnecting the floodplain, protecting and stabilizing streambanks, excavating flood deposits, and revegetating the project area with native species. The project aimed to provide a sustainable floodplain design to protect the safety of neighborhood residents while enhancing habitat and improving river function and resilience.

4.5.1 Site Details

This section provides details about the Mountain Shadows 1 site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program)
- **Design engineer(s)** – Brad Florentin, Muller Engineering
- **Construction oversight engineer(s)** – Brad Florentin, Muller Engineering
- **Construction contractor** – Kiewit Infrastructure Company, Iron Woman Construction, and FlyWater
- **Vegetation designer** – Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – October 2, 2017 – May 11, 2018
- **Select design flow(s)** – winter baseflow (25 cfs), summer baseflow (125 cfs), bankfull flow (550 cfs), 10-year (960 cfs), 25-year (2,280 cfs), 50-year (3,960 cfs), 100-year (6,450 cfs), 500-year (15,690 cfs)

- **Select activation flow(s)** – NA

River System Information:
- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Waltonia upstream of the project; Mountain Shadows 2 downstream of project; CDOT reconstruction of US 34 within project boundaries
- **Fish passage barriers** – Olympus tunnel upstream
- **Diversion structures** – Olympus Tunnel (part of C-BT project) is located approximately 9 miles upstream; no other diversions until Dille Tunnel approximately 7.5 miles downstream
- **Nearest flow gauge** – Big Thompson River Below Lake Estes (BTBLESCO) approximately 9 miles upstream of project area, jointly operated by Northern Water and Bureau of Reclamation

Restoration Methods:
- **Seeding methods** – 3 zones (bankfull bench, floodplain, upland); Linger Longer only had 2 zones (floodplain, upland), broadcast vs hydroseed
- **Planting zones** – 4 zones (channel margin, bankfull bench, floodplain, upland); Linger Longer only had 1 zone (floodplain)
- **Willow installation method(s)** – Installed by hand with rebar and jackhammer for especially difficult installation areas after heavy construction/grading was completed
- **Topsoil added?** – Approximately 1000 CY of imported topsoil added to project area
- **Erosion control** – Coir mat and hydromulch used in the main project area; hydromulch only used at Linger Longer
- **Irrigation** – Western States conducted hand watering of container stock during one-year warranty period

Stakeholder Information:
- **Percent public/private land** – 100% private
- **Number of private landowners** – 6
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:
- BTWC visited the site in June and September 2018 to repeat photo points and conduct an SVAP assessment. BTWC visited again in June 2019 for high-water inundation monitoring.

4.5.2 Project Goals and Monitoring Questions

The Mountain Shadows 1 project's Basis of Design Report lists the following primary objectives:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land; and
(3) Restore the discharge capacity of the stream to pre-flood levels to the maximum extent practical where feasible and possible.

Anticipated ancillary benefits from the project were also listed in the Basis of Design Report, as follows:

(4) Improve water quality from the reduction of sediment loading caused by bank erosion;
(5) Enhance riparian habitat from the addition of vegetation; and
(6) Improve fish habitat from additional vegetation, improved water quality, and better habitat complexity.

Finally, additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(7) Verify design flows for floodplain benches.

4.5.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.5.2, the following monitoring parameters are recommended for the Mountain Shadows 1 flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1) and (3). Suggested cross-section locations are Stations 881+42 and 864+86 (refer to Appendix U for a map of the suggested locations).

Structure surveys – Formal surveys of particular structures are not required at Mountain Shadows 1. However, walking the site and visually inspecting the installed bank protection structures, cobble bar stabilization structures, and boulder cascades, specifically looking for significant shifting of structural components or signs of erosion, is recommended if resources are available. In cases of uncertainty, photo documentation and/or narrative descriptions may be shared with project designers to obtain input on whether adaptive management actions may be warranted.

Water quality and chemistry – Measuring select water quality parameters addresses project/monitoring goals (4) and (6). At the Mountain Shadows 1 site, temperature, dissolved oxygen, and turbidity are of the greatest interest because water quality goals relate to improved fish habitat and reduced sedimentation. The Big Thompson Watershed Forum (BTWF) has an established water quality monitoring location approximately 9 miles upstream of Mountain Shadows 1 just below Olympus Dam (site M50), and another site approximately 2 miles downstream of Mountain Shadows 1 just above Drake (site M60). Data including water quality parameters, certain metals, and nutrients are collected by BTWF at these locations at least every other year. Review these data to provide information about water quality at Mountain Shadows 1; if water quality results at the two BTWF monitoring locations are substantially different, efforts may be pursued to determine the location and potential source(s) of changes in water quality along the Big Thompson corridor.

Vegetation surveys – To address project/monitoring goals (2), (5), and (6), vegetation transect surveys should be conducted. These transects should be co-located with the two recommended cross-section survey transects. The LHWC monitoring method is suggested here, likely with fewer zones due to the narrow canyon setting, and with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Fish population monitoring – Monitoring fish quantity, size, and distribution would address project/monitoring goal (6). CPW conducts repeat electrofishing surveys at their Waltonia site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout (> 150mm) per mile almost returning to pre-flood numbers by 2016. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the Mountain Shadows 1 project site. Consider occupying some of the BTWC/CWCB (Tracy Wendt/Kim Lennberg) or Muller Engineering (Brad Florentin/Joe Juergensen) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), and (6).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (4), (5), and (6). Annual EWP inspections should also be completed at the Mountain Shadows 1 project site.

Flow – A stream gauge maintained cooperatively by Northern Water and the Bureau of Reclamation, Big Thompson River Below Lake Estes (BTBLESCO), is located approximately 9 miles upstream of project area. Floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations during high flow periods such as spring runoff, particularly at as-built cross sections where possible (refer to Appendix U for a map of the suggested cross-section locations). Measuring inundation levels during high flow at Stations 881+42 and 864+86 will address project/monitoring goals (3) and (7).

4.6 MOUNTAIN SHADOWS 2

The Mountain Shadows 2 community experienced a catastrophic flood in 1976, and again in 2013, causing the Big Thompson River to overflow and flood. Damage from the 2013 flood included erosion along the main channel and erosion and deposition in the isolated small floodplains that exist through the upper canyon, including the Mountain Shadows 2 neighborhood. The area also experienced damage from channel widening, bank erosion, channel shifting, and areas of sediment deposition. As a result, large sections of roads were destroyed, bridges quickly clogged with flood debris, and homes were lost or severely damaged. In the immediate aftermath of the flood, restoring roads and bridges were high priorities. Some of the work completed in that effort further impaired the river corridor by straightening and homogenizing the channel, removing material from the channel to be used as fill and embankment armor for the road, and armoring the banks with rock, absent of soil and vegetation.

The Mountain Shadows 2 project rehabilitated 1,100 feet of river corridor by re-establishing a low-flow channel, reconnecting the floodplain, protecting and stabilizing streambanks, excavating flood deposits, and revegetating the project area with native species. The project aimed to provide a sustainable floodplain design to protect the safety of neighborhood residents while enhancing habitat and improving river function and resilience.

4.6.1 Site Details

This section provides details about the Mountain Shadows 2 site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program)
- **Design engineer(s)** – Brad Florentin, Muller Engineering
- **Construction oversight engineer(s)** – Brad Florentin, Muller Engineering
- **Construction contractor** – Kiewit Infrastructure Company, Iron Woman Construction, and FlyWater
- **Vegetation designer** – Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – October 2, 2017 – May 11, 2018
- **Select design flow(s)** – winter baseflow (25 cfs), summer baseflow (125 cfs), bankfull flow (550 cfs), 10-year (960 cfs), 25-year (2,280 cfs), 50-year (3,960 cfs), 100-year (6,450 cfs), 500-year (15,690 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Waltonia and Mountain Shadows 1 upstream of the project; CDOT reconstruction of US 34 within project boundaries
- **Fish passage barriers** – Olympus tunnel upstream
- **Diversion structures** – Olympus Tunnel (part of C-BT project) is located approximately 9 miles upstream; no other diversions until Dille Tunnel approximately 7.5 miles downstream
- **Nearest flow gauge** – Big Thompson River Below Lake Estes (BTBLESCO) approximately 10 miles upstream of project area, jointly operated by Northern Water and Bureau of Reclamation

Restoration Methods:

- **Seeding methods** – 4 zones (channel margin, bankfull bench, floodplain, upland), broadcast seeding
- **Planting zones** – 4 zones
- **Willow installation method(s)** – Installed by hand with rebar and jackhammer for especially difficult installation areas after heavy construction/grading was completed
- **Topsoil added?** – Approximately 615 CY of imported topsoil added to project area
- **Erosion control** – Mix of coir mat, coconut blanket, and hydromulch
- **Irrigation** – Western States conducted hand watering of container stock during one-year warranty period

Stakeholder Information:
- **Percent public/private land** – 100% private
- **Number of private landowners** – 3 (in 6 parcels)
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:
- BTWC visited the site in June and September 2018 to repeat photo points and conduct an SVAP assessment. BTWC visited again in June 2019 for high-water inundation monitoring.

4.6.2 Project Goals and Monitoring Questions

The Mountain Shadows 2 project's Basis of Design Report lists the following primary objectives:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land; and
(3) Restore the discharge capacity of the stream to pre-flood levels to the maximum extent practical where feasible and possible.

Anticipated ancillary benefits from the project were also listed in the Basis of Design Report, as follows:

(4) Improve water quality from the reduction of sediment loading caused by bank erosion;
(5) Enhance riparian habitat from the addition of vegetation; and
(6) Improve fish habitat from additional vegetation, improved water quality, and better habitat complexity.

Finally, additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(7) Verify design flows for floodplain benches.

4.6.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.6.2, the following monitoring parameters are recommended for the Mountain Shadows 2 flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1) and (3). Suggested cross-section locations are Stations 836+60 and 830+82 (refer to Appendix U for a map of the suggested locations).

Structure surveys – Formal surveys of particular structures are not required at Mountain Shadows 2. However, walking the site and visually inspecting the installed bank protection structures, cobble bar stabilization structures, and boulder cascades, specifically looking for significant shifting of structural components or signs of erosion, is recommended if resources are available. In cases of uncertainty, photo documentation and/or narrative descriptions may be shared with project designers to obtain input on whether adaptive management actions may be warranted.

Water quality and chemistry – Measuring select water quality parameters addresses project/monitoring goals (4) and (6). At the Mountain Shadows 2 site, temperature, dissolved oxygen, and turbidity are of the greatest interest because water quality goals relate to improved fish habitat and reduced sedimentation. The Big Thompson Watershed Forum (BTWF) has an established water quality monitoring location approximately 10 miles upstream of Mountain Shadows 2 just below Olympus Dam (site M50), and another site approximately 1 mile downstream of Mountain Shadows 2 just above Drake (site M60). Data including water quality parameters, certain metals, and nutrients are collected by BTWF at these locations at least every other year. Review these data to provide information about water quality at Mountain Shadows 2; if water quality results at the two BTWF monitoring locations are substantially different, efforts may be pursued to determine the location and potential source(s) of changes in water quality along the Big Thompson corridor.

Vegetation surveys – To address project/monitoring goals (2), (5), and (6), vegetation transect surveys should be conducted. These transects should be co-located with the two recommended cross-section survey transects. The LWOG monitoring method is suggested here, likely with fewer zones due to the narrow canyon setting, and with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Fish population monitoring – Monitoring fish quantity, size, and distribution would address project/monitoring goal (6). CPW conducts repeat electrofishing surveys at their Waltonia site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout (> 150mm) per mile almost returning to pre-flood numbers by 2016. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the Mountain Shadows 2 project site. Consider occupying some of the BTWC/CWCB (Tracy Wendt/Kim Lennberg) or Muller Engineering (Brad Florentin/Joe Juergensen) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), and (6).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (4), (5), and (6). Annual EWP inspections should also be completed at the Mountain Shadows 2 project site.

Flow – A stream gauge maintained cooperatively by Northern Water and the Bureau of Reclamation, Big Thompson River Below Lake Estes (BTBLESCO), is located approximately 10 miles upstream of project area. Floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations during high flow periods such as spring runoff, particularly at as-built cross sections where possible (refer to Appendix U for a map of the suggested cross-section locations). Measuring inundation levels during high flow at Stations 836+60 and 830+82 will address project/monitoring goals (3) and (7).

4.7 MOODIE

Flood damage in the Big Thompson Canyon in 2013 occurred as a result of flows spilling out of the river banks and into the overbanks. The flood flows caused heavy erosion to occur along the banks of the Moodie reach, resulting in significant loss of property for several residences along the right bank. In addition, portions of Highway 34 and the Moodie Street Bridge were washed out (the Rose Hall Bridge, at the downstream end of the project reach, survived the flood). In the immediate aftermath of the flood, restoring roads and bridges were high priorities. Rock from the river channel was utilized to support and protect the road grade, the Moodie Street Bridge was replaced with a temporary culvert crossing, and banks in front of residences were temporarily stabilized with riprap. Some of the work completed in the emergency efforts further impaired the river corridor.

The Moodie project spans approximately 1,300 feet of river corridor. CDOT designed and implemented permanent roadway improvements along Highway 34, as well as a permanent replacement structure for the Moodie Street Bridge. The CDOT project also constructed improvements for the left river bank and the river bottom. The EWP project rehabilitated the right river bank (where private residences exist) using toe rock and vegetation, and implemented a seeding and planting plan for both the right bank and channel bottom.

4.7.1 Site Details

This section provides details about the Moodie site, project, and surroundings for reference during future monitoring events.

<u>Project Details:</u>

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB) (note that the majority of the project was completed by CDOT, with a small portion funded by the EWP Program)
- **Design engineer(s)** – Joe Juergensen, Muller Engineering
- **Construction oversight engineer(s)** – Otak on behalf of Rocksol, who provided oversight to the Kiewit team on all US 34/CDOT-led projects
- **Construction contractor** – Kiewit Infrastructure Company, Iron Woman Construction, and FlyWater
- **Vegetation designer** – Great Ecology
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – February 25 – May 25, 2018
- **Select design flow(s)** –bankfull flow (650 cfs)
- **Select activation flow(s)** – NA

<u>River System Information</u>:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Drake project less than a mile upstream of the project; CDOT reconstruction of US 34 and Moodie Street Bridge within project boundaries
- **Fish passage barriers** – Olympus tunnel upstream
- **Diversion structures** – Olympus Tunnel (part of C-BT project) upstream; no other diversions until Dille Tunnel downstream
- **Nearest flow gauge** – Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO) approximately 5 miles downstream of project area, operated by the Colorado Department of Water Resources

Restoration Methods:

- **Seeding methods** – 2 zones (floodplain and upland, many near-channel locations were submerged at time of seeding and therefore not seeded as part of the EWP project)
- **Planting zones** – 2 zones (bankfull bench and floodplain)
- **Willow installation method(s)** – Installed by hand after grading was completed
- **Topsoil added?** – Approximately 615 CY of imported topsoil added to project area
- **Erosion control** – Mix of coir mat, coconut blanket, and hydromulch
- **Irrigation** – Hand-watered during one-year warranty period; unknown how often or how much

Stakeholder Information:

- **Percent public/private land** – 100% private
- **Number of private landowners** – 7
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:

- In June 2019, BTWC, CDOT, Rocksol, Kiewit, Western States, and Great Ecology conducted a one-year plant warranty walkthrough. Results of that walkthrough noted observations that a total of 10 container plants had died and required replacement, and 25 willows required replacement. CDOT/Rocksol submitted an annual to EWP on June 24, 2019.

