Executive Summary
(To Do: To be compiled once design has been finished)

I certify to the best of my professional knowledge, judgment, and belief, these plans (or this report) meets applicable NRCS standards.
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1. Matrix Design Group Team Overview

The Matrix Design Group Team (Design Team) consisted of five different firms across a range of disciplines. All of the members on our team have worked on flood recovery projects with other members of the team. Below are descriptions of each firm’s role on this Project.

- **Matrix**—project management, channel restoration design, hydrology and hydraulics
- **Otak**—channel restoration design, fluvial geomorphology, and sediment transport
- **THK**—native revegetation and public engagement
- **ERO**—environmental resources and permitting
- **Blue Mountain Consultants**—fishery biology

Below is an organization chart of the team along with description of each team and their role on the project and key members that provided analysis and design as part of this Project.

![Figure 1. Organization Chart](image)

2. Project Funding

Funding for this study was through a Community Development Block Grant Disaster Recovery (CDBG-DR) Resilience Planning Program grant through the State of Colorado Department of Local Affairs (DOLA). The grant was applied for by Boulder County Parks and Open Space (BCPOS). The amount of the grant request was for $300,000 to evaluate a 3.2 mile reach of the South St Vrain Creek. In order to receive grant funding from DOLA certain design requirements must be met. Coordination with representatives with DOLA have taken place multiple times throughout this design either at public meetings or design review calls.
While the project scope, funded by DOLA, included an engineering analysis and survey of the entire 3.2 miles of the South St. Vrain Creek two sub reaches of the project are eligible for Emergency Watershed Protection (EWP) funding for a natural channel stream restoration for needed parts of the reach from the Hall 2 property to downstream of the new fish passage diversion for the South Ledge and Meadows Ditches at approximately 2.2 miles of the South St. Vrain Creek (EWP Reach 1) and directly upstream of the eastern bridge for the Old St Vrain Road where it ties into Highway 7 (EWP Reach 2). Both EWP reaches currently have funding allocated for actual construction. EWP Reach 1 has $1,573,189 and EWP Reach has $161,630 for budgeted for actual construction. Design guidelines from EWP that were followed as part of this project can be found on their website: coloradoewp.com

3. Project Location

The project area extends just west of the town of Lyons along the South St Vrain Creek from the County’s Custode Open Space property, in the canyon at the US Forest Service Boundary, to the eastern-most Old St Vrain Road bridge at the downstream end. Boulder County through its Parks and Open Space (BCPOS) department, owns and manages a nearly continuous 3.2 mile section of the creek through this reach including Custode, Hall Ranch 2, and Hall Ranch (also referred to as Hall Meadows) Open Spaces. Colorado State Highway 7 borders the planning area to the north, and Old St. Vrain Road (CR 84S) borders the planning area on the south. The planning area also contains a few private properties, as well as land owned by the City of Longmont. The Andesite Quarry (Colorado Division of Reclamation, Mining, and Safety permit number M-1977-141, also referred to as the Lyons Quarry) is located on the County’s Hall Ranch 2 Open Space property. Reclamation for the mine site is the responsibility of the mine operator; however, the section of creek across Hall Ranch 2 Open Space is included in the planning area.

The South St Vrain Creek at this location has a drainage area of approximate 92 square miles and is located about a half a mile upstream from the confluence with the North St. Vrain Creek which combine to form the St Vrain Creek. The South St Vrain Creek begins with its headwaters at the Continental Divide in the area of Brainard Lake near Nederland, CO. From there it flows east towards the Peak to Peak Highway (Highway 72) and receives tributary inflow along the way. The creek then reaches it confluences with the Middle St Vrain Creek near Highway 7. It then runs parallel to Highway 7 through the US National Forest through the canyon and into our project area. Beyond out project area the creek enters the town of Lyons and the confluence with the North St Vrain Creek.

Throughout the entire 3.2 mile reach there are existing projects, proposed projects, mining activities, and destroyed infrastructure in the form of bridges and diversions. Coordination with concurrent projects has taken place throughout this design process to ensure a holistic design is developed. The locations of these pertinent aspects have been included on the Vicinity Map on the following page.

As mentioned previously, along with the entire 3.2 mile stretch there are two reaches of the creek that are eligible for funding from the EWP Program. One of these reaches is located in about the middle of the entire 3.2 mile reach, in the Hall Meadows area, while the second reach is located at the very downstream end of the 3.2 mile reach near the bridge on the Old St Vrain Road. The EWP projects will be discussed more in depth later.
a. 2013 Flood Impacts and Aftermath (Grant Application)

Disaster damage occurred along the entire 3.2 mile reach, including to the stream course, banks, riparian and upland areas, as well as ditches, a Longmont water supply line, bridges, roads and private homes. The very severe damage in this project area was due to the volume and velocity of water immediately exiting the canyon and entering the valley. The braided channels, avulsions, deposition and flooding patterns formed as a result of this energy and volume seeking its path through the loose alluvial fields, combined with the constrictions of existing canyon walls, roads, bridges, ditches and home infrastructure. As a result, numerous locations within the 3.2 mile creek project area are unstable, eroding and channelized, undefined and prone to shifting path, aggraded or degraded in elevation, and temporarily linearized and hardened. Severe impacts outside of the creek bed include missing or damaged bridges, roads, ditches, and pipeline infrastructure, and damaged and continuously flooding homes, or homes and roads that continue to be under the threat of new flooding. Specific impacts include:

- In sections, the low flow channel location of South St. Vrain Creek is now on a perched, aggraded, braided, channel midway in the floodplain.
- The post-flood low flow channel location of the stream is now along Highway 7. The high flow channel is along the toe of Old South St. Vrain Creek Road. Emergency work completed in spring 2014 moved the low flow channel north towards Highway 7 in another new flood created channel.
- The Longmont water main crossing was exposed by the floodwater along the split flow channel that now serves as the post-flood low flow channel. Longmont has been working to reinforce this water line and to further protect it by relocating the low flow channel back to its pre-flood location.
- The South Ledge Ditch head gate was located off-channel and served by pipe diversion from the pre-flood channel before the flood. The diversion and headgate were destroyed by the flood when the channel relocated.
- The Meadows Ditch head gate was a channel edge diversion from the pre-flood channel. While part of the headwall remains, the diversion itself is non-functional due to damage to the head gate, inlet sedimentation, and the stream gradient change at the head gate.
- A stream hard point was created following the 1969 flood. The hard point was created using overburden and waste rock from the immediately upstream Andesite Quarry, to protect the downstream overbank pasture. Unfortunately, this hard point directs flow against the highway embankment and towards the homes further downstream. During the 2013 flood, this hard point caused water to flow against the left bank adjacent to the Colorado Highway 7 and washed away enough of the highway to cause its closure until it could be temporarily repaired. It was also a source of flooding concern to the residents on the left bank further downstream.
- The bridge providing access to the Andesite Quarry and the upstream access to the homes along Old South St. Vrain Creek Road was washed away during the 2013 flood. This is a County bridge and that will be replaced.
- A portion of Old South St. Vrain Creek Road approximately 1300’ upstream of the Andesite Quarry bridge and adjacent to a major rock outcrop has washed away, eliminating the major access to the former quarry for remediation purposes and for future use as access to a new County open space/recreation area. Boulder County is currently working with FEMA on repair of the road. However, the creek will continue to impact the road at this location.
A stream avulsion occurred during the 2013 flood that resulted in a new post-flood low flow channel mostly located on non-County owned property. During the avulsion, the cutting of the new channel included eroding a portion of the edge of Colorado State Highway 7, to a post-flood location at the toe of the repaired highway embankment.

Various ongoing factors are currently posing a severe threat to the health, safety and welfare of the community. Mainly, this type of threat is to private homes, bridges, roads, ditches and pipeline infrastructure. These risks are in the form of potential new flooding that could cause damage to homes and other infrastructure, loss of business profit from lost irrigation, and direct threat to life and human health due to contact with new flood waters, contamination of drinking water supply, or the inability to escape new flooding. Most of these threats are exacerbated by the unknown volume of water that changes annually due to natural variations (i.e. snowmelt), or the threat of a new flood.

The conditions which are creating the greatest threats include:

- Dangerous proximity of post-flood creek alignment to infrastructure.
- Unstable and eroding condition of creek channels, compounded by braiding and split-flow paths.
- Elevation changes to creek bed and water surface.
- Linearized and hardened channels with increased velocity.
- Missing or damaged bridges and roads.
- Missing or damaged ditch diversions, headgates and water supply line.

### b. Post-Flood Repairs

In the last two years, numerous projects by various entities have been undertaken within the planning area. Emergency debris removal, which was funded by FEMA, removed debris within the post-flood channel below the 5-year flow event. This occurred primarily near the Andesite Bridge, the Old St. Vrain Bridge, and along the southern high flow channel where it was constrained within existing vegetation. Some grading was done post-flood on private property to protect homes along Highway 7. To minimize the risk to these homes and others, BCPOS removed some sediment within a post-flood channel, and constructed a rock vane to split high flows into two newly created post-flood channels. The northern channel is the main stem, while the southern channel alignment takes some water during high spring flows. Two years of high spring flows following the September 2013 flood have continued to shape the stream channels, but have not led to any new avulsions or severe erosion, however areas of instability remain.

During the spring of 2015, the city of Longmont rebuilt its water pipeline and diversion infrastructure and restored the stream channel to its pre-flood alignment immediately downstream. Additionally, BCPOS, working with the St. Vrain Chapter of Trout Unlimited, Colorado Parks and Wildlife, the US Fish & Wildlife Service and the Colorado Water Conservation Board, rebuilt the South Ledge and Meadows ditches into a shared diversion structure that chases grade upstream so as to preclude the need for a diversion dam that would inhibit fish passage.

In addition to these repairs, a number of other projects are anticipated throughout the corridor over the next several years, many of which will be funded by FEMA, including:

- Reconstruction of the Otto, Carl Holcomb, and Matthews ditches
- Repairs to the Andesite Quarry access road on the county’s Hall Ranch 2 property
• Replacement of the Andesite Bridge at the west end of Old St. Vrain Road by Boulder County Transportation

Some of these existing and proposed projects are discussed in more depth in the following section.

4. Project Goals and Objectives
   a. Existing Goal Statements
      A project goals statement was generated as one of the first tasks of this project. The project goals statement was developed from information gathered from the Request for Proposal (RFP), the Colorado Resilience Planning Grant Program Application, the St Vrain Creek Master Plan, and Public Comments. The aspects the Project Goals Statement was developed upon are compiled below.

      i. RFP
         The requested services are needed to provide a 30% design that provides mitigation measures to reduce the impact of future flooding, provide public safety, protect public and private infrastructure, maintain or re-establish floodplain connectivity, and restore the creek channel and surrounding areas to stable, resilient, and ecologically rich habitats.

      ii. Grant Request
         The goal of the project is to create a stream channel that will be sustainable and benefit ecological values while minimizing future flood risks to surrounding homes and roads.