4.7.2 Project Goals and Monitoring Questions

The Moodie project's Basis of Design Technical Memorandum lists the following primary objectives:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land;
(3) Reduce threats to life or property; and
(4) Restore the discharge capacity of the stream to pre-flood levels to the maximum extent practical where feasible and possible.

Anticipated ancillary benefits from the project were also listed in the Basis of Design Report, as follows:

(5) Improve water quality from the reduction of sediment loading caused by bank erosion;
(6) Enhance riparian habitat from the addition of vegetation; and

(7) Improve fish habitat from additional vegetation, improved water quality, and better habitat complexity.

However, this monitoring plan is only considering the EWP-funded portion of the Moodie project, which involved bank protection on river right and revegetation. Therefore, the plan addresses portions of project/monitoring goals (1), (2), (3), (5), (6), and the vegetation component of (7).

4.7.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.7.2, the following monitoring parameters are recommended for the Moodie flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. If possible, reoccupying a subset of established photo point locations would benefit from visits in both spring and fall seasons.

<u>Structure surveys</u> – Bank protection structures on river right should be inspected to address project/monitoring goals (1) and (3). Prior to the project, severe erosion compromised nearby residences and other structures. The intended functions of the bank protection structures are to stabilize the bank and protect infrastructure. In cases of uncertainty, photo documentation and/or narrative descriptions may be shared with project designers to obtain input on whether adaptive management actions may be warranted.

<u>Vegetation surveys</u> – To address project/monitoring goals (2), (6), and (7), a vegetation transect survey should be conducted near Station 767+09 (refer to Appendix V for location). The LHWC monitoring method is suggested here, likely with fewer zones due to the narrow canyon setting, and with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

<u>Photo points</u> – Photo points should be established for monitoring at the Moodie project site. Consider occupying some of the BTWC/CWCB (Shayna Jones/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (3), (6), and (7).

<u>Visual assessments</u> – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (3), (5), (6), and (7). Annual EWP inspections should also be completed at the Moodie project site.

4.8 CEDAR COVE

The Cedar Cove reach of the Big Thompson River lies in a canyon pocket, where the steep narrow canyon walls upstream open up and the valley flattens before constricting once again. During large flood events, such as in 1976 and more recently in 2013, this reach functions to store sediment and debris scoured from the canyon upstream. As the water slows and sediment deposits, the river becomes unpredictable, choosing multiple channels and often claiming the entire corridor.

Cedar Cove experienced both river avulsion and significant aggradation as a result of the 2013 flood. The flood cut off access roads and severely damaged several homes in the reach. Tragically, two lives were lost. After the flood, the pre-flood channel was re-excavated to restore residential access and protect US Highway 34. While these emergency repairs offered some short-term relief, they provided little long-term security and left the channel and floodplain in a degraded state.

Ranked as one of the watershed's highest priorities for improvements in the Master Plan, the Cedar Cove project aimed to provide a robust, resilient, and sustainable river and floodplain design. The primary project goals were to reduce the impact of future flooding, stabilize the channel during multiple flow events, protect life and property, and create aquatic and riparian habitat.

4.8.1 Site Details

This section provides details about the Cedar Cove site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program)
- **Design engineer(s)** – Randy Walsh, Stantec
- **Construction oversight engineer(s)** – TC Dinkins, Stantec
- **Construction contractor** – Kiewit and FlyWater
- **Vegetation designer** – Stantec
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – August 3 – November 16, 2017
- **Select design flow(s)** – low flow (30 cfs), bankfull flow (650 cfs), 10-year (2,116 cfs), 25-year (4,538 cfs), 50-year (7,495 cfs), 100-year (11,803 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Viestenz-Smith Mountain Park flood recovery project approximately one mile upstream of project boundary; Highway 34 road/river construction approximately 1-1.5 miles upstream; Jasper Lake flood recovery project less than a mile downstream of project boundary
- **Fish passage barriers** – Dille tunnel/diversion approximately 1.5 miles downstream
- **Diversion structures** – Dille tunnel/diversion approximately 1.5 miles downstream
- **Nearest staff gauge** – Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO) just downstream of project area within the Jasper Lake project boundary, operated by the Colorado Department of Water Resources

Restoration Methods:

- **Seeding methods** – 3 zones (lower riparian, upper riparian, upland), broadcast and hand-raked
- **Planting zones** – 3 zones

- **Willow installation method(s)** – Some willows installed as part of bank protection in soil lifts and other floodplain sills/brush trenches. Other willows along upper riparian banks installed by hand with rebar after grading was completed.
- **Topsoil added?** – Approximately 940 CY of imported topsoil added to project area
- **Erosion control** – Coir and jute mat, wood strand mulch
- **Irrigation** – Hand-watered during one-year warranty period; unknown how often or how much (estimated once per month after initial watering)

Stakeholder Information:

- **Percent public/private land** – Approximately 40% public, 60% private
- **Number of private landowners** – 14
- **Public land agencies** – Larimer County, City of Loveland

Post-Construction Inspections/Site Visits:

- Stantec has a photo log of before/after photos.
- BTWC visited the site in November 2018 to repeat photo points. BTWC visited again in June 2019 for high-water inundation monitoring.

4.8.2 Project Goals and Monitoring Questions

The Cedar Cove project's Basis of Design Report lists very broad objectives, so the general EWP objectives are listed here:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land;
(3) Improve floodplain capacity and connection;
(4) Improve water quality from the reduction of sediment loading caused by bank erosion;
(5) Enrich riparian habitat from the addition of topsoil, seeding, and vegetation; and
(6) Enhance aquatic habitat through improved vegetation, water quality, and habitat complexity.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(7) Establish a community of predominantly native species through revegetation of a successional trajectory;
(8) Maintain geometry of the Honstein bend;
(9) Monitor the floodplain upstream of Honstein bend as an non-revegetated "control" floodplain; and
(10) Verify design flows for floodplain benches.

4.8.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.8.2, the following monitoring parameters are recommended for the Cedar Cove flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Measuring discharge during high flows and associating discharge measurements with inundation levels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1), (3), and (8). Permanent cross-section survey transects are suggested at Stations 25+36, 31+29, 34+47, 46+81, and 47+84 (refer to Appendix V for a map of the suggested cross-section locations).

Substrate surveys – A point bar assessment should be conducted at the Honstein bend point bar to address project/monitoring goal (8). Collecting point bar samples at this location will provide information about particle size movement within the project reach. Any excessive sedimentation on the point bar should be noted.

Structure surveys – Because individual installed structures do not relate directly to project or monitoring goals, no formal structure surveys are recommended at the Cedar Cove site. However, structures can be opportunistically documented during annual inspections and/or regular site visits. At approximately Station 25+36, the “woody debris toe protection” structure on the outside of the Honstein bend, and the point bar on the inside of the bend, may be monitored via photo point documentation and narrative descriptions to address project/monitoring goal (8).

Aquatic habitat feature surveys – Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. The rapid method for aquatic habitat feature surveys is recommended at Cedar Cove to address project/monitoring goal (6).

Water quality and chemistry – Measuring select water quality parameters addresses project/monitoring goals (4) and (6). At the Cedar Cove site, temperature, dissolved oxygen, and turbidity are of the greatest interest because water quality goals relate to improved fish habitat and reduced sedimentation. The Big Thompson Watershed Forum (BTWF) has an established water quality monitoring within the Jasper Lake reach just downstream of Cedar Cove (site M70). Data including water quality parameters, certain metals, and nutrients are collected by BTWF at these locations at least every other year. Review these data to provide information about water quality at Cedar Cove.

Vegetation surveys – To address project/monitoring goals (2), (5), (7), and (9), vegetation transect surveys should be conducted. These transects should be co-located with 2-3 of the recommended cross-section survey transects. The LHWC monitoring method is suggested here, with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level. In addition, the point bar on river left at the upstream end of the project (approximately Station 16+00 to 22+00) received no supplemental revegetation treatments as part of the Cedar Cove project. This floodplain bench may be used as a control against which to compare success of supplemental vegetation.

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goals (4) and (6) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (6). While no known macroinvertebrate monitoring has been performed near Cedar Cove, CPW conducts repeat electrofishing surveys at their Cedar Cove site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout (> 6 in) per mile slowly increasing, particularly re-stocked rainbow trout. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

<u>Photo points</u> – Photo points should be established for monitoring at the Cedar Cove project site. Consider occupying some of the Stantec (TC Dinkins/Randy Walsh) and BTWC/CWCB (Tracy Wendt/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Coordinates for established Stantec photo point locations are provided in the file Cedar_Cove_Photo_Points.xlsx (provided in Appendix V). Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), (7), (8), and (9).

<u>Visual assessments</u> – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (3), (4), (5), and (6). Annual EWP inspections should also be completed at the Cedar Cove project site.

<u>Flow</u> – A stream gauge operated by the Colorado Department of Water Resources, Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO), is located just downstream of project area within the Jasper Lake project boundary. Floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations during high flow periods such as spring runoff, particularly at useful hydraulic cross sections where possible. Measuring inundation levels during high flow at Stations 18+74, 25+36, 29+29, and 46+81 (Appendix V) will address project/monitoring goals (3) and (10).

4.9 JASPER LAKE

Energized by the 2013 flood, the Big Thompson River through the Jasper Lake reach reclaimed some of its former channel through the natural processes of widening and aggradation. Structures built within the river corridor were impacted by the deposition of large amounts of sediment and debris, and several homes, bridges, and private access roads were severely damaged or destroyed.

Ranked as the watershed's highest priority for improvements in the Master Plan, the Jasper Lake project aimed to provide a robust, resilient, and sustainable river and floodplain design. The purpose of the project was to protect vulnerable infrastructure located within the river corridor from future flood damage while repairing and enhancing riparian and aquatic habitat.

4.9.1 Site Details

This section provides details about the Jasper Lake site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – Senate Bill SB14-179, NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program)
- **Design engineer(s)** – Randy Walsh, Stantec
- **Construction oversight engineer(s)** – TC Dinkins, Stantec
- **Construction contractor** – RMC Construction
- **Vegetation designer** – Stantec
- **Vegetation contractor** – Research Services, LLC and RMC
- **Construction dates** – March 7 – May 22, 2017
- **Select design flow(s)** – low flow (30 cfs), bankfull flow (650 cfs), 10-year (2,693 cfs), 25-year (5,582 cfs), 50-year (9,048 cfs), 100-year (14,020 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Cedar Cove flood recovery project less than one mile upstream of project boundary; Highway 34 road/river construction directly downstream of project; Sylvan Dale Guest Ranch flood recovery project approximately 3 miles downstream of project
- **Fish passage barriers** – Dille tunnel/diversion approximately 1.5 miles downstream
- **Diversion structures** – Dille tunnel/diversion approximately 1.5 miles downstream
- **Nearest staff gauge** – Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO) within the project boundary just downstream of the Jasper Lake Bridge, operated by the Colorado Department of Water Resources

Restoration Methods:

- **Seeding methods** – 3 zones (upland, riparian/mesic, and wetland)
- **Planting zones** – 3 zones
- **Willow installation method(s)** – All willows installed by hand after completion of grading and heavy construction; willows deemed to be incorrectly installed during warranty period; willows re-installed as part of warranty in fall 2017
- **Topsoil added?** – Approximately 820 CY of imported topsoil added to project area
- **Erosion control** – Coir fabric and wood straw
- **Irrigation** – Hand-watered during one-year warranty period; unknown how often or how much (estimated once per month)

Stakeholder Information:

- **Percent public/private land** – Approximately 20% public, 80% private
- **Number of private landowners** – 10
- **Public land agencies** – Larimer County

Post-Construction Inspections/Site Visits:

- The CWCB monitoring team visited the Jasper Lake project site on October 17, 2018, after the project had already experienced two spring runoff events, to collect baseline data at the site. The team conducted vegetation plot surveys, aquatic habitat facet delineation, pool area mapping (where applicable), photo points, and wood counts.

- BTWC visited the site for annual inspection visits in October 2017 and accompanied the CWCB monitoring team in October 2018, and summarized findings in a memorandum and PowerPoint document submitted to the State on January 25, 2019.
- Larimer County Department of Natural Resources visited the site in 2018 to assess and manage noxious weeds. Refer to Appendix T for details regarding weed presence and management at Jasper Lake.
- The CWCB monitoring team visited Jasper Lake on September 9, 2019 to collect vegetation transect and photo point data at the baseline locations. Photo points were revisited on October 21, 2019.

4.9.2 Project Goals and Monitoring Questions

The Jasper Lake project's Basis of Design Report lists very broad objectives, so the general EWP objectives are listed here:

(1) Stabilize streambanks to protect against additional damage to existing infrastructure;
(2) Establish cover on critically eroding land;
(3) Improve floodplain capacity and connection;
(4) Improve water quality from the reduction of sediment loading caused by bank erosion;
(5) Enrich riparian habitat from the addition of topsoil, seeding, and vegetation; and
(6) Enhance aquatic habitat through improved vegetation, water quality, and habitat complexity.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(7) Establish a community of predominantly native species through revegetation of a successional trajectory;
(8) Create a point bar at Narrows Park that slowly aggrades over time;
(9) Monitor the first boulder cascade structure immediately downstream of the US 34 bridge; and
(10)Verify design flows for floodplain benches.

4.9.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.9.2, the following monitoring parameters are recommended for the Jasper Lake flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Measuring discharge during high flows and associating discharge measurements with inundation levels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1), (3), and (8). Permanent cross-section survey transects are suggested at Stations 1+64, 4+75, 11+02, and 17+80 (refer to Appendix V for a map of the suggested cross-section locations).

Substrate surveys – A point bar assessment should be conducted at the Narrows Park point bar to address project/monitoring goal (8). Collecting point bar samples at this location will provide information about particle size movement within the project reach and test the hypothesis that the Narrows Park point bar will slowly aggrade over time. Photos should supplement the point bar sample, and observations about sedimentation on the point bar should be noted.

Structure surveys – Because individual installed structures do not relate directly to project or monitoring goals, no formal structure surveys are recommended at the Jasper Lake site. However, structures can be opportunistically documented during annual inspections and/or regular site visits. The first boulder cascade structure immediately downstream of the US 34 bridge at approximately Station 15+84 should be monitored closely via photo point documentation and narrative descriptions to address project/monitoring goal (9). In particular, the vane arm on river right was showing signs of scour on the downstream side of the structure after construction.