         The resiliency objectives of the project are to restore the stream channel in a way that both protects and increases the ability of critical infrastructure and environmental and cultural resources to withstand future disaster, while reducing future recovery time by mitigating risk and assisting in local community disaster preparedness. Sustainability objectives will focus on reconstructing the channel in a way that protects the existing homes and built environment, while also improving the local economic, social and natural environments.

      iii. Master Plan
         The purpose of this alternative is to implement a channel alignment that will optimize the interaction with completed, ongoing, and funded projects while being sensitive to the constraints presented by the presence of numerous private residences throughout this river corridor. The implementation of this alternative will expedite the maturation of this reach by re-establishing a natural channel, repairing erosion scars, re-establishing floodplain benches, building point-bars and excavating pools, re-vegetating denuded areas, and stabilizing channel banks.

      iv. Public Comments
         A multitude of public comments have been received over the past 2.5 years since the September 2013 flood. Some of these comments were received prior to the project and were provided compiled by the BCPOS project manager. Many new comments were also provided to the Design Team via public meetings, personal homeowner site visits, St Vrain Creek Working 4B Group Meetings, and online submissions.
b. Project Goals Statement

Once a Project goals Statement was developed and vetted internally by the Design Team BCPOS reviewed the letter and provided their final edits. Below is the final project goals statement:

“Provide a conceptual design for the entire South Saint Vrain Creek project area that restores and improves the channel and surrounding floodplain areas to a safe, natural, resilient, functioning, and ecologically rich habitat. This project will use qualitative research, quantitative data, and community input to inform resilient design that shall utilize natural system principles and onsite materials to expedite recovery from the 2013 floods and set up for better performance in future flood events. Components to meet goals include incorporating natural channel diversity and character, re-establishing floodplain benches for lateral connectivity, reducing longitudinal connectivity constraints, improving flow conveyance and sediment transport to maintain environmental values, promote naturally functioning stream processes, protect public and private infrastructure, improve public safety, repair unstable erosion scars in high-risk areas, and revegetate denuded areas.”

c. Project Objectives

The objective of this project was extracted directly from the Request for Proposals and is presented below:

“The objective of this project is to provide a 30% design that is based on the Consultant’s evaluation of the baseline site conditions, hydrology, hydraulics, geomorphic processes, sediment transport, habitat requirements, and alternatives analyses. The 30% design will establish mitigation measures to reduce the impact of future flooding, protect public and private infrastructure, offer public safety, provide for channel stabilization, protect and restore aquatic, wetland, riparian, and upland habitats, and assign a detailed cost estimate for the preferred alternative. In addition, the Consultant will prioritize by sub-reach each mitigation and restoration activity based on need and desire.”

The 30% designs are to supply a sufficient level of detail to evaluate major design features prior to advancing the project to either a design-build phase or complete construction drawings. CDBG-DR dictates that 30% designs will provide clear direction so that detailed project engineering and specifications can be developed in the future. The planning and design work should incorporate information for low flows, average high flows and flood flows to promote a resilient and naturally stable river.

d. Emergency Watershed Protection Program

While the design of the 3.2 mile reach is funded under DOLA, EWP has allocated funding for actual construction along two reaches in this project. Since EWP will be funding actual construction their objectives and criteria must also be met. The Colorado EWP Program provides funding to implement emergency recovery measures to address hazards to life and property in watersheds impaired by the 2013 Colorado flood event. The program provides financial and technical assistance to local project sponsors to reduce erosion and threats from future flooding, protect streambanks, repair conservation practices, remove debris, and more. The Colorado EWP program is funded and administered by the USDA Natural Resources Conservation Service and managed by the Colorado Water Conservation Board on behalf of the State (EWP Website).

Colorado EWP Vision: To implement watershed recovery projects that reduce risk to life and property, enhance riparian ecosystems, and generate long-term stream system resilience through a collaborative, watershed-based approach that incorporates the needs of diverse stakeholders.
5. Summary of Relevant Background Information

Relevant background information was evaluated from multiple sources in various forms. Review of existing plans and studies along with interviews of stakeholders and County officials took place and are discussed here. Meeting minutes for these meetings can be found in Appendix X. Excerpts and pertinent information from the documents have been compiled here. Some of the documents are supplied in the appendices also for further information.

a. Meeting with BCPOS

Initially a kick-off meeting with BCPOS took place to provide introductions and discuss the purpose and goals of this project. This meeting took place on May 11th at the BCPOS. This meeting was the basis of the initial project development. Multiple topics were discussed at this meeting including available resources, recently completed, ongoing and proposed projects throughout the corridor, available staff at BCPOS and the background information they could provide. The majority of the information discussed at this meeting related to concurrent or ongoing projects along with the goals of BCPOS.

b. LiDAR Mapping (2011 and 2014)

Light Detection and Ranging (LiDAR) mapping from both 2011 and 2014 was provided by BCPOS to facilitate setting up a base map with pre- and post-flood contours. The LiDAR was acquired from the Colorado GeoData Cache. This information was used to compile an existing grade surface that could be supplemented with on the ground survey performed by Matrix. The 2011 LiDAR mapping available was only 2 foot contours, while the 2014 LiDAR could be used to generate 1 foot contours. Both data sets were used to determine the changes throughout the project reach and determine various aggradation and degradation zones.

- 2011 LiDAR: The project area was produced from LiDAR flown over portions of the County of Boulder, CO and surrounding areas. Data was produced in Colorado State Plane North (NAD 1983 HARN US Survey Feet), WKID 2876 NAVD 88. The LiDAR collection vendor (under separate contract – Colorado LiDAR Task Order AERO-PTS-003-attached) collected and delivered calibrated and initially processed LiDAR Data to Boulder County. The final accuracy assessment from the Vendor indicated a Final RMSEz of 0.243 ft. Based on the accuracy in the supplied LiDAR data the contours were compiled to meet 2 foot contour accuracy, however in areas of extreme slope as indicated by USGS TM11-B4 Vertical Accuracy “Slopes that exceed 10% should be avoided” as part of the overall accuracy LiDAR base testing. The contours were “smoothed” appropriately to maintain an acceptable level of accuracy and cartographic quality. As part of the pilot data review the County and McKim & Creed agreed to produce the 2 foot contours in the areas of extreme relief in order to provide more topographic detail and visualization than would normally be available for only Index contours to provide detailed contour data at 2 foot interval.

- 2014 LiDAR: Merrick acquired accurate, high-resolution LiDAR data for flood damaged areas in Colorado. Note that the shape files used in the processing represented a combination of a 1,500 ft buffer on each side of the stream and the 500 year floodplain, whichever is larger. The LiDAR data was processed to produce a classified point cloud, bare earth elevation models and related products, necessary to support flood recovery efforts. The project produced LiDAR data and elevation products for approximately 458 square miles over damage areas in several Colorado counties. The contours were downloaded from State of Colorado data repository and processed for the Boulder County environment. To provide detailed contour data at 1 foot interval for watersheds in Boulder County. Derived from LiDAR data captured in 2014 was to support disaster response, recovery, long term recovery, and other future disaster loss reduction efforts.
c. Post Flood Hydrology

Post flood hydrology was developed from the “Hydrologic Evaluation of the St. Vrain Watershed” and “St. Vrain Creek Channel Flood Recovery Design-Build Services” reports. The first report was used to set the less frequent recurrence interval flows including the 100 year hydrology that will be used for the floodplain development permit. The latter report will be used to set the more frequent recurrence interval flows including the bankfull hydrology. Further in-depth discussion of the hydrology will be presented further in this report.

d. St Vrain Creek Watershed Master Plan

Following the flood a number of agencies and groups along the St. Vrain Creek formed the St Vrain Creek Coalition (SVCC). The forming of this group first facilitated developing the St. Vrain Creek Watershed Master Plan (Master Plan) (Michael Bake, et al 2014). The Master Plan “articulates the vision for the future of the watershed and guides future planning and development activity by highlighting recommended projects that align with diverse community priorities” and provides a “road-map for long-term recovery” along St. Vrain Creek. Boulder County adopted the Master Plan on February 26, 2015.

The Master Plan was first evaluated to determine existing recommendations already developed since the 2013 flood. The Master Plan had specific information relating to the South St Vrain Creek corridor through our project area. The Master Plan had high level project recommendations that were evaluated more in-depth as part of this project. Below is an excerpt from the Master Plan related to Reach 4B which is our project area.

“The purpose of this alternative is to implement a channel alignment that will optimize the interaction with completed, ongoing, and funded projects while being sensitive to the constraints presented by the presence of numerous private residences throughout this river corridor. The implementation of this alternative will expedite the maturation of this reach by re-establishing a natural channel, repairing erosion scars, re-establishing floodplain benches, building point-bars and excavating pools, re-vegetating denuded areas, and stabilizing channel banks.”

The Master Plan also called out the following restoration strategies for this reach:

- Incorporate/stabilize a low flow channel section with lower width-to-depth ratio
- Increase in-stream habitat complexity by incorporating pools, boulders, rock clusters, and LWD (large woody vegetation)
- Revegetate riparian corridor with native species where needed

The information from this Master Plan was used as the starting point for determining various alternatives to applied through or project reach. Applicable sections from the Master Plan have been in included in Appendix X.
e. Emergency Watershed Protection Program

The Colorado EWP Program is funded through the USDA Natural Resources Conservation Service and managed by the Colorado Water Conservation Board to implement emergency recovery measures to address hazards to life and property in watersheds impaired by the 2013 flood. The EWP program will be one of the funding sources to provide actual construction funding throughout two reaches of our project. Members of the EWP were consulted as the project progressed and were allowed opportunities to comment on the Draft and 30% Design Plans. Furthermore, BCPOS has met with the EWP technical team multiple times before and throughout this project to help direct designs. The Colorado EWP team has developed multiple guidance documents for all flood impaired creeks and reach specific reports. Below is a synopsis of a few of the important documents.

i. Damage Survey Report

A Damage Survey Report (DSR) (USDA NRCS, 2015) was developed as part of the EWP process. The DSR evaluates damage received from the event along with the eligibility of each site to receive funding. The DSR was developed for multiple reaches along the South St Vrain Creek corridor including two through our project area, but was not broken out in the DSR, but was in the Scope of Work, which is discussed later. The preferred alternatives developed from evaluation of the site by EWP personnel is below:

**Preferred Alternative: Restore river to pre flood measures to withhold a 100 year event contingent upon completion of CR investigation and in compliance with requirements of F&WS emergency consultation and all applicable categorical exclusions.**

An environment evaluation and environmental concerns were developed in the DSR which compared the preferred alternative proposed action to the no action alternative. The economic benefits of the proposed action also evaluated the number of properties to protect, including private homes, bridges and business. The total near term damage reduction by implementing the preferred alternative was estimated at $4,500,000. Also provided in the DSR was an engineering cost estimate that determined it would cost $2,409,099 to implement recovery measures. An EWP funding priority was also completed that determined the project site had serious, but not immediate threat to human life and would protect or conserve federally-listed threatened and endangered species or critical habitat and maintain or improve current water quality conditions. A copy of the DSR is in Appendix X.

ii. Project Engineering Guidance

A Project Engineering Guidance document was also supplied by the EWP Program. This document outlined design objectives, standards and approaches that should be used as part of flood recovery work. It also included supplemental information on sediment and debris removal, permitting aspects and other environmental concerns. Information with regards to permitting and design documents that must be submitted as part of the NRCS funding was included.

iii. Preliminary Scope of Work

Along with the DSR and the Project Engineering Guidance a Preliminary Scope of work was evaluated. The preliminary scope of work included three different project areas. The two most upstream project areas are included as part of this project.

**Proposed Work: All project areas have one or more of the following treatments: Sediment removal to establish a flood plain, bioengineering to stabilize stream banks, armored resiliency to stabilize stream banks, critical area treatment (CAT) including willow planting, seeding, mulching and topsoiling.**
The Scope of Work was broken into three different project for the South St Vrain Reach 4b. Our project area encompasses two of these project sites. Project Site 1 is the most upstream of the three projects in an area called the Hall Meadow. This project site has $1,573,189 budget for construction. The proposed recovery measures at this site location are armored resiliency, streambank shaping, sediment removal, seeding and mulching and topsoil. The second site is Project Site 2 which is located just upstream of the bridge near the intersection of Highway 7 and the Old St Vrain Road, which has a construction budget of $161,630. The proposed recovery measures along this site include streambank shaping, sediment removal, seeding and mulching and topsoil. A copy of the Scope of Work is included in Appendix X.

f. St Vrain Creek Channel Flood Recovery Design-Build Services

Data and recommendations from the report titled “St Vrain Creek Channel Flood Recovery Design-Build Services” (Otak, 2016) provided initial guidance on stream geomorphic trajectory. The purpose of the St. Vrain Creek Channel Flood Recovery Design-Build Project was to repair flood damage and increase resiliency in the system for reduced damage during future flood events. The project included three phases:

- Design-Build Construction along North St. Vrain Creek and mainstem St. Vrain Creek in the vicinity of the Town;
- Preliminary evaluation of numerous design alternatives, including those not constructable under this grant award due to previous and conflicting funding awards; and
- Expanded Area Study on North, South, and mainstem St. Vrain creeks to characterize geomorphic- and sediment-specific longitudinal trajectories.