Aquatic habitat feature surveys – Baseline aquatic habitat feature surveys were conducted by the CWCB monitoring team in 2018, and will be revisited as needed in future years. These surveys address project/monitoring goal (6). Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. Because the CWCB monitoring team is conducting these surveys in the project reach, additional monitoring by the coalition is not necessary at this time.

Pool area mapping – The CWCB monitoring team conducted an RPD survey in the project reach in 2018, and two pools (one created by the boulder cascade at approximately Station 15+84 and a small one near approximately Station 17+00) were the only pools that met the depth criteria (greater than 1.5 feet). They will continue to revisit this measurement as needed. In addition to this survey, counting pools and measuring their maximum depth over time can be a simple yet quantitative way to address project/monitoring goal (6).

Water quality parameters – Measuring select water quality parameters addresses project/monitoring goals (4) and (6). At the Jasper Lake site, temperature, dissolved oxygen, and turbidity are of the greatest interest because water quality goals relate to improved fish habitat and reduced sedimentation. The Big Thompson Watershed Forum (BTWF) has an established water quality monitoring within the Jasper Lake reach (site M70). Data including water quality parameters, certain metals, and nutrients are collected by BTWF at these locations at least every other year. BTWF also recently installed a temporary real-time USGS monitoring station in the Jasper Lake project reach to measure temperature, conductivity, pH, and turbidity at 15-minute intervals during winter 2017-2018. Review these data to provide information about water quality at Jasper Lake.

Vegetation surveys – Vegetation transect surveys are being conducted by the CWCB monitoring team at three plots within the project reach (river right at approximately Station 4+00, river right at approximately Station 11+00, and river left at approximately Station 18+00). Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional vegetation surveys are recommended at the Jasper Lake project site. Vegetation monitoring addresses project/monitoring goals (2), (5), and (7).

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goals (4) and (6) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (6). While no known macroinvertebrate monitoring has been performed near Jasper Lake, CPW conducts repeat electrofishing surveys within the Jasper Lake reach at their Narrows Park site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout (> 6 in) per mile slowly increasing over time. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the Jasper Lake project site. Consider occupying some of the Stantec (TC Dinkins/Randy Walsh) and BTWC/CWCB (Tracy Wendt/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Coordinates for established Stantec photo point locations are provided in the file Jasper_Lake_Photo_Points.xlsx (provided in Appendix V). Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), (7), (8), and (9).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (3), (4), (5), and (6). Annual EWP inspections should also be completed at the Jasper Lake project site.

Flow – A stream gauge operated by the Colorado Department of Water Resources, Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO), is located within the Jasper Lake project boundary. Floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations during high flow periods such as spring runoff, particularly at useful hydraulic cross sections where possible. Measuring inundation levels during high flow at Stations 4+75, 11+02, and 17+80 (Appendix V) will address project/monitoring goals (3) and (10).

4.10 SYLVAN DALE RANCH

The Sylvan Dale Guest Ranch (SDGR), located within the river corridor at the mouth of the Big Thompson Canyon, was severely damaged by the massive 2013 flood. The force of the flood waters and extensive sediment deposition scoured existing natural features, destroyed the Ranch's main lodge and several cabins, and severely damaged other Ranch infrastructure and nearby county roads.

The SDGR project was used as a demonstration project to showcase river restoration techniques at a small scale. Some components of the project included defining a low-flow channel to concentrate water in the river for aquatic organisms during dry times; replicating natural bedforms such as pools, riffles, glides, and point bars; placing boulder clusters in the active river channel to enhance pools and improve aquatic habitat; grading to reconnect the channel with its floodplain in order to improve conveyance of future flood waters and sediment; and revegetation with native seeds and willows. A side channel habitat feature was also created as part of this project.

4.10.1 Site Details

This section provides details about the Sylvan Dale Guest Ranch site, project, and surroundings for reference during future monitoring events.

Project Details:
- **Funding Source(s)** – DOLA CDBG-DR Watershed Implementation Grant Program
- **Design engineer(s)** – Troy Thompson, Ecological Resource Consultants
- **Construction oversight engineer(s)** – James Koehler, Ecological Resource Consultants
- **Construction contractor** – Tezak Heavy Equipment
- **Vegetation designer** – ERC
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – March 16 – May 5, 2017
- **Select design flow(s)** – 10-year (3,800 cfs), 100-year (15,450 cfs)
- **Select activation flow(s)** – Side channel (10-year)

River System Information:
- **Position in watershed** – Canyon mouth
- **Adjacent restoration projects** – Jasper Lake flood recovery project approximately 3 miles upstream of project; Highway 34 road/river construction approximately 2 miles upstream of project; City of Loveland Wastewater Treatment Plant flood recovery project just downstream of project boundary
- **Fish passage barriers** – Handy Ditch approximately 0.5 miles upstream of project; Home Supply Ditch approximately 0.5 miles downstream of project; Southside, Louden, and George Rist diversions approximately miles downstream of project
- **Diversion structures** – Handy Ditch approximately 0.5 miles upstream of project; Home Supply Ditch approximately 0.5 miles downstream of project; Southside, Louden, and George Rist diversions approximately miles downstream of project
- **Nearest staff gauge** – Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO) approximately 3 miles upstream of the project site, operated by the Colorado Department of Water Resources

Restoration Methods:
- **Seeding methods** – Hydroseed in all disturbance areas
- **Planting zones** – None
- **Willow installation method(s)** – NA
- **Topsoil added?** – No
- **Erosion control** – No erosion control used; work primarily completed in channel or floodplain benches
- **Irrigation** – No

Stakeholder Information:
- **Percent public/private land** – 100% private
- **Number of private landowners** – 2
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (fall 2019).

4.10.2 Project Goals and Monitoring Questions

The Sylvan Dale Guest Ranch project's general objectives are listed here:

(1) Demonstrate river restoration techniques at a small scale;
(2) Reconnect floodplain and increase floodplain capacity through sediment removal and grading;
(3) Enhance riparian and aquatic habitat;
(4) Establish cover on critically eroding land; and
(5) Stabilize streambanks to protect against additional damage to existing infrastructure.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(6) Ensure that the diversion structure is functioning as intended (including monitoring headgate at upstream end of project).

4.10.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.10.2, the following monitoring parameters are recommended for the Sylvan Dale Guest Ranch flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Reoccupying a subset of established photo point locations may benefit from visits in both spring and fall seasons.

<u>Physical surveys</u> – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (2) and (5). Permanent cross-section survey transects are suggested at approximately Stations 17+00 (within a riffle) and 15+00 (at the downstream end of the constructed pool).

<u>Structure surveys</u> – Because individual installed structures do not relate directly to project or monitoring goals, no formal structure surveys are recommended at the SDGR site. However, structures can be opportunistically documented during annual inspections and/or regular site visits. The head gate in the diversion side channel should be monitored closely via photo point documentation and narrative descriptions to address project/monitoring goal (6).

<u>Aquatic habitat feature surveys</u> – Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. The rapid method for aquatic habitat feature surveys is recommended at SDGR to address project/monitoring goal (3). In addition, angling guides regularly visit SDGR to provide recreational fishing opportunities to ranch guests and other clients. Interviewing them would be a qualitative but informative way to glean information about the fishery and associated aquatic habitat.

<u>Vegetation surveys</u> – Vegetation transect surveys may be conducted to address project/monitoring goal (4). However, according to the design engineer, this project was

dominated by in-stream work, with limited effort geared toward revegetation. If the coalition chooses to conduct vegetation monitoring activities, transects should be located predominantly on floodplain benches. The LHWC monitoring method is suggested here, likely with fewer zones due to the narrow canyon setting, and with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goal (3) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (3). While no known macroinvertebrate monitoring has been performed near SDGR, CPW conducts repeat electrofishing surveys just upstream of the SDGR reach at their Roosevelt Pullout site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout per mile (> 150 mm) per mile slowly increasing over time. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health. In addition, angling guides regularly visit SDGR to provide recreational fishing opportunities to ranch guests and other clients. Interviewing them would be a qualitative but informative way to glean information about the fishery and associated aquatic habitat.

Photo points – Photo points should be established for monitoring at the SDGR project site. Consider occupying some of the ERC (Troy Thompson) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. The design engineer suggests at least one photo point at each of the riffles, pools, and glides in the project. Photo points can be used to inform all of the project/monitoring goals.

Visual assessments – The SVAP assessment should be conducted annually to address most of the project/monitoring goals, particularly (2), (3), (4), and (5).

4.11 CITY OF LOVELAND WATER TREATMENT PLANT

The City of Loveland Water Treatment Plant (COL WTP), located within the river corridor at the mouth of the Big Thompson Canyon, was extensively damaged by the massive 2013 flood. The force of the flood waters and extensive sediment deposition resulted in significant damage to the WTP's critical infrastructure and operations.

Alongside the SDGR project, the COL WTP project was used as a demonstration project to showcase river restoration techniques at a small scale. Some components of the project included defining a low-flow channel to concentrate water in the river for aquatic organisms during dry times; replicating natural bedforms such as pools, riffles, glides, and point bars; placing boulder clusters in the active river channel to enhance pools and improve aquatic habitat; grading to reconnect the channel with its floodplain in order to improve conveyance of future flood waters and sediment; and revegetation with native seeds, container plants, and willows. The split flow at the water intake plant was reconstructed into a single thread meandering channel with ample room for flooding over the constructed point bar.

4.11.1 Site Details

This section provides details about the City of Loveland Water Treatment Plant site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Watershed Implementation Grant Program
- **Design engineer(s)** – Troy Thompson, Ecological Resource Consultants
- **Construction oversight engineer(s)** – James Koehler, Ecological Resource Consultants
- **Construction contractor** – Tezak Heavy Equipment
- **Vegetation designer** – ERC
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – March 16 – May 5, 2017
- **Select design flow(s)** – 10-year (3,800 cfs), 100-year (15,450 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon mouth
- **Adjacent restoration projects** – Sylvan Dale Guest Ranch flood recovery project just upstream of project boundary; Highway 34 road/river construction approximately 2 miles upstream of project; Wild Natural Area (and Neighbors, Reach 28) flood recovery project approximately 2 miles downstream of project boundary
- **Fish passage barriers** – Handy Ditch approximately 0.5 miles upstream of project; Home Supply Ditch approximately 0.5 miles downstream of project; Southside, Louden, and George Rist diversions approximately miles downstream of project
- **Diversion structures** – Handy Ditch approximately 0.5 miles upstream of project; Home Supply Ditch approximately 0.5 miles downstream of project; Southside, Louden, and George Rist diversions approximately miles downstream of project
- **Nearest staff gauge** – Big Thompson River Above Canyon Mouth at Cedar Cove, CO (BTABCMCO) approximately 3 miles upstream of the project site, operated by the Colorado Department of Water Resources

Restoration Methods:

- **Seeding methods** – Hydroseed in all disturbance areas
- **Planting zones** – Minimal planting; willow staking used as bank stabilization for approximately 400 linear feet between Stations 0+00 and 5+00
- **Willow installation method(s)** – Installed by hand after grading
- **Topsoil added?** – No
- **Erosion control** – Hydromulch
- **Irrigation** – No

Stakeholder Information:

- **Percent public/private land** – 100% public
- **Number of private landowners** – 1
- **Public land agencies** – City of Loveland

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (fall 2019).

4.11.2 Project Goals and Monitoring Questions

The COL WTP project's general objectives are listed here:

(1) Demonstrate river restoration techniques at a small scale;
(2) Reconnect floodplain and increase floodplain capacity through sediment removal and grading;
(3) Enhance riparian and aquatic habitat;
(4) Establish cover on critically eroding land; and
(5) Stabilize streambanks to protect against additional damage to existing infrastructure.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(6) Monitor the large terrace/point bar on river right at the downstream end of the project just upstream of the bridge.

4.11.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.11.2, the following monitoring parameters are recommended for the City of Loveland Water Treatment Plant flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Reoccupying a subset of established photo point locations may benefit from visits in both spring and fall seasons.

<u>Substrate surveys</u> – A point bar assessment should be conducted at the constructed point bar on river right just upstream of the bridge (approximately Station 3+00) to address project/monitoring goal (6). Collecting point bar samples at this location will provide information about particle size movement within the project reach and document whether terrace/point bar construction was successful at this location. Photos should supplement the point bar sample, and observations about sedimentation on the point bar should be noted.

<u>Structure surveys</u> – Because individual installed structures do not relate directly to project or monitoring goals, no formal structure surveys are recommended at the COL WTP site. However, constructed riffles can be opportunistically documented during annual inspections and/or regular site visits.

<u>Aquatic habitat feature surveys</u> – Presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. The rapid method for aquatic habitat feature surveys is recommended at COL WTP to address project/monitoring goal (3).

<u>Vegetation surveys</u> – Vegetation transect surveys may be conducted to address project/monitoring goal (4). However, according to the design engineer, this project was dominated by in-stream work, with limited effort geared toward revegetation. If the coalition chooses to conduct vegetation monitoring activities, transects should be located predominantly

on floodplain benches. The LHWC monitoring method is suggested here, likely with fewer zones due to the narrow canyon setting, and with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goal (3) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (3). While no known macroinvertebrate monitoring has been performed near COL WTP, CPW conducts repeat electrofishing surveys upstream of the COL WTP reach at their Roosevelt Pullout site annually. Based on their data, the fishery appears to be recovering from the flood disturbance, with population estimates of total trout per mile (> 150 mm) per mile slowly increasing over time. Full datasets should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the COL WTP project site. Consider occupying some of the ERC (Troy Thompson) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. The design engineer suggests at least one photo point at each of the riffles, pools, and glides in the project. Photo points can be used to inform all of the project/monitoring goals.

Visual assessments – The SVAP assessment should be conducted annually to address most of the project/monitoring goals, particularly (2), (3), (4), and (5).

4.12 WILD NATURAL AREA (& NEIGHBORS) / REACH 28

Reach 28, a response reach located east of the Big Thompson Canyon and west of the City of Loveland, was significantly altered as a result of the 2013 flood. Deposits of approximately 10 feet of sediment occurred in the pre-flood channel, resulting in a channel avulsion, loss of most of the riparian vegetation, a degraded and unstable channel, and extensive property damage.

The Reach 28 project, also referred to as the Wild Natural Area (& Neighbors) project, is a multi-objective project that aimed to improve aquatic and riparian habitat and reduce geomorphic risk through ecosystem restoration, channel enhancement, and stabilization activities. Like a natural channel, restoration of this reach was approached with a design that will allow the stream to migrate in response to flow and sediment loads, but is intended to maintain its basic form without significant aggradation or degradation.