Key conclusions and recommendations resulting from the modeling and analysis performed as part of the Expanded Area Study provided resource managers and design teams with reach-scale hydraulic, geomorphic and restoration guidance to help inform the planning of future projects. The discussion of the results of the study provides interpretations for three geographic subsets of the project area – Apple Valley, Hall Meadows, and the Town. The discussion provides linkages between analysis results and recommended flood mitigation and restoration actions.

The primary tools used to develop these recommendations are the River Styles characterizations, Stream Evolution Model (SEM) (Cluer and Thorne, 2013), and the sediment balance and stream power calculations. From the analysis of the results, three project-wide recommendations became apparent:

- The need for long-term monitoring. Results of the geomorphic analysis show that the reaches covered in the expanded modeling footprint are in various stages of geomorphic response to the flood. Perhaps most dramatically, the South St. Vrain Creek can be expected to undergo substantial adjustment as the stream seeks equilibrium geometries, responding to fluctuating sediment loads. Monitoring the response will provide much-needed information that can be used to more thoroughly plan for future flood events.
- Floodplains are critical for stream recovery and flood mitigation. Many of the reaches in the study area are incised requiring substantial flows before floodplains are accessed. Under this incised configuration, stream power is concentrated in the channel, enhancing the geomorphic impact of more frequently occurring flows.
- Buyout properties provide opportunities to reconnect floodplain where the stream was previously disconnected and options for re-purposing them as effective floodplain should be evaluated from hydraulic, geomorphic, and ecologic contexts.
Specific to South St. Vrain, reaches in Hall Valley were found to have highly degradational tendencies, but results depend on the flow used in the calculation, indicating widespread imbalances. Much sediment has aggraded in the alluvial valley, suggesting the creek will work to export sediment from the valley. Channel base elevations will likely drop, as the channel abandons its former floodplain. This inset channel is likely to then cycle through sequences of incision and widening as the channel seeks an equilibrium slope, creating much instability in the system. Therefore, restoration through Hall Valley should focus on re-connecting the channel and floodplain and a coordinated establishment of equilibrium channel dimensions (slope and cross section) throughout the valley. Re-connecting the floodplain will restore a number of functions, perhaps most importantly flood energy reduction and sediment storage.

g. St. Vrain Pipeline 2013 Flood Repair
The 2013 flood caused damage to the existing City of Longmont Diversion pipeline. The cross channel diversion intercepts flow in the South St Vrain Creek near the downstream extents of our project. During the flood the existing diversion abutment was scoured away along the south bank of the creek. This erosion caused the piping at the abutment to fail. The overall diversion itself remained intact during the flood and required minimal repairs along the southern abutment, beyond replacement of a 27” concrete encased pipe. Grading repairs downstream of the diversion along the southern bank also took place to re-establish the bank slopes. A sloping grouted drop structure was designed to be installed as part of this project but had to be removed due to permitting aspects. A manhole and flow control structure were also installed as part of this project in the adjacent floodplain to the diversion. The piping then makes it way north east where it crosses the South St Vrain Creek at a bridge along the Old St Vrain Road. The pipe crossing the creek is encased in concrete.

h. Meadow and South Ledge Diversion Reconstruction and Fish Passage Demonstration
During the 2013 flood the Meadows and the South Ledge diversion headgates were destroyed. Since the flood the diversion were combined and moved upstream, while also removing impediments to native fish passage. The points of diversion were moved upstream so that a cross stream diversion structure was not necessary. The newly designed diversion includes an at grade diversion with a trash rack and sediment sluice constructed in a concrete inlet structures. Minimal instream work took place near the proposed location. The addition of root wads, boulders and vegetation along both banks of the creek were installed to provide additional bank stabilization. The diversion then conveyed water towards the Old St Vrain Road to a splitter box where the flows for the Meadow and South Ledge were spilt and diverted to their appropriate ditches.

i. County’s Management Plans
A number of County-adopted management plans were evaluated as part of this design. These management plans direct current and future direction of the County’s open space lands within the project area. These management plans generally direct the BCPOS to manage the properties for their natural resources values, including riparian areas and species of concerns. Currently the project area is closed to the public and there is no access allowed. Access to the creek itself is also not allowed by boaters and other recreationalist.

Below is a list of documents supplied by BCPOS for review as part of this design process.

- Boulder County Comprehensive Plan – Environmental Resources Element (2014)
- St. Vrain Creek Corridor Open Space Management Plan (2004)
- St. Vrain Trail Master Plan (2004)
• Hall Ranch Meadows Natural Resource Assessment (2005)
• Environmental Assessment – South St. Vrain Creek (2000)

j. Public Comments
A multitude of public comments have been received over the past 2.5 years since the September 2013 flood. Some of these comments were received prior to the project and were provided compiled by the BCPOS project manager. Many new comments were also provided to the design team via public meetings, personal homeowner site visits, St Vrain Creek Working 4B Group Meetings, and online submissions. These comments have been compiled into Addendum X (South St. Vrain Comments).

6. Watershed Site Assessment Information
a. Review of Existing Documentation
The aforementioned relevant background information was reviewed and pertinent information was compiled and developed as part of this planning process.

b. Survey
Topographic information for the purposes of the project were developed from multiple sources. The base information was supplied using Light Detection and Ranging (LiDAR) data collected in October 2014 by the Colorado Water Conservation Board. Ground survey as part of this project was conducted by Matrix, but was supplemented with ground survey from CivilArts and AECOM.

Matrix's in house survey team was responsible for acquiring new ground survey for the project. Existing conditions for this project were gathered using a combination of existing LiDAR data supplemented with conventional GPS surveying. The GPS survey data is based on the Boulder County control network. Bearings for the survey data are grid bearings of the Colorado state plane north zone as measured between control point T3NR70WS19N and control point LL1431_LYONS, as described by Boulder County records, having a bearing of North 17°18’14” East. The elevations are based on Boulder County control point LL1431_Lyons having a published NAVD88 elevation of 5485.20 feet.

The project data GPS data was collected during the third week of May, 2016 and consists of a sampling of the 3.2 mile project area as directed by project engineering. The data acquired consists of profile data for the existing river, 115 cross sections spread throughout the project area, water surface elevations and various critical locations as specified by the project engineers.

Ground survey topography was also developed from two outside sources. The first source was from CivilArts, who was contracted through the St Vrain Creek Channel Flood Recovery Design-Build Services for Lyons. Ground survey included bathymetric cross sections collected in March and November 2015 and March and April 2016. The second outside source of ground survey was acquired in 2015 and developed by AECOM as part of the CHAMP and RiskMap study being performed by CWCB.
For our project area a surface was generated from the ground survey information acquired from all three sources. Ground survey information was developed into breaklines that were used to interpolate the bathymetric information between the cross sections. This information was then pasted into the LiDAR surface that was developed to develop a complete topographic model. The ground survey information was used for data within the channel banks and overflow channels while the LiDAR supplemented that survey outside of the banks.

LiDAR survey was also developed from 2011 as pre-flood data to evaluate overall changes in the ground surface from pre-flood to post flood.

c. Riparian Assessment and Wetland Delineation

The Riparian Assessment and Wetland Delineation used onsite observations and calculations, as well as state and national resources, to determine riparian health, ecologic diversity, wetland locations, invasive species concerns and the ecosystem character of the project reach.

Objectives:
- Determine how the 2013 floods modified historic processes and ecosystem health
- Document existing wetland, riparian and upland plant communities
- Document denuded areas that are void of vegetation
- Document and assess pockets of unique vegetation and micro-climates related to secondary channels and groundwater seeps
- Document extent and location of revegetation opportunities
- Identify individual plant species to determine ecosystem character and biodiversity
- Develop a comprehensive plant list for the project reach
- Document both native and invasive or noxious plant species
- Address any measures that the County has taken to deter or eliminate invasive or noxious plants
- Assess onsite soil conditions and develop revegetation strategies for specific onsite conditions
- Identify erosion issues and bank instability
- Investigate public and stakeholder concerns
- Assess terrestrial species presence and habitat within riparian and wetland areas
- Develop opportunities for native revegetation within denuded areas

i. Existing Restoration Data

State and national resources that have inventoried wetland and riparian ecosystems were used to gather background information and guide the revegetation process of the project. These resources include former studies and data that provide information on the historical presence of onsite wetland areas. This information was used to determine what a native wetland habitat in this area would have resembled and identify the location in which it occurred.

The National Wetland Inventory Wetlands Mapper (FWS, 2009) indicates five different classifications of wetlands present in the project extents along the South St. Vrain. These wetland types are historically found in specific locations along the channel as seen in Figure 1. Below is an excerpt from The National Wetland Inventory Wetlands Mapper website outlining the five wetland types found within the project reach.

1. PUSC – Palustrine Unconsolidated Shore Seasonally Flooded
Wetland Type: Freshwater Pond

P – Palustrine (System): Includes all nontidal wetlands dominated by trees, shrubs, persistent emergent, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) areas less that 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2.5 m (8.2 ft) at low water, and (4) salinity due to ocean-derived salts less than 0.5 ppt.

US - Unconsolidated Shore (Class): Includes all wetland habitats having two characteristics: (1) unconsolidated substrates with less than 75 percent areal cover of stones, boulders or bedrock and; (2) less than 30 percent areal cover of vegetation. Landforms such as beaches, bars, and flats are included in the Unconsolidated Shore class.

C - Seasonally Flooded (Water Regime): Surface water is present for extended periods especially early in the growing season, but is absent by the end of the growing season in most years. The water table after flooding ceases is variable, extending from saturated to the surface to a water table well below the ground surface. (FWS, 2009)

2. RSUBH – Riverine Unknown Perennial Unconsolidated Bottom Permanently Flooded

Wetland Type: Riverine

R – Riverine (System): Includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts of 0.5 ppt or greater. A channel is an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water.

S – Unknown Perennial (SubSystem): This Subsystem designation was created specifically for use when the distinction between lower perennial, upper perennial, and tidal cannot be made from aerial photography and no data is available.

UB-Unconsolidated Bottom (Class): Includes all wetlands and deepwater habitats with at least 25% cover of particles smaller than stones (less than 6-7 cm), and a vegetative cover less than 30%.

H – Permanently Flooded (Water Regime): Water covers the substrate throughout the year in all years. (FWS, 2009)

3. PFOA – Palustrine Forested Temporary Flooded

Wetland Type: Freshwater Forested / Shrub Wetland

P – Palustrine (System): Includes all nontidal wetlands dominated by trees, shrubs, persistent emergent, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) areas less that 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2.5 m (8.2 ft) at low water, and (4) salinity due to ocean-derived salts less than 0.5 ppt.
FO-Forested (Class): Characterized by woody vegetation that is 6 m tall or taller.

A-Temporary Flooded (Water Regime): Surface water is present for brief periods (from a few days to a few weeks) during the growing season, but the water table usually lies well below the ground surface for the most of the season. (FWS, 2009)

4. R3USA – Riverine Upper Perennial Unconsolidated Shore Temporary Flooded

Wetland Type: Freshwater Forested / Shrub Wetland

R – Riverine (System): Includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts of 0.5 ppt or greater. A channel is an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water.