4.12.1 Site Details

This section provides details about the Wild Natural Area (& Neighbors) site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Resilience Planning Program, DOLA CDBG-DR Watershed Implementation Grant Program

- **Design engineer(s)** – Troy Thompson, ERC
- **Construction oversight engineer(s)** – James Koehler, ERC
- **Construction contractor** – Tezak Heavy Equipment
- **Vegetation designer** – David Blauch, ERC
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – March 4 – August 2, 2019
- **Select design flow(s)** – Bankfull flow (500 cfs), 100-year flow (14,300 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Plains
- **Adjacent restoration projects** – Sylvan Dale Guest Ranch and City of Loveland Water Treatment Plant flood recovery projects approximately 4 miles upstream of project reach; Rossum-Wilson and Rist-Goss flood recovery projects approximately 1 mile downstream of project reach
- **Fish passage barriers** – Rist-Goss Diversion approximately 1 mile downstream has been improved to allow fish passage, but passage success has not yet been montiored
- **Diversion structures** – Big Barnes Ditch upstream; Louden Ditch and Rist-Goss Diversion downstream
- **Nearest staff gauge** – Big Thompson River at Loveland, CO (BIGLOVCO) approximately 8 miles downstream of project reach, operated by USGS

Restoration Methods:

- **Seeding methods** – 3 zones (upland, riparian); upland was hydroseeded with fertilizer mulch mix and riparian was hand raked in and covered with erosion blanket
- **Planting zones** – 3 zones (willow stakes at bankfull edge, riparian shrub nursery stock 0-8 feet from bankfull edge, upland shrubs/trees 10-50 feet from bankfull edge)
- **Willow installation method(s)** – installed by hand at bank edge after grading, nursery stock installed just above
- **Topsoil added?** – No; native soil was amended with fertilizer and soil amendments and topped with mulch for upland shrubs/trees
- **Erosion control** – Finely woven erosion blanket installed in riparian zone
- **Irrigation** – ERC worked with the Big Thompson Water Commissioner to determine best irrigation practices; 5-gallon buckets were used to draw water out of the river; amount used was recorded and conveyed to the COL WTP (upstream of the project site) who released an equal amount of water into the river.

Stakeholder Information:

- **Percent public/private land** – 25% public, 75% private
- **Number of private landowners** – 3
- **Public land agencies** – City of Loveland

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (fall 2019).

4.12.2 Project Goals and Monitoring Questions

The project's Basis of Design Report states that the primary goal of the Wild Natural Area (& Neighbors)/Reach 28 project was to improve aquatic and riparian habitat while reducing geomorphic and future flood risk. Specific project objectives were listed in the report as follows:

(1) Establish a main river channel to accommodate a wide range (both high and low) of anticipated flows;
(2) Establish in-stream aquatic habitat variety (bed form diversity) for local fish populations;
(3) Establish appropriate bankfull geometries including width-depth ratio;
(4) Maintain correct sediment transport capabilities;
(5) Develop floodplain terraces (point bars);
(6) Maximize floodplain conveyance and storage during flood events;
(7) Increase flood resiliency;
(8) Stabilize streambanks;
(9) Establish a riparian habitat corridor;
(10) Reclaim riparian and upland natural vegetation communities and lands damaged by flooding; and
(11) Given the significant undeveloped stream corridor and floodplain within the project area, allow the stream to adjust in a natural manner as it responds to flows and sediment loads.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(12) Track point bar development and particle size, as well as sediment deposition in riffles, to gain information about sediment transport;
(13) Maintain a low-flow channel over time; and
(14) Verify design flows for floodplain benches.

4.12.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.12.2, the following monitoring parameters are recommended for the Wild Natural Area (& Neighbors)/Reach 28 flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1), (3), (4), (5), (6), (8), and (11). Permanent cross-sections are suggested at 1-2 riffle/pool/glide "pods." For example, survey a series of 3 cross sections at Station 5+50 (riffle), Station 4+00 (pool), and Station 3+00 (glide). If resources are available for another pod, Station 18+00 (riffle), Station 17+00 (pool), and Station 16+00 (glide) may be surveyed.

Thalweg survey – A survey of thalweg depth is recommended to address project/monitoring goals (1) and (13), and ensure that a well-defined low-flow channel persists over time. The depth of the channel thalweg should be measured in random locations at approximately 50-foot intervals, for a total of 40-50 measurements. Depths should be recorded, and an average depth should be computed to compare to in future years.

Substrate surveys – Substrate surveys are recommended to ensure that excessive sedimentation is not occurring in this response reach. Pebble counts should be conducted at 3 riffles within the project site to address project/monitoring goals (4), (11), and (12). In addition, any new point bars that have been created should be noted, and point bar assessments should be conducted at 2 representative point bars to address project/monitoring goals (5), (11), and (12). For reference, Section 3.3 of the project's Basis of Design Report indicates the following pre-project substrate sizes: representative riffle D50 (110 mm), point bar D50 (12 mm).

Structure surveys – Because individual installed structures do not relate directly to project or monitoring goals, no formal structure surveys are recommended at the Wild Natural Area (& Neighbors)/Reach 28 site. However, structures can be opportunistically documented during annual inspections and/or regular site visits.

Aquatic habitat feature surveys – The USFS channel unit inventory should be conducted on a sub-reach within the project reach to address project/monitoring goal (2). This survey method will evaluate the goal of increasing in-stream habitat complexity by monitoring the presence of all types of aquatic habitat features over time and tracking changes in pool size and location. If resources do not allow for this detailed method, the rapid method for aquatic habitat feature surveys may be used to confirm the presence and persistence of all types of aquatic habitat features. Regardless of which method is implemented, a 1,000-ft sub-reach is recommended to capture riffle/pool/glide sequences 2 and 3 from upstream to downstream: Station 10+94 to Station 1+80.

Vegetation surveys – To address project/monitoring goals (9) and (10), vegetation transect surveys should be conducted. These transects should be co-located with the three recommended cross-section survey transects. The LHWC monitoring method is suggested here, with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Photo points – Photo points should be established for monitoring at the Wild Natural Area (& Neighbors)/Reach 28 project site. Consider occupying some of the BTWC photos taken before construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (5), (8), (9), (10), and (11).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (4), (8), (9), and (10).

Flow – Discharge should be measured or estimated at the Wild Natural Area (& Neighbors)/Reach 28 project because although established stream gauges exist both upstream and downstream of the project site, numerous diversions and return flows occur between the gauges and the project site. If possible, installation of a staff gauge and periodic measurement of discharge at a range of flows using a flow meter to develop a stage-discharge rating curve is recommended. Flow should be measured during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations, particularly at as-built or monitoring cross-sections where possible, to address project/monitoring goals (1) and (14).

4.13 ROSSUM-WILSON

During the 2013 flood, the Big Thompson River avulsed in multiple locations within the 1.6-mile (8,525 ft) Rossum-Wilson project reach. Channel movement resulting from the flood caused extensive damage to adjacent properties and destroyed stream banks in numerous locations. Emergency operations conducted by property owners and others returned the river to the pre-flood channel and reinforced banks in some areas, but these repairs were not suited to long-term resilience.

The Rossum-Wilson flood recovery project aimed to implement improvements that build resilience into the Big Thompson River within the project reach. Resiliency is primarily achieved by reducing flood, geomorphic, and ecologic risks and improving stream health. Project objectives were developed based on conversations with stakeholders and the coalition, with the main goals of reconnecting the floodplain; improving river health and system function; and working harmoniously with the adjacent Rist-Goss diversion reconstruction project and Namaqua bridge replacement project.

4.13.1 Site Details

This section provides details about the Rossum-Wilson site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Resilience Planning Program, DOLA CDBG-DR Watershed Implementation Grant Program
- **Design engineer(s)** – Rachel Williams, Otak
- **Construction oversight engineer(s)** – Rachel Williams, Otak
- **Construction contractor** – ECI Site Management Services, with Flywater and Connell
- **Vegetation designer** – Ecosystem Services (Ecos)
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – December 21, 2018 - August 30, 2019
- **Select design flow(s)** – Low flow (53 cfs), 1.5-year (562 cfs), 2-year (826 cfs), 5-year (3,247 cfs), 10-year (4,332 cfs), 25-year (8,383 cfs), 50-year (12,941 cfs), 100-year (19,021 cfs), 500-year (40,535 cfs)
- **Select activation flow(s)** – overflow channels 1, 5, and 6 (1.5-year flow); overflow channel 4 (2-year flow); overflow channels 2 and 8 (10-year flow); overflow channels 3, 7, and 9 (25-50-year flow)

River System Information:

- **Position in watershed** – Plains

- **Adjacent restoration projects** – Reach 28 project approximately 1 mile upstream of the project reach; replacement of Namaqua Bridge, improvements to Wilson Bridge, and Rist-Goss diversion reconstruction project within the project reach
- **Fish passage barriers** – Greeley-Loveland diversion structure approximately 1,300 ft downstream of project; Big Barnes Ditch approximately 500 ft upstream of project
- **Diversion structures** – Greeley-Loveland diversion structure approximately 1,300 ft downstream of project; Big Barnes Ditch approximately 500 ft upstream of project
- **Nearest staff gauge** – Big Thompson River At Loveland, CO (BIGLOVCO) approximately 6 miles downstream of project reach, operated by USGS

Restoration Methods:

- **Seeding methods** – 3 zones (upland, riparian, wetland); drill seeding preferred, with some locations requiring hydroseeding or broadcasting followed by hand raking
- **Planting zones** – 4 zones (upland, riparian, brush trench, wetland)
- **Willow installation method(s)** – Willows in brush trenches installed with small machinery; willows elsewhere on banks installed by hand with rebar and other tools
- **Topsoil added?** – Yes; approximately 1250 CY (Rossum to Namaqua) and 1475 CY (Namaqua to Wilson Area)
- **Erosion control** – Mix of coir fabric (bank slopes) coconut matting (overflow channel slopes), wood straw, and wood mulch
- **Irrigation** – Yes; overhead spray irrigation system being installed for seed and container plants; watering schedule for trees and shrubs is: Nov – Feb: once every three weeks; March – May: Once every two weeks, June – August: once per week; Sept – Oct: once every two weeks; willow cutting will be watered according to schedule if soil not saturated; seeding areas will be served by irrigation system and watered as needed

Stakeholder Information:

- **Percent public/private land** – 60% private, 40% public
- **Number of private landowners** – 1
- **Public land agencies** – City of Loveland Open Lands

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (fall 2019).

4.13.2 Project Goals and Monitoring Questions

The project's Basis of Design Report states that the primary goal of the Rossum-Wilson project was to build resilience by reducing flood, geomorphic, and ecologic risks and improving stream health. Specific project objectives were listed in the report as follows:

(1) Increase channel-floodplain connection for a range of flow events (2-year to 25-year) by lowering bankfull and high benches along the main channel, adding overflow channels, and adding connections to existing ponds;
(2) Increase the amount of cover, holding habitat, and organic matter through the reach by incorporating large wood structures;
(3) Encourage channel narrowing at over-widened portions of the project reach by constructing point bars;
(4) Protect banks through addition of primarily bioengineered, deformable treatments; and

(5) Reduce surface erosion and increase the quality of riparian and upland habitat by revegetating channel banks and floodplains.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(6) Track point bar development and particle size, as well as sediment deposition in riffles, to gain information about sediment transport;
(7) Check persistence of constructed point bars and channel widths over time;
(8) Evaluate wood structures for pool scouring, sediment collection, and/or bank erosion; and
(9) Verify design flows for floodplain benches.

4.13.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.13.2, the following monitoring parameters are recommended for the Rossum-Wilson flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches and overflow channels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

<u>Physical surveys</u> – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1), (3), and (7). Permanent cross-sections are suggested at the following approximate locations (or a subset, if resources do not allow for surveying all suggested locations): Stations 101+90, 99+50, 93+50, 74+20, 46+00, 29+50, and 19+20. Refer to Appendix W for a map of the suggested locations.

<u>Substrate surveys</u> – Substrate surveys are recommended to ensure that excessive sedimentation is not occurring in this response reach. Pebble counts should be conducted at 3 riffles within the project site (suggested locations include approximately Station 93+50, 74+20 and Station 19+20) to address project/monitoring goals (5) and (6). In addition, any new point bars that have been created should be noted, and point bar assessments should be conducted at 2 representative point bars (suggested locations include approximately Station 101+90 and Station 29+50) to address project/monitoring goals (3), (6), and (7). For reference, Section 3.3 of the project's Basis of Design Report indicates the following pre-project substrate sizes: Reach 1 D50/D84 (79/146 mm), Reach 2 D50/D84 (69/122 mm), Reach 5 upstream D50/D84 (86/146 mm), Reach 5 downstream D50/D84 (55/83 mm). Refer to Appendix W for a map of the suggested locations for substrate surveys.

<u>Structure surveys</u> – Surveying the installed large wood structures throughout the project (approximately Stations 101+00, 95+00, and 29+00 on river left) addresses project/monitoring goals (2) and (8). These woody bank stabilization structures should be evaluated to determine whether they are fulfilling their intended functions: reduce water velocities and dissipate energy; stabilize banks; create pools; provide cover; and direct flow away from the bank.

Vegetation surveys – To address project/monitoring goal (5), vegetation transect surveys should be conducted. These transects should be co-located with three recommended cross-section survey transects. The LHWC monitoring method is suggested here, with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Photo points – Photo points should be established for monitoring at the Rossum-Wilson project site. Consider occupying some of the BTWC/Otak photos taken before construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (3), (4), (5), (7), and (8).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (2), (4), and (5).

Flow – Discharge should be measured or estimated at the Rossum-Wilson project because although established stream gauges exist both upstream and downstream of the project site, numerous diversions and return flows occur between the gauges and the project site. If possible, installation of a staff gauge and periodic measurement of discharge at a range of flows using a flow meter to develop a stage-discharge rating curve is recommended. Flow should be measured during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations, particularly at as-built or monitoring cross-sections where possible (refer to Appendix W for a map of the suggested cross-section locations), to address project/monitoring goals (1), (3), and (9).

4.14 RIST-GOSS DIVERSION

The aging dam infrastructure at the Rist-Goss diversion site on the Big Thompson River was damaged during the 2013 flood. Located in the middle of the Rossum-Wilson flood recovery project reach, the Rist-Goss diversion was a channel-spanning 6-foot high concrete structure. The diversion posed a barrier to fish passage and impeded natural conveyance of sediment, causing deposition for hundreds of feet upstream of the structure, and requiring constant maintenance.

The primary goals of the Rist-Goss diversion reconstruction project were to develop a resilient design for the river channel and floodplain 1,875 feet upstream and downstream of the diversion; to address damages sustained from the 2013 flood and continued sedimentation maintenance; to address fish passage obstacles; and to create a cohesive design between the project and other adjacent projects (Rossum-Wilson flood recovery project and Namaqua Bridge replacement project).