3 – Upper Perennial (Subsystem): This Subsystem is characterized by a high gradient. There is no tidal influence, and some water flows all year, except during years of extreme drought. The substrate consists of rock, cobbles, or gravel with occasional patches of sand. The natural dissolved oxygen concentration is normally near saturation. The fauna is characteristic of running water, and there are few or no planktonic forms. The gradient is high compared with that of the Lower Perennial Subsystem, and there is very little floodplain development.

US – Unconsolidated Shore (Class): Includes all wetland habitats having two characteristics: (1) unconsolidated substrates with less than 75 percent areal cover of stones, boulders or bedrock and; (2) less than 30 percent areal cover of vegetation. Landforms such as beaches, bars, and flats are included in the Unconsolidated Shore class.

A-Temporary Flooded (Water Regime): Surface water is present for brief periods (from a few days to a few weeks) during the growing season, but the water table usually lies well below the ground surface for the most of the season. (FWS, 2009)

5. PSSC – Palustrine Scrub-Shrub Seasonally Flooded

Wetland Type: Freshwater Forested / Shrub Wetland

P – Palustrine (System): Includes all nontidal wetlands dominated by trees, shrubs, persistent emergent, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) areas less that 8 ha (2o acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2.5 m (8.2 ft) at low water, and (4) salinity due to ocean-derived salts less than 0.5 ppt.

SS – Scrub-Shrub (Class): Includes areas dominated by woody vegetation less than 6 m (20 feet) tall. The species include tree shrubs, young trees (saplings), and trees or shrubs that are small or stunted because of environmental conditions.

C - Seasonally Flooded (Water Regime): Surface water is present for extended periods especially early in the growing season, but is absent by the end of the growing season in most years. The water table
after flooding ceases is variable, extending from saturated to the surface to a water table well below the ground surface. (FWS, 2009)
The Colorado National Heritage Program (CNHP) and the Colorado Wetland Inventory Mapping tool (CHNP, 2009) was used to determine the location and composition of onsite wetlands, as seen in Figure 2, and provides locations of further plant community sub categories which include:

- Rp1FO – Riparian Lotic Forested
- Rp1EM – Riparian Lotic Emergent
- PEMA - Palustrine, Emergent / Herbaceous, Temporarily Flooded
Further information provided by CNHP affords an overview of the corresponding riparian plant communities within the project extents. These riparian plant communities occur alongside existing wetlands outlined by the CNHP and NWI Wetland Mapping tools. This data identifies five major riparian plant communities within the site including:

- Forested Deciduous – Cottonwood
- Herbaceous – Sedges / Rushes / Mesic Grasses (Moist Soils)
- Herbaceous - General
- Shrub – General
- Upland Grass

Figure 2 CNHP Colorado Wetland Inventory Map of existing Riparian Communities within the wetland area, 2009.
THE CNHP Field Guide to Wetland and Riparian Plant Associates (*CNHP, 2003*) provides more specific information about the plant communities in the project extents. The plant communities found on the site are most closely associated with Group C – Deciduous Dominated Forests and Wetlands. Due to the elevation range and dominate species found during the onsite assessment, it is determined that the specific plant associations in the area fall under the Narrowleaf cottonwood / Sandbar willow Woodland. These plants are commonly found at an elevation between 5,200 – 8,500 feet along point bars, gravel bars and riparian benches very near or within the active stream channel and do not occur more than 3-6 feet above the high-water mark. This association of species represents an early, successional stage of this community consisting of primarily young Narrowleaf Cottonwoods trees with interspersed older, transitional stands of more mature trees and a dense Sandbar (also known as Coyote) willow understory. Due to frequent annual flooding in this area, the herbaceous undergrowth is sparse and the significant portion of undergrowth plant material is made up of non-native, invasive species. (*CNHP, 2003*)

The Environmental Protection Agency Level IV ecoregion data shows the project extents to be located in the Southern Rockies Crystalline Mid-Elevation Forests. This forest vegetation is generally characterized by the existence of Aspen, Ponderosa Pine, Douglas-fir, and areas of Lodgepole Pine and Limber Pine with a diverse understory of shrubs, grasses and wildflowers (*EPA, 2016*).

The Colorado Natural Areas Program Native Plant Revegetation Guide for Colorado (*CNAP*) further categorizes the plant communities within the project extents as an Eastern Plains and Foothills Region Riparian Community and Cottonwood / Willow Shrublands and Forests. According to the *CNAP* Native Plant Revegetation Guide for Colorado, this project extent represents a foothill riparian forest and shrubland that contains groupings of cottonwoods that form the canopy layer. Sandbar willows occur along the meandering stream edge and grasses such as switchgrass and prairie cordgrass occur between clumps of shrubs and alongside streambanks, forming wide stands of thick, tall grass. Nebraska sedge, Baltic rush and Three-Square are a few examples of plants that are found along the edge of permanent streams and at the bottom of recurrent drainages. Dense shrub layers composed of willows, currants, plums, chokecherries and hawthorns dominate the understory with more willows, red-osier dogwood and twinberry growing along the cool, moist streambank. Cottonwood / Willow Shrublands and Forests include a vast mixture of vegetation types, with wetland areas occurring along the stream edge, in backwater areas with upland / transitional vegetation communities interspersed with the wetland and riparian vegetation. (*CNAP, 1988*)

**ii. Onsite Assessment**

On July 22, 2016, members of the project team and Boulder County conducted a comprehensive site walk of the project area to assess and discuss vegetation and ecologic concerns in the project area. This assessment addressed the entire reach and successfully identified:

- Plant communities that survived the 2013 floods
- Areas that remain denuded
- Areas that show successful secondary colonization
- Extents of prominent wetland areas
- Native thriving plant communities
- Invasive plant communities
This assessment resulted in onsite observations of existing conditions that are outlined in this document and compiled into a comprehensive plant list that identifies the specific varieties of native and invasive plants that can be found onsite.

A variety of healthy ecosystems remain onsite. Due to steep banks and an incised channel in many areas, upland areas have remained established. These areas are characterized by upland vegetation including cottonwood galleries and upland meadows. Wild grape was heavily present throughout the upland areas within the project site and forms dense clusters at the base of the Cottonwood trees. Woody shrubs and grasses such as Woods Rose, Snow Berry, Rabbitbush, Ninebark, Thickspike Wheatgrass, Slender Wheatgrass and Wild Rye are also present in these areas, although it was difficult to determine which of the grass species recolonized naturally or were introduced through re-seeding measures.

The riparian areas throughout the site consist of a variety of woody and perennial plants including Coyote Willow, Dogbane, Alders, Wild Plum, Wild Asparagus, Common Horsetail, Torrey’s Rush and Switchgrass. In areas where the channel was incised, willow and Dogbane, along with a variety of grasses, could be found along the river banks. These species grew out of alluvial soils and cobble banks and provided a good case study for potential bioengineering measures related to bank stabilization.

Wetland vegetation exist in depressed areas throughout the project extents. These areas include secondary channels that were formed during the 2013 flood or historic wetland areas. These wetland areas support a variety of native wetland plant material including Spike Rush, Dudley’s Rush, Emory’s Sedge and Nebraska Sedge. Reed Canarygrass dominates the largest wetland to the south of the Longmont Diversion and there is some debate as to this plants status as a native plant. This grass has spread throughout this individual wetland area and has provided erosion control and habitat benefits. However, its spread and density has likely also reduced the spread of other native species, reducing the overall biodiversity in this one particular area. Overall, the existing wetland areas within the project limits are healthy but there is great potential for further revegetation measures and localized planting with the system.
### South St. Vrain Creek Restoration at Hall Ranch - Existing Plant List

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>National Wetland Indicator</th>
<th>Plant Type</th>
<th>Native Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panicum virgatum</strong></td>
<td>Switchgrass</td>
<td>FACW</td>
<td>grass</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Asclepias syriaca</strong></td>
<td>Milkwheat</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td><strong>Toxicodendron rydbergii</strong></td>
<td>Poison Ivy</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Cardinus nutans</strong></td>
<td>Musk Thistle</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Cistus arvensis</strong></td>
<td>Canadian Thistle</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Festuca arundinacea</strong></td>
<td>Tall Fescue</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Arctium minus</strong></td>
<td>Common Burdock (noxious weed)</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Equisetum arvense</strong></td>
<td>Canadian Horse-tail</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
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<tr>
<td><strong>Ambrosia artemisia</strong></td>
<td>Common Ragweed</td>
<td>FACU</td>
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<td>Native</td>
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<tr>
<td><strong>Helianthus annuus</strong></td>
<td>'Honey Golden Aster'</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Leptis punctata</strong></td>
<td>Blazing Star</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Solidago canadensis</strong></td>
<td>Goldenrod</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Dactylis glomerata</strong></td>
<td>Orchard Grass</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Hasperis matronalis</strong></td>
<td>Daniel's Rocket</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td><strong>Junco torreyi</strong></td>
<td>Torrey's Rush</td>
<td>FACW</td>
<td>graminoid</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Eleocharis palustris</strong></td>
<td>Spike Rush</td>
<td>OBL</td>
<td>graminoid</td>
<td>Native</td>
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<tr>
<td><strong>Junco dudleyi</strong></td>
<td>Dudley's Rush</td>
<td>FACU</td>
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<tr>
<td><strong>Junco ensifolius</strong></td>
<td>Sword leaf rush</td>
<td>FACW</td>
<td>graminoid</td>
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<tr>
<td><strong>Eupatorium ciliatum</strong></td>
<td>Fringed willow herb</td>
<td>FACW</td>
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<tr>
<td><strong>Sorghum bicolor</strong></td>
<td>Periwinkle burrgrass</td>
<td>OBL</td>
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<td>Native</td>
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<tr>
<td><strong>Carex emoryi</strong></td>
<td>Emory's sedge</td>
<td>OBL</td>
<td>sedge</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Vitis riparia</strong></td>
<td>Wild grape</td>
<td>FAC</td>
<td></td>
<td>Native</td>
</tr>
<tr>
<td><strong>Verbascum thapsus</strong></td>
<td>Mullein</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Bromus inermis</strong></td>
<td>Smooth Brome</td>
<td>FACU</td>
<td>grass</td>
<td>Non-native</td>
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<tr>
<td><strong>Lactuca serriola</strong></td>
<td>Prickly lettuce</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Melilotus officinalis</strong></td>
<td>Sweet Clover</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td><strong>Elymus lanceolatus</strong></td>
<td>Threepspike wheatgrass</td>
<td>UPL</td>
<td>grass</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Elymus trachycaulus</strong></td>
<td>Slender wheatgrass</td>
<td>FACU</td>
<td>grass</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Elymuselticus</strong></td>
<td>Wildyewrathgrass</td>
<td>FACU</td>
<td>grass</td>
<td>Native</td>
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<td><strong>Amarervas canescens</strong></td>
<td>Ladleplant amphi</td>
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<td><strong>Astragalus glycyphyllus</strong></td>
<td>Wild licorice</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td><strong>Rabbi pinnata</strong></td>
<td>Yellow coneflower</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td><strong>Sametia carinata</strong></td>
<td>Catnip</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
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<tr>
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<td>Sunflower</td>
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<td>forb</td>
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<tr>
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<td>FACU</td>
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<td><strong>Veronica angustifolia</strong></td>
<td>Speedwell</td>
<td>OBL</td>
<td>forb</td>
<td>Native</td>
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<tr>
<td><strong>Glycera grandis</strong></td>
<td>American menanggrass</td>
<td>OBL</td>
<td>graminoid</td>
<td>Native</td>
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<td>St. John's Wort</td>
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<tr>
<td><strong>Rumex crispus</strong></td>
<td>Curly dock</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Verbenas officinalis</strong></td>
<td>Blue verbenas</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Primula vulgaris</strong></td>
<td>Primrose</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Carex nebrascensis</strong></td>
<td>Nebraska Sedge</td>
<td>OBL</td>
<td>graminoid</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Liriope muiri</strong></td>
<td>False-dyed Grass</td>
<td>UPL</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Salvia pratensis</strong></td>
<td>Russian thistle</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Junco torreyi</strong></td>
<td>Arctic rush</td>
<td>FACW</td>
<td>graminoid</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Hippuris vulgaris</strong></td>
<td>Mare's tail</td>
<td>OBL</td>
<td>forb</td>
<td>Native</td>
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<tr>
<td><strong>Oxalis oregona</strong></td>
<td>Gum wood</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Dacrycrinium cuneatum</strong></td>
<td>Delphinium</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Eriogona nauseosa</strong></td>
<td>Rabbitbrush</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
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<tr>
<td><strong>Punica virginiana</strong></td>
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<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Salvia exigua</strong></td>
<td>Coyote Willow</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Rosa woodii</strong></td>
<td>Woods rose</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Asparagus officinalis</strong></td>
<td>Wild asparagus</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Populus angustifolia</strong></td>
<td>Narrow leaf cotton woods</td>
<td>FACW</td>
<td>tree</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Populus deltoides</strong></td>
<td>PInns cottonwoods</td>
<td>FACW</td>
<td>tree</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Ptelea triandra</strong></td>
<td>Three leaf sumac</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Malus domestica</strong></td>
<td>Apple tree</td>
<td>FACU</td>
<td>tree</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>Ptelea argenta</strong></td>
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<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Gledias triasactina</strong></td>
<td>Honey locust</td>
<td>FACU</td>
<td>tree</td>
<td>Non-native</td>
</tr>
<tr>
<td><strong>Symphyotrichum alpinus</strong></td>
<td>Snowberry</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td><strong>Platanus occidentalis</strong></td>
<td>Canopy weed grass</td>
<td>FACW</td>
<td>graminoid</td>
<td>Native</td>
</tr>
</tbody>
</table>

**Figure 3. Existing Plant List**
d. Photo Documentation

Photo documentation of the entire 3.2 mile project extents was very extensive. There have been over 400 photos acquired of the site. The majority of these photos were geo-tagged in a KMZ file so that they could be viewed spatially with a map viewer like Google Earth. Due to the sheer volume of photos and the digital aspect of a KMZ files, these will be included in a digital submittal as part of this report. Below are a few pictures of pertinent locations throughout the corridor moving from upstream in the canyon downstream. Pre-flood aerials dating back to 1940 were also acquired to evaluate changes in the historical alignments.

![Figure 4. Upstream in Canyon](image-url)
Figure 5. Downstream of Canyon

Figure 6. Upstream Overflow Channel
Figure 7. Andesite Quarry

Figure 8. Damaged Old St Vrain Road
Figure 9. NRCS Work on Hall Property

Figure 10. Post Flood Work at "Plug"
Figure 11. Existing Rootwad Protection at Hwy 7

Figure 12. Meadows/S. Ledge Diversion
Figure 13. Overflow Channel

Figure 14. Longmont Diversion Post-Flood Work
e. Base Map Development

The base map developed as part of this project included combining drawings and designs along with topography and utilities from multiple sources. The base map is in NAD 83 State Plan North Coordinate System. Topographic aspects were compiled with the use of ground survey from multiple sources and pasted into a LiDAR aerial survey performed in 2014. Areas of existing vegetation and wetland areas were also mapped in the EWP areas and added to the base mapping. Base mapping also included aerials for 1940, 2004, 2005, 2006, 2009, 2011.

All design aspects from previous or existing projects were on NAD83 State Plane North except for the Old St Vrain Road Bridge drawing that was Modified State Plane, but was scaled back to State Plane for this project. Aspects from the St Vrain Creek Master Plan were also included with our base mapping to holistically move from high level planning to more refined designs and recommendations. Below are the design drawings that were compiled as part of our base mapping.

- South St Vrain Pipeline 2013 Flood Repair
- Hall Ranch 2 Road Repair and Hazard Mitigation
- Meadows & South Ledge Ditch Final Reconstruction Plan
- Old St Vrain Road Bridge

The base maps also included features supplied by BCPOS thought Boulder County GIS Department. The elements supplied from BCPOS were:

- Vegetation Outlines
- Bridge Locations
- Culvert Locations
- Ditch and Irrigation Features
- Fence Lines
f. Site Inspection and Documentation
   i. Existing and Proposed Flood-Related Projects
      Throughout our 3.2 mile project extents there are two existing flood recovery projects and two proposed flood recovery projects. The existing flood-related projects are the Meadow and South Ledge Ditch Diversion Reconstruction and Fish Passage Demonstration Project and the City of Longmont’s South St Vrain Pipeline 2013 Repair project. The proposed flood-related projects are the Old St. Vrain Road Bridge (Andesite Bridge) project and the Hall Ranch 2 Road Repair and Hazard Mitigation project.

Meadow and South Ledge Ditch Diversion Reconstruction and Fish Passage Demonstration Project
The Meadows and South Ledge Diversion Project was developed to combine two diversion structures that were damaged in the flood at one location, including providing fish passage beyond these diversions. This project was completed by Crane Associates in the Spring of 2015 with a design report released in the Fall of 2015. Coordination with both the engineer and the ditch companies have taken place as part of this project. Understanding that the main channel alignment through this section of the reach must stay in its current configuration in order to allow the ditch companies to divert water is paramount.

Coordination efforts with the ditch company and other residents in the area have brought to our attention that sediment aggradation in the diversion structure itself is currently taking place and is of concern and that recommendations should be provided to alleviate or reduce the sediment being trapped in this diversion. The trapped sediment in this diversion cannot easily be removed from the diversion structure due to the fact the sediment sluice is located at the upstream end of the diversion structure so that the sediment cannot be removed with use of the sluice. The diversion then leads to a pipeline that has an engineered sag where it crosses an overflow channel near Old St Vrain Road. There is concern that the sediment is accumulating in this sag location and could cause the pipeline to become clogged.

South St Vrain Pipeline 2013 Repair
The City of Longmont has a cross channel diversion structure located near the downstream extents of our project that was damaged. During the flood the right abutment of the diversion was scoured and damaged the pipeline that conveys water away from the diversion. The diversion itself was not damaged. The post flood repairs consisted of repairing the damaged section of pipeline and installing sections of new pipeline from the diversion towards the northwest to tie into existing undamaged sections of pipeline along the Old St Vrain Road. The installation of the new pipeline also including installing a couple new manholes and also a flow control structure with another small pipeline that could convey flow back to the river. The existing pipeline was also repaired where it crosses underneath the South St Vrain Creek at the bridge on the Old St Vrain Road where it connects back into Highway 7.
From interviews with the City of Longmont and the residents it was determined that a grouted sloping drop structure was planned for the downstream area of this diversion. The sloping drop structure would have provided additional safety from the low head dam while also increasing fish passage along this reach. The sloping drop was required to be removed when about 50% complete by the Corp of Engineers due to a permitting issue.

**Hall Ranch 2 Road Repair and Hazard Mitigation**

Downstream of the andesite Quarry the Old St Vrain Road a small section of the road was washed away during the 2013 flood. This road is the only access point to the quarry and is currently being designed by BCPOS. The road is directly up against bedrock at this location and the South St Vrain Creek has a tight bend against the road here. In the flood the creek washed out the road until it hit the bedrock control.

The plans for this area are to rebuild the road in the same location. Grading for the embankment of the road will cause minor realignment of the creek back to its pre-flood location. Bank stabilization measures including soil riprap, willow staking and boulder toe protection will be emplaced along the road embankment. A floodplain bench will be graded in along the inside of the bend as allowable by existing vegetation.

**Old St. Vrain Road Bridge (Andesite Bridge)**

Downstream of the Hall Ranch 2 Road Repairs and the Andesite Quarry is a location where a bridge was washed out during the 2013 flood. This bridge is known as the Andesite Bridge. This bridge connects Old St Vrain Road back to Highway 7. BCPOS is currently in the process of designing a new bridge with JUB and Anderson Consulting Engineers. The new bridge will be a single span bridge and increase the conveyance capacity compared to the previous bridge. The proposed bridge will pass the new 50 year storm event, but be overtopped during the 100 year event.

Project coordination has taken place between our Design Team and the bridge consultants to ensure a holistic design between the two projects. Design elements including potential floodplain culverts, bank shaping, bank toe protection and revegetation were provided to the bridge consultants based upon our Teams evaluations. It was determined that floodplain culverts at this location provided little added relief to the bridge during the 100 year storm event. Proposed channel dimensions developed by our team have been included in their design.

**ii. Existing and Proposed Non-Flood Related Projects**

**Andesite Quarry**

The Andesite Quarry is currently in the process of submitting their revised reclamation plans to the state for review. Coordination with the Andesite Quarry owners, Aggregate Industries, has taken place to inform them of the proposed design our team as developed through this area. For the purposes of our design it is assumed that the toe to the mining area will remain at the same location with modifications to the existing quarry slopes along with cleanup and revegetation of the floodplain area in vicinity of the quarry.
g. Soils Mapping
The NRCS Web Soil Survey was used to determine various soil types and hydrologic groups. The majority of the area within the river corridor for our project is considered Niwot soils. Niwot soils are considered part of the hydrologic soil group B with ecological site condition as a wet meadow. The depth to the water table for the Niwot soils group is about 18 to 36 inches. Information with regard to the NRCS soils investigations has to be evaluated cautiously due to the fact we know that the flood deposited large amounts of sediment through this reach.

h. Field Sediment Sampling
Field sediment sampling took place in two different forms. The first aspect was actual in-situ bed load and suspended sediment sampling that occurred using at the downstream end of our project during average bankfull flows. The second source of field sediment sampling took place with bed and bank sampling and pebble counts throughout multiple locations of our project.

i. In-situ Bed Load and Suspended Sediment Sampling

On June 14, 2016 sediment transport and discharge measurements were made on South St. Vrain Creek near the Old St Vrain Road Bridge to estimate the bedload and suspended sediment transport rates near bankfull flow conditions. Two bedload measurements were taken; one from 6 to 7 am and the other from 8 to 9 am, by using a six-inch Helly-Smith sampler suspended from a truck mounted crane off the bridge. Each sample consisted of 10 equally spaced verticals across the bridge span, sampling at two minutes per vertical. Samples from the ten verticals were aggregated in a heavy-duty plastic bag, labeled, and taken back to the laboratory for analysis. A suspended sediment sample was taken after each bedload sample using a depth-integrating DH-59 sampler to collect approximately 300 ml of water from 3 verticals (100 ml/vertical). Standard laboratory methods were used to analyze both the bedload (organics removal, oven drying and sieving) and suspended sediment (filtration, oven drying and sand/wash load fraction determination). A summary of the laboratory analysis is presented in Appendix X.

A single discharge measurement was taken between 10 am and 10:50 am on June 14, 2016 just upstream from the bridge at a location that was conducive to wading. Stretching a tape perpendicular to the flow from the left to right bank, measurements were made at 24 verticals using a top-setting wading rod, a Price AA current meter and Model 3000 Swoffer data logger. Using the standard USGS incremental width methodology to calculate flow, the measured discharge was 355 ft³/s. A summary of the discharge measurement is presented in Appendix X.

Analysis

Figure 1 shows the June 2016 hydrographs for 3 stream gages in the St Vrain system, as well as the timing for the measured sediment and discharge samples on June 14th. Bankfull discharge is estimated to be 450 ft³/s and based on our discharge measurement, the lag to the St Vrain stream gage in Lyons (SVCLYOCO) and the North St Vrain gage below Button Rock Reservoir (NSVBBRCCO), the discharges at the bridge during the sediment samples are estimated to be 437 ft³/s and 411 ft³/s, respectively. We will assume, with the natural variability in sediment transport rates, these measurements were taken close enough to bankfull discharge to average the two samples. The estimated bankfull bedload transport rate is 0.5813 kg/s and the estimated bankfull suspended sediment concentration is 122.28 mg/l (sand fraction, only).
To get an estimate of average annual sediment yield, we can use the dimensionless sediment transport rating curves developed by Rosgen (2006) and the bankfull sediment transport estimates and apply them to a hydrograph or flow duration curve. While there is no current stream gage on South St. Vrain Creek in the vicinity of our study, the USGS did operate a stream gage for four water years (1977-1980: USGS Gage No. 06723400) that was located within a few hundred feet of where we took our June 14th discharge measurement (Figure 2). Though the gage was operated for only a short period of the time, the flows it measured represent a reasonable range of discharges from wet and dry years (Figure 3) and I would rather use flows measured at that location than scale flows from other nearby gages that perhaps would not reflect the operational hydrology and flow regulation that influences the South St. Vrain Creek hydrograph.