4.14.1 Site Details

This section provides details about the Rist-Goss diversion site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Resilience Planning Program, DOLA CDBG-DR Watershed Implementation Grant Program, with matching funds from Northern Water
- **Design engineer(s)** – Kyle Hardie, CDM Smith
- **Construction oversight engineer(s)** – Kyle Hardie, CDM Smith
- **Construction contractor** – ECI Site Management Services, with Flywater and Connell
- **Vegetation designer** – Ecosystem Services (Ecos)
- **Vegetation contractor** – Western States Reclamation
- **Construction dates** – December 21, 2018 - August 30, 2019
- **Select design flow(s)** – Annual low flow (35-57 cfs), agricultural (Apr-Sep) low flow (49-96 cfs), 1-year (224-282 cfs), 1.25-year (443-496 cfs), bankfull (2-year) (840 cfs), 5-year (2,147 cfs), 10-year (4,318 cfs), 25-year (8,371 cfs), 50-year (12,923 cfs), 100-year (18,997 cfs), 500-year (40,400 cfs)
- **Select activation flow(s)** – NA

<u>River System Information</u>:
- **Position in watershed** – Plains
- **Adjacent restoration projects** – Rist-Goss diversion reconstruction project occurs within Rossum-Wilson flood recovery project limits
- **Fish passage barriers** – Greeley-Loveland diversion structure approximately 1,300 ft downstream of project; Big Barnes Ditch approximately 500 ft upstream of project
- **Diversion structures** – Rist-Goss diversion
- **Nearest staff gauge** – Big Thompson River at Loveland, CO (BIGLOVCO) approximately 6 miles downstream of project reach, operated by USGS

<u>Restoration Methods</u>:
- **Seeding methods** – 3 zones (wetland, riparian, perennial riparian)
- **Planting zones** – 3 zones (willow toe/wetland sod, brush trench/willow cuttings, riparian trees and shrubs)
- **Willow installation method(s)** – by hand after grading (except brush trenches)
- **Topsoil added?** – No (excess cut was amended on site)
- **Erosion control** – Mix of coir fabric and wood mulch
- **Irrigation** – Yes; overhead spray irrigation system being installed for seed and container plants; watering schedule for trees and shrubs is: Nov – Feb: once every three weeks; March – May: Once every two weeks, June – August: once per week; Sept – Oct: once every two weeks; willow cutting will be watered according to schedule if soil not saturated; seeding areas will be served by irrigation system and watered as needed

<u>Stakeholder Information</u>:
- **Percent public/private land** – 50% private, 50% public
- **Number of private landowners** – 1
- **Public land agencies** – City of Loveland Open Lands

<u>Post-Construction Inspections/Site Visits</u>:
- None known as of the drafting of this report (fall 2019).

4.14.2 Project Goals and Monitoring Questions

The project's Basis of Design Report states that the primary goal of the Rist-Goss diversion reconstruction project was to develop a resilient design that improved sediment transport and fish passage through the diversion while continuing to convey a full decree of water to water rights holders. Specific project objectives were listed in the report and conveyed by BTWC as follows:

(1) Reconstruct Rist-Goss diversion structure to provide a full decree of irrigation water (6.7 cfs) to the City of Loveland and Loveland Ready Mix across a range of anticipated flow events;
(2) Promote long-term resilience and provide sustainable infrastructure improvements;
(3) Incorporate fish and recreational passage into diversion reconstruction design;
(4) Improve sediment conveyance by replacing the existing Rist-Goss dam with a series of riffle structures; and
(5) Maintain grade control and water delivery in accordance with existing water rights by moving the point of diversion approximately 500 feet upstream.

Additional monitoring goals and questions based on project review, conversations with design and field engineers, and project monitoring and adaptive management plan include:

(6) Create a compound channel via bankfull benching;
(7) Narrow over-widened portions of the channel;
(8) Stabilize eroding streambanks;
(9) Increase organic matter and cover in the reach;
(10) Increase riparian and upland vegetation cover and minimize weed cover;
(11) Improve aquatic habitat through channel and flow diversity and enhancing macroinvertebrate communities; and
(12) Accommodate future City of Loveland land-use plans.

4.14.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 4.14.2, the following monitoring parameters are recommended for the Rist-Goss diversion reconstruction flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

It should be noted that this is a mitigation project funded by Northern Water, and they hired ERO Resource Consultants to monitor the project. The consultant is qualitatively assessing vegetation cover and noxious weed cover, looking for erosion or other issues, and establishing permanent photo points, as required by USACE to meet success criteria for a relatively small area.

<u>Physical surveys</u> – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (2), (5), (6), (7), and (8). Permanent cross-sections are

suggested at the following approximate locations: Stations 8+00 (59+00 on Rossum-Wilson plan set) and 1+00 (53+80 on Rossum-Wilson plan set). Refer to Appendix W for a map of the suggested locations.

Substrate surveys – Substrate surveys are recommended to ensure that excessive sedimentation is not occurring, since one of the main objectives of this project was to improve sediment conveyance. Pebble counts should be conducted at 2 riffles within the project site (suggested locations are Stations 8+00 (59+00 on Rossum-Wilson plan set) and 1+00 (53+80 on Rossum-Wilson plan set) to address project/monitoring goals (4) and (11). For reference, Table 3 of the project's Basis of Design Report indicates the following pre-project substrate sizes: upstream of project extent D50/D84 (69/122 mm), downstream of project extent D50/D84 (86/146 mm). Refer to Appendix W for a map of the suggested locations for substrate surveys.

Structure surveys – Visual inspection of the diversion structure should be conducted at each site visit, particularly to ensure that sedimentation is not occurring in front of the intake structure and that fish passage obstructions are not present, thereby addressing project/monitoring goals (1), (2), and (3).

Aquatic habitat feature surveys – The USFS channel unit inventory should be conducted on the entire project reach to address project/monitoring goal (11). This survey method will evaluate the goal of increasing in-stream habitat complexity by monitoring the presence of all types of aquatic habitat features over time and tracking changes in pool size and location. If resources do not allow for this detailed method, or if flows are too high to safely conduct the survey, the rapid method for aquatic habitat feature surveys may be used to confirm the presence and persistence of all types of aquatic habitat features.

Vegetation surveys – To address project/monitoring goal (10), vegetation transect surveys should be conducted. These transects should be co-located with the two recommended cross-section survey transects. The LHWC monitoring method is suggested here, with an option to follow the guild-based methodology used by the CWCB monitoring team if non-woody vegetation cannot be identified to the species level.

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health, and one way to address project/monitoring goal (11) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (3), particularly in the determination of whether the diversion reconstruction improved fish passage in the reach. Currently, no known macroinvertebrate or fish population monitoring has been performed at the Rist-Goss site. Working with CPW or other entities to monitor these parameters is recommended for evaluating project goals.

Photo points – Photo points should be established for monitoring at the Rossum-Wilson project site. Consider occupying some of the BTWC photos taken before construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (2), (3), (6), (7), (8), (10), and (11).

<u>Visual assessments</u> – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (3), (4), (7), (8), (9), (10), and (11). In addition, to address project/monitoring goal (1), discharge records should be reviewed annually with input from the ditch manager to determine what portion of the full decree (6.7 cfs) of irrigation water was taken and whether that amount met the needs of the water rights holder. City of Loveland open space and recreational user data may also be reviewed annually to address project/monitoring goal (12).

5.0 FOURMILE WATERSHED FLOOD RECOVERY PROJECTS

The Fourmile watershed sustained considerable damage as a result of natural disasters in the last decade, with the Fourmile Canyon Fire burning a significant portion of the watershed in 2010, followed by extensive flooding from the Front Range flood in 2013. These events compounded one another and led to significant erosion and debris flows throughout the watershed. Federal, state, and local funding was secured by the Fourmile Watershed Coalition after the flood to complete 7 flood recovery projects in the years following the flood: Sunset Pond, Wall Street, Ingram Gulch, Upper Ingram, Black Swan, Logan Mill, and Lower Fourmile Streambanks. Monitoring plans for each of these projects are provided in the sections that follow. A summary of monitoring parameters by project is provided in Table 3. While this matrix may be used for reference, it should not supplement the details provided in the monitoring plan sections of this report.

Boulder County Transportation also completed several additional flood recovery projects within the watershed. Although project-specific monitoring plans were not developed for those projects as part of this effort, similar monitoring parameters may be used to evaluate those project areas as desired.

In addition, although an “unrestored” site is not identified in this plan, it is recommended that if possible, similar monitoring parameters be applied to such an area in order to collect comparable data from a site in the watershed that was impacted by the wildfire and the flood, but left untreated.

5.1 SUNSET POND

The Sunset Pond project in upper Fourmile Canyon rehabilitated a 450-foot stretch of Fourmile Creek and built a new diversion structure to store water in the adjacent Sunset Pond for firefighting activities.

Prior to the 2013 flood, upper Fourmile Creek maintained a stable step-pool channel bedform and had a working diversion that successfully diverted flows to the Sunset Pond. The 2013 flood resulted in massive sediment and debris deposition in upper Fourmile Creek, causing the creek to cut a new incised, unstable channel that generated several headcuts and limited floodplain connectivity in the years following the flood. The channel migration also rendered the pre-flood diversion ineffective. The Sunset Pond project reconstructed the creek channel in the location of a historical abandoned channel, aiming to recreate its step-pool bedform and provide adequate separation between the creek channel and the diversion ditch. The project also built a new functional diversion structure to redirect a portion of the creek flow to Sunset Pond.

5.1.1 Site Details

This section provides details about the Sunset Pond site, project, and surroundings for reference during future monitoring events.

<u>Project Details:</u>

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB, Four Mile Fire Protection District and donated rock material from Boulder County)
- **Design engineer(s)** – Rob Molacek and TJ Burr, NRCS
- **Construction oversight engineer(s)** – Rob Molacek and TJ Burr, NRCS
- **Construction contractor** – Frontier Environmental
- **Vegetation designer** – AlpineEco
- **Vegetation contractor** – Frontier Environmental
- **Construction dates** – March 27 - June 1, 2017
- **Select design flow(s)** – Bankfull flow (50 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – none upstream of project; Boulder Canyon Transportation upper Fourmile Canyon road rehabilitation project directly downstream of project; Wall Street EWP/DR flood recovery project 4 miles downstream of project
- **Fish passage barriers** – Glacier Lake dam at the top of Pennsylvania Gulch upstream of project
- **Diversion structures** – Diversion structure built as part of Sunset Pond project
- **Nearest flow gauge** – No proximal gauges

Restoration Methods:

- **Seeding methods** – Native seed mix hand seeded with broadcast seed spreader, lightly raked into soil, and mulched with wood mulch
- **Planting zones** – 3 zones (channel edge (0-1 ft above channel), lower riparian (1-2 ft above channel), upper riparian (2-2.5 ft above channel))
- **Willow installation method(s)** – Willows stakes were harvested onsite and installed by hand after construction was completed.
- **Topsoil added?** – No
- **Erosion control** – Coir fabric installed along floodplain benches
- **Irrigation** – Container plants watered every 1-2 weeks for first growing season

Stakeholder Information:

- **Percent public/private land** – 100% private
- **Number of private landowners** – 3
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:

- TJ Burr (NRCS) visited the site on July 20, 2017, approximately 3 months after construction. His notes for suggested repairs are attached in Appendix X. He found several locations where rocks had shifted, particularly within constructed cross vanes as a result of spring runoff, and suggested a few additional improvements. However, it was determined that while the locations noted should continue to be inspected, adaptive management activities should only be initiated at one location. An angular boulder from off-site was used to replace the rounded boulder that became dislodged in the cross vane directly downstream of the diversion structure. This adaptive management activity was completed in order to assure that the diversion structure and immediate streambed remained stable and functional. A mini excavator was mobilized in September 2018 to complete the work.

- Great Ecology completed an assessment of vegetation survivorship in May 2018 on behalf of the State. Findings for Sunset Pond are as follows: Zone 2 – willow survivorship (75%), container survivorship (85%), cover (50%), and seed germination (Fair). Zone 3/4 – container survivorship (20%), cover (35%), and seed germination (Fair). The accompanying report recommended that the contractor install new container plants and increase irrigation to achieve the survivability standard (65%) and ensure long-term survivability.

5.1.2 Project Goals and Monitoring Questions

The project's Basis of Design Report states that the primary goal of the Sunset Pond project was to decrease flood risk while reducing the ecological and geomorphic degradation that resulted from the 2013 flood event and incorporating a new water diversion. Specific project objectives were listed in the report as follows:

(1) Create a stable step-pool channel section;
(2) Remove debris and extensive sediment deposition to regain floodplain capacity;
(3) Increase in-stream habitat complexity;
(4) Rehabilitate vegetation that typically exists adjacent to the river and in the floodplain; and
(5) Reduce erosion along unstable creek banks.

Additional monitoring goals and questions based on project review and conversations with design and field engineers include:

(6) Ensure that the diversion structure is functioning as intended and delivering water to Sunset Pond (including monitoring potential problems with sedimentation in front of the intake structure);
(7) Check to see if pools created by cross vane structures are scouring as expected;
(8) Track point bar development and measure particle size in point bars to gain information about sediment transport; and
(9) Monitor the site for potential headcut formation and channel incision.

5.1.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 5.1.2, the following monitoring parameters are recommended for the Sunset Pond flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Because the Sunset Pond project site is in a narrow canyon with a relatively small floodplain, and because one of the main goals of this project is to create a stable step-pool channel section, a longitudinal profile survey is recommended. The profile will provide information about pool scour, thalweg depth, and channel pattern. Longitudinal profile surveys will address project/monitoring goals (1), (3), (5), (7), and (9). If possible (i.e., if time and budget allow), cross-section surveys may also be conducted to provide additional geomorphic information at specific locations. Suggested cross-section locations are:

- At the riffle below the diversion cross vane (cross vane 1) near Station 1+20
- At another representative riffle within the project site
- Across the deepest part of the pool created by cross vane 2 near Station 2+20 (at the site of a previous headcut)

Surveying cross-sections at these locations will address project/monitoring goals (1), (2), (5), (7), and (9).

<u>Substrate surveys</u> – Substrate surveys are recommended to ensure that excessive sedimentation is not occurring in this transport reach. Pebble counts should be conducted at 2-3 riffles within the project site to address project/monitoring goals (2) and (5). In addition, any new point bars that have been created should be noted, and point bar assessments should be conducted at 2 representative point bars to address project/monitoring goal (8). For reference, the "Project Area Morphological Characteristics" table on page 4 of the project's Basis of Design Report lists the following expected substrate sizes: active bed D50 (44 mm), active bed D84 (132 mm), point bar D50 (32 mm), point bar D84 (105 mm), largest particle size to be moved (140 mm).

<u>Structure surveys</u> – Visual inspection of the diversion structure should be conducted at each site visit, particularly to ensure that sedimentation is not occurring in front of the intake structure and that the piping is intact and delivering sufficient water to Sunset Pond, thereby addressing project/monitoring goal (6). In addition, all five cross vanes should be inspected to see whether any rocks have shifted, if flanking is occurring, or if water is being directed toward channel banks. The CWCB SOP for Assessment of In-Channel Structures (Appendix F) may be used to assist the evaluator with inspection of the cross vanes. These inspections will address project/monitoring goals (1) and (5).