To estimate sediment yield using the four years of South St Vrain Gage data, I divided seasonal daily mean flow (Q) values (April 1 to September 30) by the bankfull value 450 ft3/s (Qb). Seasonal flow values were used because very little if any sediment is being transported by the low flows from October 1 to March 31 (Figure 2). Using four dimensionless sediment transport equations (Rosgen 2006), I calculated dimensionless sediment transport value for each seasonal daily mean flow in the period of record based on sediment type and stream channel stability. Multiplying each dimensionless sediment transport value by the bankfull estimate, converting units from kg/s or mg/l to tons/day, summing all dates and dividing 4 (4 years in the period of record) provides an estimate of average annual sediment in South St. Vrain Creek (Table1).

- Equation 1. Dimensionless Bedload (Good/Fair) = -0.0113+1.0139(Q/Qb)2.1929
- Equation 2. Dimensionless Bedload (Poor) = 0.0718+1.0218(Q/Qb)2.3772
- Equation 3. Dimensionless Suspended (Good/Fair) = 0.0636+0.9326(Q/Qb)2.4085
- Equation 4. Dimensionless Suspended (Poor) = 0.0989+0.9213(Q/Qb)3.659

The Good/Fair and Poor designations refer to stream channel stability ratings, which pre-flood would have been Good/Fair for the majority of the reach while post-flood is dominated by Poor sections. Comparing sediment transport by channel stability is both an indication how much more sediment is being transported post-disturbance but also of the potential to reduce downstream sediment delivery by properly stabilizing and restoring sections of the river generating the excess sediment from bed and banks. Because the dimensionless sediment transport equations are based on measured data, as are the South St. Vrain Creek bankfull sediment values, the resulting estimates of sediment yield should be reasonable values.

<table>
<thead>
<tr>
<th></th>
<th>Average Annual Sediment Yield (Tons)</th>
<th></th>
<th></th>
</tr>
</thead>
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<tr>
<td></td>
<td>Bedload</td>
<td>Suspended (sand) Load</td>
<td>Total</td>
</tr>
<tr>
<td>Good/Fair</td>
<td>1185</td>
<td>3045</td>
<td>4230</td>
</tr>
<tr>
<td>Poor</td>
<td>1935</td>
<td>3677</td>
<td>5613</td>
</tr>
<tr>
<td>Difference</td>
<td>750</td>
<td>632</td>
<td>1383</td>
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<tr>
<td>Percent Difference</td>
<td>63.3%</td>
<td>20.8%</td>
<td>32.7%</td>
</tr>
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</table>

Table 1. Summary of Average Annual Sediment Yield
ii. **Bed and Bank Sediment Sampling**

During the geomorphic site assessments, reach-representative locations were determined for pebble counts in all eight reaches, including several overflow channel locations. These pebble count data provide quantitative comparisons of bed material size longitudinally through a reach as well as among reaches. They are also used as inputs for the sediment transport capacity modeling and design calculations discussed below.

Sediment Sampling location map is included in Appendix X and shows the locations of the pebble counts, and the sediment gradation results are presented in **Error! Reference source not found.** and **Error! Reference source not found.**. The median bed material size found along the project reach ranges from coarse gravel to small cobble. The shape of the sediment gradation curves are fairly similar for most of the main channel locations, with the exception of the sediment sample collected in Reach 5 (PB5), where there is a lack of the smaller material (D10 is 41, compared to the other reaches with D10 of less than 10), and the sediment samples collected in Reach 2 (PB2-2) and Reach 7 (PB7) where the upper range of the gradation includes smaller material than other reaches.

### Table 2. South St Vrain Sediment Gradation Summary

<table>
<thead>
<tr>
<th>SSVCR Reach (Expanded Study Reach #)</th>
<th>R1 (SSV-03)</th>
<th>R2 (SSV-04)</th>
<th>R3 (SSV-05)</th>
<th>R4 (SSV-06)</th>
<th>R5 (SSV-07)</th>
<th>R6 (SSV-08)</th>
<th>R7 (SSV-09)</th>
<th>R8 (SSV-10)</th>
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<tbody>
<tr>
<td>Sample ID</td>
<td>dstrm</td>
<td>upstrm</td>
<td>ofc</td>
<td>dstrm</td>
<td>upstrm</td>
<td>ofc</td>
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<td>D10</td>
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<td>6.9</td>
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<tr>
<td>D25</td>
<td>56</td>
<td>25</td>
<td>30</td>
<td>21</td>
<td>49</td>
<td>19</td>
<td>79</td>
<td>39</td>
</tr>
<tr>
<td>D50</td>
<td>101</td>
<td>44</td>
<td>64</td>
<td>81</td>
<td>85</td>
<td>64</td>
<td>115</td>
<td>86</td>
</tr>
<tr>
<td>D75</td>
<td>153</td>
<td>81</td>
<td>115</td>
<td>119</td>
<td>141</td>
<td>109</td>
<td>167</td>
<td>129</td>
</tr>
<tr>
<td>D84</td>
<td>185</td>
<td>101</td>
<td>149</td>
<td>139</td>
<td>171</td>
<td>133</td>
<td>207</td>
<td>174</td>
</tr>
<tr>
<td>D90</td>
<td>218</td>
<td>121</td>
<td>176</td>
<td>162</td>
<td>252</td>
<td>189</td>
<td>250</td>
<td>221</td>
</tr>
<tr>
<td>D_MAX</td>
<td>1024</td>
<td>250</td>
<td>370</td>
<td>370</td>
<td>730</td>
<td>350</td>
<td>660</td>
<td>600</td>
</tr>
</tbody>
</table>


7. Hydrology/Hydraulics Data
   a. Hydrology

   Hydrology as part of this project was evaluated from multiple different sources. Existing hydrology for the project area was validated to verify accurateness of channel forming hydrology and ascertain flood hydrology for this project area. In this section the data sources will be discussed and recommendations for channel forming and flood hydrology are developed.

   Several floods have been noted in the project area. In Crane Associates design report for the Meadows and South Ledge Diversion project it noted that 10 notable floods have occurred in the past 150 years on St Vrain Creek (Crane, 2015). The largest peak discharge on record prior to the September 2013 flood was 10,500 cfs in June 1941, which mainly originated on South St. Vrain Creek with a very rapid rising and falling of floodwaters. It is assumed that an very localized cloudburst occurring over South St. Vrain Creek just upstream of Lyons caused this event (FEMA, 2012). The preliminary peak discharges estimated on the South St Vrain Creek as a result of the September 2013 flood is 8,886 cfs above the confluence with the North St Vrain Creek (Jacobs, 2014)
i. **FEMA: Flood Insurance Study**

The effective Flood Insurance Study (FIS) for Boulder County was revised and made effective on December 18, 2012. This FIS data was found in the CDOT Hydrologic Evaluation of the St. Vrain Watershed, Post September 2013 Flood Event (Jacobs, 2014). The hydrologic and hydraulic analyses for the unincorporated areas of Boulder County, including the South St. Vrain Creek watershed, were completed by the U.S. Soil Conservation Service (SCS) in August 1974. These records were analyzed using a log-Pearson Type II analysis of peak runoff recorded at gages on St. Vrain Creek near Lyons in accordance with U.S. Water Resources Council Bulletin 15. Subsequent hydrologic and hydraulic analyses were prepared for the Town of Lyons by Howard, Needles, Tammen & Bergendorff in October 1977. These updated discharge-frequency relationships in the St. Vrain Creek basin were generated with data from the June 1972 and September 1972 Floodplain Information Reports, by the U.S. Army Corps of Engineers. This report was based on an updated statistical analysis of gages on the St. Vrain Creek at Lyons. Synthetic unit hydrographs were developed for the South St. Vrain Creek, as a sub-basin of the St. Vrain Creek basin.

<table>
<thead>
<tr>
<th>Design Point</th>
<th>Drainage Area [sq mi]</th>
<th>Design Storm Hydrology [cfs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMA FIS</td>
<td>92</td>
<td>10 Year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 Year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 Year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500 Year</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>0.2%</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: FIS Study**

ii. **Blue Mountain Consultants: Geomorphic Indicators Paired with Discharges**

Blue Mountain Consultants conducted a study to establish bankfull conveyance of the South St. Vrain Creek using geomorphic indicators surveyed by the United States Forest Service (USFS) in 1988. By pairing the survey data with flow conditions taken by the USFS in 1990, bankfull capacity can be calculated. Table 3 summarizes the calculated flow for a return period of 1.5 years.

<table>
<thead>
<tr>
<th>Design Point</th>
<th>Drainage Area [sq mi]</th>
<th>Design Storm Hydrology 1.5 Year [cfs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMC LLC. - USFS</td>
<td>83</td>
<td>450</td>
</tr>
</tbody>
</table>

**Table 4. BMC LLC./USFS Bankfull Hydrology**

iii. **CDOT Hydrologic Evaluation of the St Vrain Creek Watershed**

A study on the St. Vrain Creek watershed was prepared by Jacobs in 2014 for Colorado Department of Transportation (CDOT) to ascertain the approximate magnitude of the September 2013 flood event and to prepare estimates of peak discharges associated with various return periods. The St. Vrain Creek is the receiving body of the South St. Vrain Creek. South St. Vrain Creek is considered part of the St. Vrain Creek watershed, therefore hydrology calculations were performed on the South St. Vrain Creek sub basin.
The total watershed was divided into 59 basins, ranging in size from 0.25 square miles to 10 square miles. In order to compare the peak discharge estimates at investigation sites to the calibrated model, basins were manually subdivided. There were two investigation sites on the South St. Vrain Creek: below Middle St. Vrain Creek and above the Town of Lyons.

This study was performed using the HEC-GeoHMS and HEC-HMS software platforms. Spatial data was acquired from USGS and used to delineate and characterize watersheds. Runoff parameters and lag times were computed and applied to the Snyder Unit Hydrograph to determine peak flow measurements.

Once the watersheds physical characteristics were initially modeled, they were calibrated based upon observed flows from high water marks. Initially, Button Rock Dam was modeled as a simple junction with no runoff storage or attenuation. During the calibration process the stage-storage-discharge relationship for Button Rock Dam was incorporated.

Calibration efforts were being conducted concurrently in the Big Thompson River Watershed, adjacent and to the north of the St. Vrain Creek Watershed. U.S. Bureau of Reclamation provided a stage-storage relationship for Lake Estes, along with stage-storage-discharge time-series data during the 2013 Flood Event. This allowed for better calibration and optimization routines based upon the Lake Estes inflow hydrograph.

South St. Vrain Creek experienced significant rainfall totals and intensities within the study area. The average 24 hour rainfall depth experienced during the September event was greater than a 100 year storm. The graphic on the following page produced by NOAA displays the annual exceedance probabilities for the heaviest rainfall over a 7-day period.

Table 4 outlines the estimated September event and various design storms for South St. Vrain Creek watershed developed for the CDOT study. The estimated September event flow was based upon the maximum rainfall that occurred over the ten day event. This value was then used to calibrate the hydrological model to develop a typical 24 hour NOAA storm. An area rainfall reduction was not performed on South St. Vrain Creek in this study due to the relative magnitude of the event that happened.