<u>Aquatic habitat feature surveys</u> – The USFS channel unit inventory can be conducted on the Sunset reach to address project/monitoring goals (1), (3), and (7). This aquatic habitat feature survey method will monitor whether a step-pool system has been achieved and evaluate the effectiveness of cross vane scouring mechanisms. Monitoring the presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. Although other aquatic habitat survey protocols may be more efficient at this location, this method will be used at other project reaches on Fourmile Creek, so it is recommended at Sunset as well in order to allow for future habitat comparisons across projects in the watershed. The channel unit inventory is recommended for the entire project area. For consistency in temporal comparisons, measurements should always be conducted at approximately the same time of year and relative flow (e.g., summer baseflow in August/September). Observations of excessive sedimentation in the pools should be noted at each site visit as well.

<u>Vegetation surveys</u> – To address project/monitoring goal (4), vegetation transect surveys should be conducted. These transects should be co-located with the three recommended cross-section survey transects. The AlpineEco vegetation monitoring method is planned to consistently monitor all Fourmile watershed projects.

Benthic macroinvertebrate community monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health. One way to address project/monitoring goal (3) related to in-stream habitat is to assess the condition of the benthic community. FWC collected macroinvertebrate samples in conjunction with CDPHE at the Sunset Pond project site in August 2018. Benthic sampling should be repeated annually or every other year to detect changes in the macroinvertebrate community over time.

Photo points – Photo points should be established for monitoring at the Sunset Pond project site. Consider occupying some of the NRCS (TJ Burr) and FWC/CWCB (Maya MacHamer/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (3) and (4).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (3), (4), (5), and (9). Annual EWP inspections should also be completed at the Sunset Pond project site.

Flow – Discharge should be measured or estimated at the Sunset Pond project because no established stream gauges exist in relative proximity to the project site. Because flow monitoring is not directly related to project goals, these measurements are recommended but not required. Installation of a staff gauge and periodic measurement of discharge at a range of flows using a flow meter to develop a stage-discharge rating curve is recommended, and staff gauge installation was completed on May 10, 2019. The gauge was installed on diversion intake structure, and a rating curve is being developed to associate water height with discharge at that location. Flow should be measured during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at 1-2 as-built or monitoring cross sections where possible. As-built cross sections are located at Stations 1+42, 1+99, 2+32, 2+66, 3+30, 4+17, and 4+50. Height of water in the Parshall Flume measuring flow through the diversion ditch should be recorded at each site visit, along with corresponding discharge rates (see table in Appendix Y).

5.2 WALL STREET

The Wall Street community and surrounding Upper Fourmile Creek Watershed experienced a sequence of compounding disasters in the last decade. In September 2010, the Fourmile Canyon Fire burned 23 percent of the watershed, destroyed more than 160 homes, and left the watershed more vulnerable to future flooding. Typical summer thunderstorms in 2011 and 2012 produced flash floods that transported a significant amount of sediment and debris into the creek corridor, plugging culverts and reducing channel capacity. The following year, 13-18 inches of rain fell over the wildfire's burn scar during the September 2013 flood, inundating the creek corridor with floodwaters, sediment, and debris. The flood destroyed large sections of local roads and residential properties built within the active river corridor, and washed out every creek crossing in the Wall Street neighborhood. Some residents were stranded due to impassable roads and had to hike to a nearby ridge and await helicopter evacuation.

The primary objective of the Wall Street project was to remove flood-deposited sediment and debris from the channel and floodplains in order to increase the capacity of the creek corridor to convey future floodwaters, and provide locations for sediment from future events to be deposited away from homes and roadways. The project also constructed two fish-friendly diversion structures that feed water to ponds used by the Four Mile Fire Protection District for firefighting and wildfire mitigation activities.

5.2.1 Site Details

This section provides details about the Wall Street site, project, and surroundings for reference during future monitoring events.

Project Details:
- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program), DOLA CDBG-DR Watershed Planning for Resilience Program
- **Design engineer(s)** – Katie Jagt, Watershed Science and Design
- **Construction oversight engineer(s)** – Katie Jagt, Watershed Science and Design
- **Construction contractor** – Edge Contracting
- **Vegetation designer** – Andy Herb, AlpineEco
- **Vegetation contractor** – CDI Environmental Contractor
- **Construction dates** – August 21 – December 6, 2017
- **Select design flow(s)** – winter baseflow (<1 cfs), summer baseflow (6 cfs), spring average flow (65 cfs), bankfull flow (175 cfs), 5-year (343 cfs), 10-year (400 cfs), 25-year (789 cfs), 50-year (1,209 cfs), 100-year (1,969 cfs), 500-year (3,388 cfs)
- **Select activation flow(s)** – Alpine Gulch overflow channel (between 5-10 year flow), overflow at 6149 Fourmile Canyon Drive crossing (bankfull flow)

River System Information:
- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Boulder County Transportation road projects on Fourmile Canyon Drive upstream of project, downstream of project, and within the project reach (specific locations within project extent are (1) north slope up to road across from Hester diversion (Boulder County road construction); (2) construction of the Dane bridge at 6149 Fourmile Canyon Drive (Flood Recovery County Bridge); and (3) staging site at Alpine Gulch (Boulder County road construction)).
- **Fish passage barriers** – NA
- **Diversion structures** – Two diversion structure built as part of Wall Street project; Sunset Pond diversion upstream of project; Pine Brook diversion downstream of project
- **Nearest flow gauge** – No proximal gauges; one expected to be installed by Pine Brook Water District in 2020 near the Poorman's Fourmile Fire Station downstream of the Gold Run confluence; one expected to be installed by USGS in April 2020 at the Logan Mill bridge; and one existing at the mouth of Fourmile Canyon just upstream of the confluence with Boulder Creek (Fourmile Creek at Orodell, CO (USGS 06727500) operated by USGS).

Restoration Methods:
- **Seeding methods** – Native seed mix applied via hydroseeding
- **Planting zones** – 3 zones: zone 1 or A channel edge (0-1 ft above channel), zone 2 or B lower riparian (1-2 ft above channel), zone 3 or C upper riparian (2-3 ft above channel), zone 4 or upland (3+ ft above channel)

- **Willow installation method(s)** – Hand-install during and following construction
- **Topsoil added?** – No - native soils amended with compost
- **Erosion control** – Coir fabric blankets at top of project, hydromulch throughout
- **Irrigation** – Contractor used water truck for post-construction summer/fall season.

Stakeholder Information:

- **Percent public/private land** – 95% private; 5% public
- **Number of private landowners** – 19
- **Public land agencies** – Boulder County (buyout property at Alpine Gulch)

Post-Construction Inspections/Site Visits:

- The CWCB monitoring team visited the Wall Street project site on May 9, 2018 to collect baseline data at the site. Data collection efforts were focused in 2 project sub-sections: approximately Station 200+00 to 207+00 (Pod 2, 5 transects), and approximately Station 217+00 to 220+00 (Pod 3, 3 transects). At each pod, the team conducted cross-section surveys, vegetation transect surveys, pool area mapping, photo points, wood counts, and test banks. Photo points were also completed in the Alpine Gulch area (Pod 1).
- Great Ecology completed an assessment of vegetation survivorship in May 2018 on behalf of the State. Findings for Wall Street are as follows: Zone 1 – willow survivorship (90%), cover (10%), and seed germination (Low). Zone 2 – willow survivorship (85%), container survivorship (85%), cover (50%), and seed germination (Fair). Zone 3 – container survivorship (85%), cover (50%), and seed germination (Fair). Zone 4 – cover (40%) and seed germination (Fair). The accompanying report noted that the container plants could benefit from increased irrigation to ensure long-term survivability.
- The CWCB monitoring team returned to Wall Street on June 14, 2019 to collect photo point data at the baseline locations.
- The CWCB monitoring team visited Wall Street on August 14, 2019 to collect photo point data, and again on September 3, 2019 to collect vegetation transect, cross section, photo point, and pool area data at the baseline locations.

5.2.2 Project Goals and Monitoring Questions

The project's Basis of Design Report states that the primary objectives of the Wall Street project were to reduce threats to life and property and increase resiliency through the following specific project objectives:

(1) Remove sediment to provide storage locations for future sediment pulses;
(2) Stabilize streambanks, stream beds, and floodplains to protect against additional damage to homes and infrastructure;
(3) Restore the discharge capacity of the creek to pre-flood levels where feasible;
(4) Remove flood debris and trash from the riparian corridor;
(5) Establish vegetative cover on critically eroding land;
(6) Reduce flood risk and increase community safety;
(7) Protect public and private infrastructure and property;
(8) Improve water quality by reducing sediment loading caused by bank erosion;
(9) Enrich riparian habitat via the addition of topsoil, seeding, and native vegetation;
(10) Enhance aquatic habitat through added complexity, additional vegetation, and improved water quality;

(11) Protect historical structures;
(12) Restore riparian and floodplain function;
(13) Protect and enhance other flood recovery projects;
(14) Build community resiliency; and
(15) Enhance aesthetics.

Additional monitoring goals and questions based on project review and conversations with the coalition, as well as design and field engineers, include:

(16) Evaluate efficacy of bioengineering structures, including monitoring decay of large wood structures over time;
(17) Verify design flows for floodplain benches and overflow channels;
(18) Survey cross vanes at diversion structures;
(19) Inspect the structural stability of rock walls;
(20) Document visible sources of sediment to the stream;
(21) Monitor the area near the relocated channel near the telephone pole for potential headcut formation due to sediment accumulation in the pool from adjacent road drainage; and
(22) Monitor the Hoge pond embankment

5.2.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 5.2.2, the following monitoring parameters are recommended for the Wall Street flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches and in the overflow channels, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

<u>Physical surveys</u> – Cross-section surveys are being conducted by the CWCB monitoring team at two sub-reaches along this project reach. Data are accessible and available, and are continuing to be repeated as needed. For completeness, the approximate locations of existing surveys are listed here:

- Approximately Station 200+00 to 207+00 (CWCB monitoring team Pod 2, 5 transects)
- Approximately Station 217+00 to 220+00 (CWCB monitoring team Pod 3, 3 transects)

If desired, additional cross-sections surveys can be conducted in the upstream portion of the project. The following additional locations are suggested:

- Approximately Station 177+00 near boulder cascades and upstream of Nancy Mine drainage inflow
- Approximately Station 182+00 near the Hoge pond embankment (plus survey of the elevation of the apex rock at the cross vane above the Hoge diversion)
- Approximately Station 199+00 near the Hester diversion (plus survey of the elevation of the apex rock at the cross vane above the Hester diversion)

Surveying cross-sections at these locations addresses project/monitoring goals (1), (2), (3), (12), (18), and (21).

Substrate surveys – To ensure that excessive sedimentation is not occurring at the project site, substrate surveys are suggested but not required if resources are available. If conducted, pebble counts should be performed at 4 riffles within the project site at locations where pre-project pebble counts were conducted (Reaches 2b, 4, 5, and 7) to address project/monitoring goal (8). For reference, Table 4.6.1 of the project's Basis of Design Report lists the following pre-construction substrate sizes: Reach 2b D50 (75 mm), D84 (148 mm); Reach 4 D50 (63 mm), D84 (133 mm); Reach 5 D50 (66 mm), D84 (116 mm); Reach 7 D50 (77 mm), D84 (144 mm).

Structure surveys – Structures throughout the project can be opportunistically documented during annual inspections and/or regular site visits. To address project/monitoring goal (16), bioengineering structures should be assessed each year to evaluate their efficacy and document (through photos and short narrative descriptions) decay of large wood over time (including large wood complexes at approximately Stations 205+00 and 206+50 and rootwad sets at approximately Station 199+50, 200+50, 201+75, 203+25, 209+50, 217+50, 218+50, 219+75, and 222+75). These woody bank stabilization structures may be evaluated to determine whether they are fulfilling their intended functions: reduce water velocities and dissipate energy; stabilize banks; create pools; provide cover; and direct flow away from the bank. To address project/monitoring goal (19), structural stability of the constructed rock walls should also be inspected, particularly the stability of the foundation rocks. Stacked boulder toes at approximately Station 171+75, 186+75, and 221+75 should be photographed and documented.

Aquatic habitat feature surveys – The USFS channel unit inventory can be conducted in the vicinity of the CWCB monitoring Pod 2 reach to address project/monitoring goal (10). FWC designated approximately Station 203+00 to 211+00 as the channel inventory monitoring reach. Monitoring the presence of all types of aquatic habitat features over time will help to evaluate the goal of increasing in-stream habitat complexity. This method will be used at other project reaches on Fourmile Creek, so it is recommended at Wall Street as well in order to allow for future habitat comparisons across projects in the watershed. For consistency in temporal comparisons, measurements should always be conducted at approximately the same time of year and relative flow (e.g., summer baseflow in August/September). Observations of excessive sedimentation should be noted at each site visit as well, helping to address project/monitoring goal (20).

Water quality and chemistry – Another way to address the project/monitoring goals (8) and (10) related to improved water quality and enhanced aquatic habitat is by measuring select water quality parameters. At Wall Street, temperature, dissolved oxygen, turbidity, pH, and conductivity are of the greatest interest. In conjunction with Trout Unlimited, FWC measured water quality parameters and select metals and nutrients at one location within the Wall Street project area (below Emerson Gulch) in 2017. Continuation of water chemistry measurements is recommended to evaluate whether the Wall Street flood recovery project had any positive mitigation effects on low pH or elevated metals concentrations contributed by mine-impacted gulches. A continuous temperature logger could also be installed in the project reach to provide temperature data during the summer months for aquatic habitat.

Vegetation surveys – Vegetation transect surveys are being conducted by the CWCB monitoring team at 8 cross-sections. Data are accessible and available, and are continuing to be repeated as needed. Therefore, no additional vegetation surveys are necessary at the Wall Street project site. However, if time and resources allow, the AlpineEco vegetation monitoring method is also planned at one of the CWCB monitoring team pod areas to consistently monitor all Fourmile watershed projects. Vegetation monitoring addresses project/monitoring goals (4), (5), (9), (10), and (12).

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health. One way to address project/monitoring goals (8) and (10) related to water quality and in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (10). FWC collected macroinvertebrate samples in conjunction with CDPHE at one location within the Wall Street project site (just below Alpine Gulch) in August 2018. Benthic sampling should be repeated annually or every other year to detect changes in the macroinvertebrate community over time. For the first time, CPW collected fish population data in August 2019 a site within the Wall Street project area. Full datasets for this location, as well as unrestored locations upstream and downstream of the project (below Longs Gulch and Crisman area) should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the Wall Street project site. Consider occupying some of the FWC/CWCB (Cat Price/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (4), (5), (7), (10), (11), (15), (16), and (19). Photos should be taken of the area near the telephone pole relocation and the Hoge pond embankment to address project/monitoring goals (21) and (22).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (5), (8), (9), (10), and (12). Annual EWP inspections should also be completed at the Wall Street project site.

Flow – Discharge should be measured or estimated at the Wall Street project because no established stream gauges exist in relative proximity to the project site. If possible, installation of a staff gauge and periodic measurement of discharge at a range of flows using a flow meter to develop a stage-discharge rating curve is recommended. Flow should be measured during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at a series of locations, particularly at as-built or monitoring cross-sections where possible. Suggested locations for monitoring inundation levels during high-flow conditions include transects in the vicinity of Station 171+00 (Alpine Gulch overflow channel), Station 185+25 (6149 Fourmile Canyon Drive overflow channel), 207+00 (wetland area with ample floodplain), 218+00 (channel relocation near telephone pole), and any other opportunistic locations with activated floodplain benches during spring runoff. These activities will address project/monitoring goals (3), (6), and (17).

5.3 INGRAM GULCH

The Fourmile Watershed's steep Ingram Gulch was completely burned in the 2010 Fourmile Canyon fire. Severe debris flows caused by heavy rain on the burn scar followed in 2011, impairing roadway infrastructure at the bottom of the gulch. The September 2013 flood resulted in additional damage to public infrastructure and private properties, and destroyed all of the rehabilitation treatments administered after the fire. Left untreated, erosion and gullying would continue to contribute large quantities of sediment and debris to the upper reaches of Fourmile Creek and create hazards for the community of Salina.

The Ingram Gulch project aimed to stabilize the gulch to allow for high flows with less infrastructure and ecological damage, and to minimize sediment input to the channel from erosion of steep hillslopes. Goals were accomplished through sediment and debris removal, installation of grade control structures and channel roughness elements, and grading steep slopes to reduce erosion.

5.3.1 Site Details

This section provides details about the Ingram Gulch site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – NRCS EWP Program (with local match from CWCB and the DOLA CDBG-DR Watershed Implementation Grant Program), DOLA CDBG-DR Watershed Planning for Resilience Program
- **Design engineer(s)** – Paul Kos, Norwest Corporation
- **Construction oversight engineer(s)** – Paul Kos, Norwest Corporation
- **Construction contractor** – Frontier Environmental Services
- **Vegetation designer** – AloTerra Restoration Services
- **Vegetation contractor** – Frontier Environmental Services
- **Construction dates** – September 18, 2017 – May 20, 2018
- **Select design flow(s)** – Bankfull flow (34 cfs), 5-year (46 cfs), 10-year (55 cfs), 25-year (71 cfs), 50-year (110 cfs), 100-year (148 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Upper Ingram Gulch project directly above Ingram Gulch project planned for 2019; Gold Run flood recovery project in Gold Run downstream of project
- **Fish passage barriers** – Culvert at the downstream end of Ingram Gulch at the confluence with Gold Run
- **Diversion structures** – NA
- **Nearest staff gauge** – No proximal staff gauges; flow is intermittent in Ingram Gulch

Restoration Methods:

- **Seeding methods** – 4 zones seeded via hydroseeding
- **Planting zones** – 3 zones (channel edge (0-1 ft above channel), lower riparian (1-2 ft above channel), upper riparian (2-3 ft above channel))
- **Willow installation method(s)** – installed by hand during and following construction
- **Topsoil added?** – Yes, 260 cu yds
- **Erosion control** – Coir fabric blankets/matting, biologs, wood straw, hydromulch

- **Irrigation** – Drip irrigation system on majority of site, but not always utilized appropriately.

Stakeholder Information:
- **Percent public/private land** – 100%
- **Number of private landowners** – 2
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:
- The CWCB monitoring team visited the Wall Street project site on May 10, 2018 to collect baseline data at the site, consisting of photo point documentation only.
- Great Ecology completed an assessment of vegetation survivorship in May 2018 on behalf of the State. Findings for Ingram Gulch are as follows: Zone 1 – cover (25%) and seed germination (Low). Zone 2 – willow survivorship (25%), container survivorship (25%), cover (50%), and seed germination (Fair). Zone 3/4 – cover (15%) and seed germination (Low). The accompanying report recommended controlling the non-native species mechanically and that the poor seed germination was likely due to inadequate irrigation and/or improper planting technique. Increased irrigation was recommended to ensure long-term survivability.
- The CWCB monitoring team visited Ingram Gulch on August 15, 2019 to collect photo point data, and again on September 3, 2019 to collect aerial imagery via drone.

5.3.2 Project Goals and Monitoring Questions

The project's As-Built Final Report states the following objectives:

(1) Stabilize Ingram Gulch channel while restoring riparian habitat;
(2) Reduce future flood risk to homes and Salina;
(3) Protect public and private infrastructure;
(4) Address water quality issues that may pose a threat to human and aquatic health;
(5) Address severe environmental degradation; and
(6) Create a model plan or process that can be used in other similarly complex areas.

Additional monitoring goals and questions based on project review, conversations with design and field engineers, and coalition input include:

(7) Improve floodplain function where possible;
(8) Track vegetation growth in the channel, including any noxious weeds;
(9) Monitor areas with seeps or off-channel drainages;
(10) Evaluate the effectiveness of the biologs placed in the upper channel;
(11) Assess the stability of the rock wall held in place by dywidags in the upper channel;
(12) Check erosion and grass germination on the upper slopes;
(13) Monitor inputs into the upper sediment pond.

5.3.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 5.3.2, the following monitoring parameters are recommended for the Ingram Gulch flood recovery project. In general, most of these monitoring activities can and should be conducted in the late summer timeframe before the growing season ends.

Substrate surveys – While traditional substrate surveys are not recommended at Ingram Gulch, sediment input over time should be monitored in the upper sediment pond to address project/monitoring goal (13). This can be done using photographs and narrative descriptions. Elevations may be measured by the CWCB monitoring team using detailed drone survey as well.

Structure surveys – Inspection of the dywidags, rock wall, and biologs installed in the upper channel is recommended to address project/monitoring goals (10) and (11). In particular, the toe of the rock wall stabilized by dywidags should be carefully examined to make sure the rocks are not shifting or moving, and the biologs should be inspected to see if they are directing water away from the rock wall and whether they are supporting any plant growth. In cases of uncertainty, photo documentation and/or narrative descriptions may be shared with project designers to obtain input on whether adaptive management actions may be warranted.

Water quality and chemistry – In conjunction with Trout Unlimited, FWC measured water quality parameters and select metals and nutrients at a site on Gold Run below Ingram Gulch in 2017, and in Ingram Gulch above the project area in 2018. Continuation of water chemistry measurements and consistency in sampling locations and analyte lists across years is recommended to address project/monitoring goals (4) and (5).

Vegetation surveys – Vegetation surveys should be conducted at 2 transects to address project/monitoring goals (1), (7), (8), and (12). The AlpineEco vegetation monitoring method is planned to consistently monitor all Fourmile watershed projects. In addition to regular transects, vegetation survey methods should include tracking vegetation growth within the channel, monitoring the presence of noxious weeds, and checking erosion and grass germination in the upper slopes (and evaluating whether a distinction exists between slopes covered with coir mat and those covered with coconut fiber).

Photo points – Photo points should be established for monitoring at the Ingram Gulch project site. Consider occupying some of the FWC/CWCB (Cat Price/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (3), (5), (7), (8), (12), and (13). In addition, to address project/monitoring goal (9), areas with seeps or off-channel drainages (rock areas approximately Stations 4+50 and 5+00 on river right, and approximately Station 7+00 to 8+50 on river left) should be inspected and photographed at each visit.

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (1), (4), (7), and (8). Annual EWP inspections should also be completed at the Ingram Gulch project site.

5.4 UPPER INGRAM

THIS SECTION WILL BE COMPLETED IN 2020.

5.4.1 Site Details

5.4.2 Project Goals and Monitoring Questions

5.4.3 Applicable Monitoring Parameters

5.5 BLACK SWAN

The Black Swan project rehabilitated approximately 5,000 feet of damaged stream corridor along Fourmile Creek. The upstream boundary of the project is at the confluence of Fourmile Creek and Gold Run, and the downstream end is just below the Logan Mill Road bridge. The damage resulting from the 2013 flood was caused by a combination of high flood flows and debris blockages in culverts and other crossings. The blockages caused lateral channel migration, which led to severe streambank erosion and undermining of infrastructure adjacent to the creek. Emergency repairs were carried out immediately following the flood, but more permanent rehabilitation was still needed. Utilizing the principles of natural channel design, the Black Swan project attempted to reconstruct a resilient stream corridor that reduces the risk of future infrastructure damage from fluvial erosion events.

5.5.1 Site Details

This section provides details about the Black Swan site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Watershed Implementation Grant Program
- **Design engineer(s)** – Case Davis, Beaver Creek Hydrology
- **Construction oversight engineer(s)** – Case Davis, Beaver Creek Hydrology
- **Construction contractor** – Frontier Environmental
- **Vegetation designer** – AlpineEco
- **Vegetation contractor** – Frontier Environmental
- **Construction dates** – August - November 2018
- **Select design flow(s)** – Bankfull flow (55 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Wall Street EWP/DR flood recovery project approximately 1.5 miles upstream of project; Gold Run EWP project in tributary directly upstream of project; expected Boulder Canyon Transportation Fourmile Canyon road rehabilitation project within project area; Logan Mill DR flood recovery project downstream of project; Logan Mill Road bridge replacement downstream of the project.
- **Fish passage barriers** – NA
- **Diversion structures** – One informal diversion at Beebe Pond (4451 Fourmile Canyon Drive)
- **Nearest flow gauge** – No proximal gauges; one expected to be installed by Pine Brook Water District in 2020 near the Poorman's Fourmile Fire Station downstream of the Gold Run confluence; one expected to be installed by USGS in April 2020 at the Logan

Mill bridge; and one existing at the mouth of Fourmile Canyon just upstream of the confluence with Boulder Creek (Fourmile Creek at Orodell, CO (USGS 06727500) operated by USGS).

Restoration Methods:

- **Seeding methods** – Hydroseeded with native seed mix in 2 riparian zones and upland zone
- **Planting zones** – 3 zones: channel edge (0-1 ft above channel), lower riparian (1-2 ft above channel), upper riparian (2-3 ft above channel)
- **Willow installation method(s)** – hand-install during and following construction
- **Topsoil added?** – No - native soils amended with compost
- **Erosion control** – Hydromulch
- **Irrigation** – Drip irrigation system activated for post-construction summer/fall

Stakeholder Information:

- **Percent public/private land** – 95% private; 5% public
- **Number of private landowners** – 13
- **Public land agencies** – Boulder County (buy-out property at 4389 Fourmile Canyon Drive)

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (fall 2019).

5.5.2 Project Goals and Monitoring Questions

The Black Swan project's Basis of Design Report lists the following primary objectives:

(1) Stabilize a low-flow channel;
(2) Create natural bank stabilization and streambank shaping;
(3) Revegetate the riparian corridor utilizing native species;
(4) Improve in-stream habitat complexity;
(5) Protect residential structures and transportation infrastructure;
(6) Restore, and expand where possible, floodplain function;
(7) Increase general resilience and overall community benefit; and
(8) Enhance aesthetics.

Additional monitoring goals and questions based on project review, conversations with design and field engineers, and conversations with the coalition include:

(9) Continue to monitor water quality and benthic macroinvertebrate community structure and diversity to determine whether removal of the historic mine tailings pile and creation of a constructed wetland in the tailings area had a measurable positive impact on these parameters by reducing concentrations of arsenic and other heavy metals and improving benthic community scores;
(10) Monitor installed rock structures (cross vanes and step-pool structures) to see if they are performing intended functions; and
(11) Verify design flows for floodplain benches.

5.5.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 5.5.2, the following monitoring parameters are recommended for the Black Swan flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

Physical surveys – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1), (2), (6), and (7). Cross-section survey locations will be determined by FWC during the summer 2020 monitoring season.

Thalweg survey – A survey of thalweg depth is recommended to address project/monitoring goal (1) and ensure that a well-defined low-flow channel persists over time. The depth of the channel thalweg should be measured in random locations at approximately 100-foot intervals, for a total of about 50 measurements. Depths should be recorded, and an average depth should be computed to compare to in future years.

Structure surveys – Three to four representative cross vanes (B stream type) and step-pool structures (A stream type) should be inspected to see whether any rocks have shifted, if flanking is occurring, if water is being directed toward channel banks, and if suitable aquatic habitat is being created. The CWCB SOP for Assessment of In-Channel Structures (Appendix F) may be used to assist the evaluator with inspection of the structures. These inspections will address project/monitoring goals (4) and (10).

Aquatic habitat feature surveys – The USFS channel unit inventory should be conducted on this reach to address project/monitoring goal (4). This survey method will evaluate the goal of increasing in-stream habitat complexity by monitoring the presence of all types of aquatic habitat features over time and tracking changes in pool size and location. The channel unit inventory is recommended at three contiguous sub-reaches:

- Station 18+00 to 24+00, where restoration activities were conducted in the upper portion of the Black Swan project;
- Station 38+00 to 43+00, a reach within the Black Swan project area where no work was conducted (skip this reach in 2019 due to ongoing Boulder County road construction project); and
- Station 49+00 to 55+00, where restoration activities were conducted as part of the Logan Mill project (see Section 5.6.3 below).

Water quality and chemistry – FWC's construction sub-contractor measured water quality parameters and select metals and nutrients at the Black Swan project site before and after project implementation (September and December 2018). Measurements of arsenic were well above detection limits. Continuation of water chemistry measurements and consistency in analyte lists across years is recommended to address project/monitoring goal (9).

Vegetation surveys – To address project/monitoring goal (3), vegetation transect surveys should be conducted. These transects should be co-located with the three recommended cross-section survey transects. The AlpineEco vegetation monitoring method is planned to consistently monitor all Fourmile watershed projects. Vegetation should also be monitored at the mine waste area (approximately Station 25+00), and a future wetland delineation in that area should be considered.

Benthic macroinvertebrate community and fish population monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health. One way to address project/monitoring goal (4) related to in-stream habitat is to assess the condition of the benthic community. Fish quantity, size, and distribution is a parameter that would also address project/monitoring goal (4). FWC collected macroinvertebrate samples in conjunction with CDPHE at the Black Swan project site in August 2018. Benthic sampling should be repeated annually or every other year to detect changes in the macroinvertebrate community over time. Continuing to monitor this parameter will also address project/monitoring goal (9). For the first time, CPW collected fish population data in August 2019 a site within the Black Swan project area. Full datasets for this location should be requested from CPW, reviewed, and used to supplement the other data sources related to in-stream habitat and aquatic health.

Photo points – Photo points should be established for monitoring at the Black Swan project site. Consider occupying some of the FWC/CWCB (Maya MacHamer/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (2), (3), (5), (7), and (8).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (3), (4), and (6).

Flow – A stream gauge is expected to be installed by USGS in June 2019 at the Logan Mill bridge at the downstream end of the Black Swan project site. Discharge should be recorded during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) to address project/monitoring goals (6) and (11).