<table>
<thead>
<tr>
<th>Design Point</th>
<th>Drainage Area [sq mi]</th>
<th>10 Year 10% [cfs]</th>
<th>25 Year 4% [cfs]</th>
<th>50 Year 2% [cfs]</th>
<th>100 Year 1% [cfs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>South St. Vrain Creek above confluence with North St Vrain Creek</td>
<td>91.27</td>
<td>1,605</td>
<td>3,168</td>
<td>4,933</td>
<td>7,234</td>
</tr>
</tbody>
</table>

iv. **St Vrain Creek Channel Flood Recovery Design-Build Services**

The St Vrain Creek Channel Flood Recovery Design-Build Services report was developed by Otak, S20 Design and Engineering and others for the Town of Lyons following the September 2013 flood. The purpose of this study was to repair flood damage and increase resiliency for reduced damage during future flood events (Otak 2016). This report was determined to be the most in-depth report for determining channel forming hydrology including base flow, Q1, Q1.5, Q2, and Q5 recurrence interval hydrology.
Since adequate gage date is not available on the South St Vrain Creek base flows were scaled based upon drainage area from the St Vrain Creek calculated discharges (Otak, 2016). The equation below used $A$ as the watershed area and $C$ as a constant to determine $Q_P$ the peak discharge. The constant, $C$, was calculated from the mainstem results for each return period and the base flow. The corresponding discharge for the North and South St. Vrain creeks was then calculated using the watershed area and the constant.

$$Q_P = C \sqrt{A}$$

Peak discharges on the mainstem of the St Vrain Creek were calculated using Log-Pearson Type III distribution (USGS, 1982) to statistically assess the annual instantaneous peak discharges from 1895 to 2013 (Otak, 2016). The assessment evaluated $Q_1$, $Q_{1.5}$, $Q_2$, and $Q_5$ return period flows. For this analysis the three highest discharges (2013-23,800 cfs; 1941-10,500 cfs; 1919-9,400 cfs) were removed from the dataset since they were produced by rainstorm events rather than the annual peak snowmelts and are therefore part of different hydrologic datasets. The data was then statistically fit to the Log-Pearson Type III distribution and the return period discharges were calculated. The results of the Log-Pearson Type III analysis were compared to StreamStats (USGS, 2016) results to provide an order-of-magnitude verification of the results.

Below are the results of the analysis from this report.

<table>
<thead>
<tr>
<th>Design Point</th>
<th>Design Storm Hydrology (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q Base</td>
</tr>
<tr>
<td>South St Vrain Creek at the Confluence</td>
<td>25</td>
</tr>
</tbody>
</table>

v. **Hydrology Summary**

In summary the hydrology for this study will be used from the CDOT Hydrologic Evaluation of the St Vrain Creek Watershed for the less frequent recurrence intervals along with floodplain analysis while the St Vrain Creek Channel Flood Recovery Design-Build Services will be used to set the channel forming hydrology along with the more frequent recurrence interval flows.
b. Preliminary Models

i. 1D HEC-RAS Models (No Rise Analysis)

A preliminary existing and proposed conditions hydraulic analysis was completed using HEC-RAS v4.1.0 computer software to determine flow depths and velocities across the range of flow rates established by the hydrologic analysis. This evaluation was also completed to show a no rise in base flood elevations when existing and proposed conditions are compared. Water surfaces generated from these analysis were generated in AutoCAD to determine various design parameters and overflow channel inverts.

Evaluation Parameters

Discussions with the floodplain management department at Boulder County help to set the base evaluation parameters for a no rise evaluation. The Effective FIS study was determined inaccurate due to the widespread changes in the channel topography coupled with the increase in hydrologic evaluations. It was determined that existing topography from post flood evaluations would be used for the existing conditions cross sections and that the hydrology developed as part of the CDOT Hydrologic Evaluation of the St Vrain Creek Watershed would be used to set the 100 year hydrology, 7,234 cfs. This approach is in line with the direction provided by the CWCB in the Guidance for Hydrology and Hydraulic Modeling memo (CWCB, 2014)

Existing Conditions Model

The existing conditions model developed for the St Vrain Creek Channel Flood Recovery Design-Build Services project was built upon to ensure coordination with downstream projects. Newly acquired surveyed cross section topography from this project was used to supplement existing information in the HEC-RAS model to better represent the creek corridor. These new cross sections were used to define the channel parameters more accurately in our existing topography surface as discussed in the Base Map section previously.

The existing model had to be extended further upstream to include the entire 3.2 mile reach with an addition of nine new cross sections. Additionally a few of the existing cross sections from the model had to be reevaluated or lengthened to better represent the hydraulic conditions and encompass the entire floodplain extents.

Cross-sections were developed off this existing conditions topography at critical points along the alignment and approximately every 250 feet. There were 145 cross sections developed along the 3.2 miles to represent and evaluate the hydraulic conditions. Channel roughness coefficients (Manning’s n) were initially estimated based upon the river channel bed material and comparison to published USGS verified roughness characteristics of natural channels. In multiple locations ineffective flow areas had to be developed due to the numerous overflow channels still existing in the corridor.

A final range of estimated Manning’s n values were used in the hydraulic analysis. A Manning’s of 0.045 was used to for the channel to reflect the gavel and cobble channel bed, steep gradient of the study and meandering plan form. A Manning’s of 0.06 was used for the overbank areas to reflect scattered trees and brush. A Manning’s of 0.02 was used in locations were Highway 7 is inundated to represent an asphalt road.
The reach currently only has one structure located at the downstream extends of our project, which is a bridge for the Old St Vrain Road where it connects to Highway 7. Due to the fact there are two proposed projects to take place between the writing of this report and the construction of proposed elements under this plan, these project aspects were included in the existing conditions model. These two projects included reconstruction of the Old St Vrain Road as part of the Hall Ranch 2 Road Repair and Hazard Mitigation and the reconstruction of a bridge through the Old St Vrain Road Bridge project. Design plans from each of these projects were evaluated and developed into the existing conditions model.

The downstream hydraulic control for the HEC-RAS model was determined by a normal depth calculation with an average channel slope of 1.2%.

**Proposed Conditions Model**

A preliminary proposed conditions model was developed as part of this project and built off of the existing conditions model. This model was used to evaluate the change in base flood elevations based upon proposed conditions. Existing channel cross sections were replaced with proposed channel cross section and analyzed in HEC-RAS. Multiple iterations were developed in order to show a no rise condition through the proposed project work zone. Proposed changes in grading and alignment had to be modified in order to meet no rise in base flood elevations.

(To Do: Proposed Conditions Model Evaluation and EWP Specific No-Rise Evaluation)

**Comparison of Models**

Once both the existing and proposed conditions model were developed evaluations took place to ensure a no rise in the base flood elevation from the proposed work throughout the corridor.

(To Do: Compared existing conditions model to proposed conditions model)

**2D SRH Models**

South St. Vrain Creek has many areas where overbank flows, at high discharges, can have many complex flow paths across the floodplain. Accounting for these flow complexities in modeling efforts is crucial for design initiatives. Considering the limitations of one-dimensional (1-D) hydraulic modeling in capturing complex overbank flow characteristics, two-dimensional 2-D models were developed. 2-D models compute transverse variations in water-surface elevations (WSE), velocities and momentum that are not captured in 1-D models. The results from a 2-D model are therefore much more comprehensive at defining hydraulic conditions in a complex hydraulic setting such as the South St. Vrain.

The SRH-2D hydraulic model produced by Yong G. Lai of the Bureau of Reclamation in SMS 12.1.6 was selected for the 2-D modeling of the Project Area. This program was selected for the powerful mesh creation capabilities of SMS and the stable computational engine that has been developed over three versions of the SRH-2D model.
Model Set-Up

A terrain model of the entire South St. Vrain was imported into SMS to develop the 2-D hydraulic model. All elevation data was extracted from this terrain to produce the mesh and for flow computations. Mesh generation began by defining the boundaries or breaklines of important features in the terrain. A combination of the hillshade terrain model and overlaid aerial imagery was utilized to delineate channel/side channel boundaries, floodplains, and roads. The mesh was developed using the paving mesh type which uses triangular mesh elements between nodes. The mesh was inspected to meet details needed to capture in-channel variations and have quality non-regular shaped mesh elements.

The boundary conditions for the 2-D model were set for the upstream and downstream edge of the mesh. An inlet-discharge time series curve was generated for the upstream boundary condition. The discharge is ramped up by doubling every half an hour of simulation until it reaches the design discharge of interest, and is then held constant. A rating curve of WSE versus discharge was chosen for the downstream boundary condition. The rating curve was derived from a pre-existing 1-D HEC-RAS model that had WSE info for each design discharge tested in the model. The cross section that aligned with the downstream boundary was selected to extract the rating curve.

The areas delineated in the mesh generation process for the stream boundary, floodplain, and roads were used to assign roughness characteristics to be used in the 2-D computations. A Manning’s n value of 0.035, 0.05, and 0.025 were selected for the stream, floodplain, and road roughness characteristics respectively.

Model results have been computed for the Q_{1.5}, Q_2, and Q_5 design discharges for at least 10 hours of simulation to reach a steady state solution for analysis.

Stream Power

Stream power is a measure of the stream’s ability to work the bed and banks. Calculation of this metric (product of the specific weight of water, discharge, and slope, per unit channel length) provides relative information about the magnitude of work a particular flow is capable of exerting on the channel and floodplain. Unit stream power (stream power per unit channel width) will be calculated using the SRH model.

(To Do: Analysis is currently in progress and section will be updated)

c. Results
(To Do: Analysis is currently in progress and section will be updated)

d. Supporting Electronic Files

Supporting electronic files in the form of CAD drawings along with HEC-RAS project files have been included in a CD or USB for further use.
8. Geomorphology

The geomorphic assessment is based on the River Styles stream classification methodology (Brierley and Fryirs, 2005). The goal of the method is to identify the dominant controls and spatial extent of behavior of the stream channel and floodplain in response to floods and over time following the 2013 flood. The primary product from this task was a reach-specific stream evolution model (SEM) that was used to guide field sampling and provide context for the sediment transport study. Bed mobility and sediment transport modeling were also conducted in conjunction with the geomorphic assessment and classification. Results from this analysis helped to inform reach-scale geomorphic stability and trajectories, as well as site-specific restoration strategies.

a. Available Data

Planform and profile analysis and a planning-level channel migration zone (pCMZ) delineation were performed as part of the St. Vrain Creek Watershed Master Plan (Baker, 2014). South St. Vrain Creek displayed some variations in planform between 1949 and 2013 (pre-flood) for the majority of the project area, but between pre- and post-flood, large-scale variations in planform were witnessed, specifically the numerous avulsions that occurred throughout the project reach. Brief descriptions of the rapid geomorphic assessment and pCMZ mapping for the reaches applicable to this project are presented below.

The process diagram showing in Figure 17. (Otak, 2016) is a useful tool for aligning reach and landscape scale geomorphic variables. The diagram shows the longitudinal (i.e., downstream) progression of dominant channel process variables. At the landscape scale, the portion of the South St. Vrain covered in this project is located in alluvial valleys, with the Town of Lyons at the downstream end of the project sitting on an alluvial fan (Reach 1, SSV-02 and SSV-01 in the process diagram). Alluvial valleys and fans are areas where rapid reduction in downstream channel gradient causes the channel to deposit its sediment load and frequently shift its alignment. Over time, the position of the channel will vary vertically and horizontally across the valley, without preference for any particular location – the channel is merely adjusting to the incoming discharge and sediment load. These landforms, in more natural states, serve the function of moderating the sediment loads to downstream reaches (Cluer and Thorne, 2013). As the high energy canyon environment transitions to lower gradient alluvial valleys, South St. Vrain creek deposits its bed load, building the floodplains upon which the Town of Lyons was constructed. Much of South St Vrain Creek has been pushed into a simplified single thread channel, with limited floodplain connection, in order to armor property and re-purpose floodplain for various land uses. The unfortunate side effect is that sediment loads transmitted downstream are increased, translating the disturbance downstream and overwhelming the capacity of the lower gradient floodplains and channels. The natural behavior of this environment was observed throughout the 2013 flood by rapid channel expansion, avulsion, and significant sediment deposition.
Figure 17. South St. Vrain Creek Geomorphic Process Diagram (Otak, 2016)
At the mouth of the canyon just upstream of the Andesite Quarry the valley slope significantly flattens, the channel becomes unconfined and the South St Vrain becomes a highly depositional gravel- and cobble-dominated, pool-riffle channel. During the flood, this segment demonstrated a propensity for braiding and lateral meander migration during floods. Alteration of the corridor and response to these depositional features has resulted in channel dredging, straightening, and berming into and through the Town of Lyons where South St. Vrain joins with the North St. Vrain Creek. However, many of these channel alterations were eliminated or substantially altered as a result of the flood.