5.6 LOGAN MILL

The Logan Mill project rehabilitated approximately 375 linear feet of damaged stream corridor along Fourmile Creek. The vegetation in this area, including large stands of pine trees, was severely burned by the Fourmile Canyon wildfire in 2010. Subsequent flooding in 2013 scoured the project site, deposited significant volumes of sediment and flood debris, created further instability of the standing dead trees, and left the area almost devoid of vegetation. Progressive channel incision was exacerbated during high flows in 2015, and the severely eroded channel had become disconnected from its floodplain. The primary efforts of the Logan Mill project were to remove flood debris, reconnect the floodplain, reshape the channel, establish a vegetated riparian zone in the creek corridor, and serve as a demonstration project for similar efforts in the area.

5.6.1 Site Details

This section provides details about the Logan Mill site, project, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Watershed Implementation Grant Program
- **Design engineer(s)** – Nathan Werner, S2O Design and Engineering
- **Construction oversight engineer(s)** – Nathan Werner, S2O Design and Engineering
- **Construction contractor** – Whinnery Construction
- **Vegetation designer** – Ecosystem Services (Ecos)
- **Vegetation contractor** – Whinnery Construction
- **Construction dates** – March - July 2017
- **Select design flow(s)** – Bankfull flow not reported; 100-year flow (210 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Black Swan DR flood recovery project directly upstream of project; Logan Mill Road bridge replacement at downstream project boundary; expected Boulder Canyon Transportation Fourmile Canyon road rehabilitation project within project area.
- **Fish passage barriers** – NA
- **Diversion structures** – NA
- **Nearest flow gauge** – No proximal gauges; one expected to be installed by Pine Brook Water District in 2020 near the Poorman's Fourmile Fire Station downstream of the Gold Run confluence; one expected to be installed by USGS in April 2020 at the Logan Mill bridge; and one existing at the mouth of Fourmile Canyon just upstream of the confluence with Boulder Creek (Fourmile Creek at Orodell, CO (USGS 06727500) operated by USGS).

Restoration Methods:

- **Seeding methods** – hand broadcast seed, improperly covered thickly with wood straw
- **Planting zones** – 4 zones: Zone 1 Toe Treatment (0-1 ft above channel), Zone 2 Lower Riparian (1-2 ft above channel), Zone 3 Upper Riparian (2-3 ft above channel), and Zone 4 Upland (3ft+ above channel)
- **Willow installation method(s)** – installed by hand during construction
- **Topsoil added?** – Yes
- **Erosion control** – coir fabric blankets on slope, wood straw
- **Irrigation** – drip irrigation installed by landowner post-construction, but not consistently/appropriately utilized

Stakeholder Information:

- **Percent public/private land** – 100% private
- **Number of private landowners** – 2
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (fall 2019).

5.6.2 Project Goals and Monitoring Questions

The Logan Mill project's Basis of Design Report lists the following primary objectives:

(1) Create a complex and compound (benched) channel that incorporates a low-flow, bankfull, and overbank channel where appropriate/applicable;
(2) Create a stable "natural appearing and functioning" bank and river channel incorporating habitat improvements for fish and other aquatic organisms;
(3) Restore riparian and floodplain function within the river corridor, constructing wetland and riparian habitats, and reestablishing vegetation where appropriate/applicable;
(4) Create wildlife habitat for a variety of species;
(5) Demonstrate restoration techniques as a model for efforts to reclaim other stream reaches;
(6) Protect infrastructure (Logan Mill Road bridge, county road);
(7) Utilize native plants and prevent the spread of noxious weeds; and
(8) Enhance aesthetics.

Additional monitoring goals and questions based on project review and conversations with the watershed coalition include:

(9) Monitor aquatic habitat quality and diversity; and
(10) Verify design flows for floodplain benches.

5.6.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 5.6.2, the following monitoring parameters are recommended for the Logan Mill flood recovery project. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

<u>Physical surveys</u> – Cross-section surveys are recommended to provide geomorphic information to address project/monitoring goals (1), (2), and (3). Suggested cross-section locations are:

- Station 0+70 through the pool and root wad structure; and
- Station 2+72 through the pool, root wad structure, and rock wall.

<u>Thalweg survey</u> – A survey of thalweg depth may be completed to address project/monitoring goals (1) and (2) and ensure that a well-defined low-flow channel persists over time. The depth of the channel thalweg should be measured in random locations at approximately 20-foot intervals, for a total of about 20 measurements. Depths should be recorded, and an average depth should be computed to compare to in future years. A thalweg survey at the Logan Mill project is added because it is relatively simple to complete on such a short reach, and a thalweg survey is recommended for the Black Swan project directly upstream. While average depths do

not need to be compared directly, interesting information may surface if average thalweg depths diverge or converge significantly between the two projects.

Aquatic habitat feature surveys – The USFS channel unit inventory should be conducted on this reach to address project/monitoring goals (2), (4), (5) and (9). This survey method will evaluate the goal of increasing in-stream habitat complexity by monitoring the presence of all types of aquatic habitat features over time, and will help to evaluate whether scouring mechanisms in the project design are effective for maintaining pool habitat. The channel unit inventory is recommended for the entire project area (Station 0+00 to 5+00, or approximately Station 49+00 to 55+00 in the Black Swan plan set). For consistency in temporal comparisons, depth measurements should always be conducted at approximately the same time of year and relative flow (e.g., summer baseflow in August/September). Observations of excessive sedimentation in the pools should be noted at each site visit as well.

Vegetation surveys – To address project/monitoring goals (3) and (7), vegetation transect surveys should be conducted. These transects should be co-located with the two recommended cross-section survey transects. The AlpineEco vegetation monitoring method is planned to consistently monitor all Fourmile watershed projects.

Photo points – Photo points should be established for monitoring at the Logan Mill project site. Consider occupying some of the FWC/CWCB (Maya MacHamer/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (2), (3), (4), (6), (7), and (8).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (3), (4), and (7).

Flow – A stream gauge is expected to be installed by USGS in summer 2019 at the Logan Mill bridge at the downstream end of the Black Swan project site. Discharge should be recorded during peak flows at spring runoff if possible, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) to address project/monitoring goals (3) and (10).

5.7 LOWER FOURMILE BANK PROTECTION PROJECTS

The Lower Fourmile Bank Protection projects include bank protection at four distinct locations, all on private property. From upstream to downstream, the projects are located at 785 Fourmile Canyon Drive (approximately 75 feet of rehabilitation), 593 Fourmile Canyon Drive (approximately 100 feet of rehabilitation), 267 Fourmile Canyon Drive (approximately 85 feet of rehabilitation), and 38899 Boulder Canyon Drive (approximately 375 feet of rehabilitation).

The stream corridor in lower Fourmile Canyon is constricted by dense home development on the west side and Fourmile Canyon Drive on the east side. During the 2013 flood, the channel experienced both scour (leading to incision and floodplain disconnection) and sediment deposition. Many of the 22 bridges and culverts within the lowest two miles of the canyon were either damaged or washed out, and multiple sections of the roadway were completely destroyed. Bank stabilization activities in these four discrete areas were conducted to protect the private and public infrastructure from continued erosion, reduce flood risk, and improve habitat and creek function.

5.7.1 Site Details

This section provides details about the Lower Fourmile bank protection sites, projects, and surroundings for reference during future monitoring events.

Project Details:

- **Funding Source(s)** – DOLA CDBG-DR Watershed Implementation Grant Program
- **Design engineer(s)** – Nathan Werner, S2O Design and Engineering
- **Construction oversight engineer(s)** – Nathan Werner, S2O Design and Engineering
- **Construction contractor** – Whinnery Construction
- **Vegetation designer** – Ecosystem Services (Ecos)
- **Vegetation contractor** – Whinnery Construction
- **Construction dates** – March - July 2017
- **Select design flow(s)** – Bankfull flow not reported; 100-year flow (210 cfs)
- **Select activation flow(s)** – NA

River System Information:

- **Position in watershed** – Canyon
- **Adjacent restoration projects** – Logan Mill DR project upstream of upstream-most project site
- **Fish passage barriers** – NA
- **Diversion structures** – Pine Brook Water District diversion structure in the upstream pond at the Poorman Station
- **Nearest staff gauge** – Existing stream gauge at the mouth of Fourmile Canyon just upstream of the confluence with Boulder Creek (Fourmile Creek at Orodell, CO (USGS 06727500) operated by USGS) close to the lowest project.

Restoration Methods:

- **Seeding methods** – hand broadcast native seed mix; hydroseed at 267 Fourmile Canyon Drive
- **Planting zones** – 4 zones: Zone 1 Toe Treatment (0-1 ft above channel), Zone 2 Lower Riparian (1-2 ft above channel), Zone 3 Upper Riparian (2-3 ft above channel), and Zone 4 Upland (3ft+ above channel)
- **Willow installation method(s)** – hand-install at the end of and following construction
- **Topsoil added?** – Yes, downstream-most project site only
- **Erosion control** – hydromulch at 267 Fourmile Canyon Drive, erosion control fabric on access route at 785 Fourmile Canyon Drive
- **Irrigation** – No, but FWC hand-watered downstream-most project site for one season

Stakeholder Information:

- **Percent public/private land** – 100% private
- **Number of private landowners** – 4
- **Public land agencies** – NA

Post-Construction Inspections/Site Visits:

- None known as of the drafting of this report (summer 2019).

5.7.2 Project Goals and Monitoring Questions

The Lower Fourmile Bank Protection project's Basis of Design Report lists the following primary objectives:

(1) Create a complex and compound (benched) channel that incorporates a low-flow, bankfull, and overbank channel where appropriate/applicable;
(2) Create a stable "natural appearing and functioning" bank and river channel incorporating habitat improvements for fish and other aquatic organisms;
(3) Restore riparian and floodplain function within the river corridor, constructing wetland and riparian habitats, and reestablishing vegetation where appropriate/applicable;
(4) Create wildlife habitat for a variety of species;
(5) Demonstrate restoration techniques as a model for efforts to reclaim other stream reaches;
(6) Protect infrastructure (Logan Mill Road bridge, county road);
(7) Utilize native plants and prevent the spread of noxious weeds; and
(8) Enhance aesthetics.

For the lower project site (38899 Boulder Canyon Drive), additional monitoring goals and questions based on project review and conversations with the watershed coalition include:

(9) Monitor aquatic habitat quality and diversity lower project site (38899 Boulder Canyon Drive);
(10) Monitor pool temperature and depth at the upper project site (785 Fourmile Canyon Drive); and
(11) Verify design flows for floodplain benches at the lower project site.

5.7.3 Applicable Monitoring Parameters

Based on the project goals, objectives, and additional monitoring questions described in Section 5.7.2, the following monitoring parameters are recommended for the Lower Fourmile Bank Protection flood recovery projects. Unless otherwise noted, most of these monitoring activities can and should be conducted in the late summer/early fall timeframe, during baseflow conditions before the growing season ends. Associating discharge with inundation levels on floodplain benches, as well as reoccupying a subset of established photo point locations, are the monitoring parameters that would benefit from visits in both spring and fall seasons.

<u>Aquatic habitat feature surveys</u> – The USFS channel unit inventory should be conducted at the lower project site (38899 Boulder Canyon Drive) to address project/monitoring goals (2), (4), and (9). This survey method will evaluate the goal of increasing in-stream habitat complexity by monitoring the presence of all types of aquatic habitat features over time.

<u>Pool depth</u> – The deepest point in the pool downstream of the bridge at the upper project site (785 Fourmile Canyon Drive) pool should be measured using a range pole, stadia rod, or similar measurement device to see how the pool develops over time, addressing project/monitoring goals (2) and (10). For consistency in temporal comparisons, depth measurements should always

be conducted at approximately the same time of year and relative flow (e.g., summer baseflow in August/September). If available, the temperature of the pool may also be measured and recorded, particularly during summer months.

Vegetation surveys – To address project/monitoring goals (3) and (7), vegetation transect surveys should be conducted at the lower project site (38899 Boulder Canyon Drive). The AlpineEco vegetation monitoring method is planned to consistently monitor all Fourmile watershed projects.

Benthic macroinvertebrate community monitoring – Benthic macroinvertebrate community structure and diversity is an excellent proxy for aquatic health. One way to address project/monitoring goal (2) related to in-stream habitat is to assess the condition of the benthic community. FWC collected macroinvertebrate samples in conjunction with CDPHE at the lowest project site (Boulder Adventure Lodge) in August 2018. Benthic sampling should be repeated annually or every other year to detect changes in the macroinvertebrate community over time.

Photo points – Photo points should be established for monitoring at the Logan Mill project site. Consider occupying some of the FWC/CWCB (Maya MacHamer/Kim Lennberg) photos taken before and after construction and establishing them as permanent photo point locations to create a longer photo record. Photo points can be used to inform most of the project/monitoring goals, particularly (1), (2), (3), (4), (6), (7), and (8).

Visual assessments – The SVAP assessment should be conducted annually to address many of the project/monitoring goals, particularly (2), (3), (4), and (7).

Flow – Discharge rates should be recorded during peak flows at spring runoff from the USGS stream gauge at Orodell, and floodplain inundation levels should be associated with discharge (via pin flags, photo documentation, and/or wetted width measurement) at the lower project site (38899 Boulder Canyon Drive) to address project/monitoring goals (3) and (11).

6.0 DATA DOCUMENTATION

Documenting and organizing data in a meaningful way is essential to the monitoring program, as monitoring data is rendered useless if simply stored on data sheets, cameras, and hard drives. A list of recommendations is provided below for organizing data in a consistent and helpful manner.

- Develop a spreadsheet or word document that lists all site visits, no matter how comprehensive or trivial. At a minimum, the information in this document should include date, approximate time, personnel, weather conditions, reason for site visit, and monitoring activities. This document will provide a record and reminder that will be useful for data summaries, future discussions, and reporting.

- Photographs should be downloaded as soon as possible from cameras or smart phones and labeled in a meaningful way. A file management system should be developed to store photographs so that they are easily retrieved (by location and date). In some cases, a photo log should be developed on an excel spreadsheet that links photo name, detailed description, and GPS coordinates of the location where the photo was taken.

- Field notes (both field notebook pages and field forms) should be scanned, labeled, and appropriately filed.

- Where applicable, location data (GPS coordinates) should be catalogued and stored in a GIS or on Google Earth. Location data generally applies to the location of a discrete monitoring activity (e.g., pebble counts, flow measurements), upstream and downstream boundaries of monitoring transects (e.g., habitat surveys), and photo point locations (e.g., location where photograph was taken).

- Data entry should be completed as soon as possible, with flow, channel inventory/aquatic habitat, vegetation, pebble count, and other data entered into applicable spreadsheets.

- Data received from consultants or laboratories (e.g., water quality data, benthic macroinvertebrate data, fish population data, cross-section or longitudinal survey data) should be filed appropriately.

If funding is available, data collected during each year’s flood recovery project monitoring effort should be reviewed, analyzed, and summarized in a data summary report. As more data are collected each year, trends can be analyzed and preliminary conclusions made.

7.0 REFERENCES

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