The pCMZ mapping included a much wider modern valley bottom (MVB) at the mouth of the South St. Vrain Canyon, compared to the canyon reaches upstream, to encompass the large depositional area (also identified as an avulsion hazard zone [AVZ]) which runs through the Town of Lyons, where historical and recent channel braiding is common.

In general, the South St. Vrain Creek flows from the southwest to the northeast, and passed through the more gently sloping sandstone escarpments of the South St. Vrain foothills. Development within the floodplain includes numerous diversions, irrigated pastures, low density residential structures, roads, bridges, and a rock quarry. The historic (pre-flood) morphology of South St. Vrain Creek in the project area was a meandering, single-thread channel with alternating pool/riffle sequences and occasional bedrock outcrops. The river channel had a wide, relatively flat, floodplain through the majority of this reach, and the river banks were composed of coarse alluvium, had dense riparian vegetation, and experienced relatively infrequent encroachment from engineered structures.

The post-flood channel morphology of South St. Vrain Creek in the project area is quasi-braided due to the formation of numerous islands and bars during the flood. Pool/riffle sequences are still present, but their spacing and arrangements have been minimized. The sinuosity of the channel remained unchanged but the meander planform had changed drastically at several locations throughout the reach. Channel avulsions were common, and numerous secondary and tertiary channels were established, sometimes abandoning the primary channel all together. The active channel and floodplain are both considerably wider than before, and many of the dense riparian zones have been completely eliminated.

Extensive in-channel work was performed following the flood, primarily in an effort to stabilize and repair State Highway 7 (CO-7) and to restore the previous channel form and stability, land use, and infrastructure. This work included in-channel and bank grading activities (including moving main channel flow back to pre-flood alignment in many locations), installation of bank armoring using blasted angular riprap, filling of eroded banks using native channel materials, construction of cabled large woody debris structures, construction of fish passage diversion structure.

**b. Geomorphic Assessment**

In general, the application of the River Styles framework to this project involved a desktop analysis of available GIS data including digital elevation models of pre- and post-flood topography, geomorphic field measurements and observations, identification of River Styles, and summary and mapping of the field data.

i. **Desktop Analysis**
As part of the Expanded Study (Otak, 2016), a desktop analysis of the GIS data for the geomorphic assessment focused on mapping the current channel alignment, calculating channel slopes, assessing valley and channel confinement, and breaking the study area into reaches. Reach breaks were identified using the LiDAR terrain model and digital elevation model (DEM) of difference calculation (i.e., difference between the pre-flood terrain [2011] and post-flood terrain [2013]) to identify changes in slope, valley confinement, and flood response. The junctions of major tributaries and prominent infrastructure were also used to define reach breaks.

In all, the study identified 8 reaches on the South St. Vrain Creek, within the project area.

ii. Field Assessment
To inform, and confirm the results of the desktop analysis, a reach-scale geomorphic field assessment was conducted as part of the Expanded Study (Otak, 2016) and a site-specific assessment was conducted as part of this study during the alternative analysis phase. The assessments included an investigation of key geomorphic characteristics, such as channel geometry, channel confinement and entrenchment, bank condition and failure modes, sediment dynamics (e.g., sediment sources, bar types), and stage of stream evolution.

iii. River Styles
Based on the desktop analysis and field assessment, the reaches were classified into River Styles. This classification structure allows for the assessment and evaluation of multiple reaches that are similar in geomorphic traits, but may be geographically dispersed throughout the study area. A large emphasis is placed on valley confinement because it is a key control over the channel’s ability to adjust. In addition to overall valley confinement, position within the landscape, confinement ratio (valley bottom width/channel top width), geomorphic characteristics, stage of stream evolution, and flood/stream stage behavior were used to group each of the reaches reach into appropriate River Styles.

As part of the Expanded Study (Otak, 2016), the reaches within the South St. Vrain project area were classified into two different River Styles. The key properties of each River Style are summarized below, and a more detailed description of the traits and properties of each River Style are included in Appendix X.

- Confined Valley with Floodplain Pockets (CFP) [Reach 8]
  - Relatively steep, single thread channel with secondary channels in floodplain pockets
  - Mostly confined by valley
  - Contains some pockets of floodplain
  - Step-pool morphology (potential for pool-riffle), large wood stored in reach

- Partly-confined, Alluvial Valley (PCAV) [Reaches 1 through 7]
  - Moderate gradient, slightly meandering, single-thread and braided channel
  - Partly confined by valley
  - Located within the transition from the canyons through the hogbacks to the alluvial plains
  - Well-developed floodplain in places
  - Pool-riffle morphology, bar complexes, large wood jams

Figure X illustrates the reaches of South St. Vrain Creek in the context of the surrounding reaches and the larger system. The profile of the creek is shown along with stream power values, valley and channel width measurements, valley setting characteristics, entrenchment, and river style.
Confined Valley with Floodplain Pockets (CFP)

**Properties:**
Generally found along meander bends in canyon settings, these reaches contain “floodplain pockets” or limited areas of less confinement where sediment may be temporarily stored and where the channel may be more alluvial in nature. Where these reaches share the valley with a road, stream banks are often heavily armored. Because this reach type tends to have a milder slope (observed average slope 1.4%) and has areas with wider valley bottoms than the confined reaches that bracket them, some upstream sediment supply may fall out of transport here aiding in channel avulsion and braiding during floods, resulting in these styles being more geomorphically sensitive and potentially hazardous. Substrate in these reaches ranges from gravel to small boulder.

**Reach: 8**

## RIVER CHARACTERISTICS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Valley Setting</strong></td>
<td>Confined. Observed confinement ratio of 4</td>
</tr>
<tr>
<td><strong>Channel Planform</strong></td>
<td>Channel is generally single thread and straight, but floodplain pockets may contain overflow, secondary, and chute channels.</td>
</tr>
<tr>
<td><strong>Bed Morphology</strong></td>
<td>Typical: step-pool, with potential pool-riffle at lower gradient pockets; Large wood is stored in these reaches, providing channel structure, floodplain roughness and jams. Observed: step-pool and plane bed</td>
</tr>
</tbody>
</table>

## RIVER BEHAVIOR

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Stream Evolution Stage</strong></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Flood Response</strong></td>
<td>Confined areas generally experienced channel degradation and expansion. Floodplain pockets experienced substantial aggradation and loss of established vegetation, with lateral channel migration and avulsions.</td>
</tr>
<tr>
<td><strong>Stage Behavior</strong></td>
<td>Low flows are generally single thread, storing sediments in pools and channel margins in confined sections. In the floodplain pocket areas, sediments are stored in bar complexes, along channel margins and in pools. At bankfull flows, pool-riffle sequences and pool structures are flushed of fine sediments. At flood stage, these steep, armored reaches have excess transport capacity for all but the largest sediment (boulders), but the pocket areas are able to store flood energy and debris. Overflow channels activate and chute cutoff channels form in response to vertical accretion in the floodplain.</td>
</tr>
</tbody>
</table>
Partially Confined, Alluvial Valley (PCAV)

Properties:
The majority of the reaches in the study area are classified under this stream style. They occupy the transition from the canyons through the hogbacks to the alluvial plain landscape units. Slopes are steep, but milder than the confined reaches (observed slopes ranged from 0.3% to 2.1%). As a result of this relative steepness, relative lack of confinement, and position downstream of confined reaches directly coupled with hillslope sediment supplies, these reaches exhibit the most geomorphic response to floods. Because these reaches experienced the most geomorphic change, many channels of this style are still evolving in response to the floods. In some cases, channels are beginning to narrow and some side channels are slowly filling in with sediment. Nevertheless, a large amount of unstable sediment ranging from sand to cobble material exists in the banks and floodplains of these reaches and will continue to be a net sediment supply to downstream reaches for some time.

Reaches: 1 through 7

RIVER CHARACTERISTICS

<table>
<thead>
<tr>
<th>Valley Setting</th>
<th>Partially confined. Observed confinement ratio ranging from 6 to 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Planform</td>
<td>Meandering channel with low sinuosity, braided in some areas after flood. High flow, side channels present.</td>
</tr>
<tr>
<td>Bed Morphology</td>
<td>Typical: pool-riffle, boulder clusters, large wood jams and roughness elements; lateral and mid-channel bars Observed: pool-riffle, plane bed, riffle-run, mid-channel/point/lateral bars, instream large wood</td>
</tr>
</tbody>
</table>

RIVER BEHAVIOR

<table>
<thead>
<tr>
<th>Current Stream Evolution Stage</th>
<th>Three of the reaches in this River Style are in the Aggradation and Widening stage, three are in the Degradation and Widening stage and one is Degradational stage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Response</td>
<td>Flood response ranged from channel widening throughout, downstream lateral migration of meander bends, channel avulsion, and braiding.</td>
</tr>
</tbody>
</table>
Stage Behavior

Low flows are generally single thread with splits around mid-channel bars. Sediment is stored in bar complexes at the channel margin. Bankfull flows activate side channels and re-work in-channel bars. Large wood has significant influence on bank erosion and sediment accumulation. At flood stages, extremely high stream power values are generated before flows can spill into extensive floodplains, dissipating stream energy. Side channels are activated through inundation and channel avulsions will likely occur. Large wood is recruited into the channel as banks and terraces become undercut and may have significant influence over channel behavior as additional wood is racked up.

Figure 19. Partially Confined Alluvial Valley (PCAV)

Sediment Transport Analysis

The sediment transport analysis performed for this project consisted of two main approaches – transport rates measured in the field and capacity-supply balance calculations based on field samples and the hydraulic models. The field measured transport rates are discussed above, Section 5.g.i. The capacity-supply balance calculations build off of the analysis and results discussed in Otak, 2016. Key points that pertain to this project and design are summarized below as they provide the basis from which to evaluate the geomorphic effectiveness of the design developed for this project.

i. Summary of Base Bed Mobility and Sediment Transport Capacity Results

Bed Mobility

As discussed in Otak, 2016, bed mobility was calculated for all reaches of South St Vrain Creek from the canyon mouth to the Town of Lyons. Bed mobility refers to the ability of a given flow rate and associated shear stress to mobilize sediment. Results show that reaches in South St Vrain Creek are more readily mobilized. Error! Reference source not found. below shows that through the South St Vrain (green line, circled in red), mobile grain sizes are relatively larger than the North St Vrain and main stem (A) and are mobilized by more frequent flows (B). This behavior is largely a response to the relatively steeper slopes finer bed observed in the South St Vrain. This also suggests that South St Vrain Creek is likely to undergo further adjustment.
Sediment Transport Capacity and Balance
The Capacity-Supply Ratio (CSR) presented in Soar and Thorne (2001) is calculated by dividing the bed material load transported through a reach (by a natural sequence of flow events over an extended time period) by the bed material load transported into the reach (by the same flow events over the same time period). Values greater than 1.0 indicate potential for degradation and values below 1.0 indicate potential for aggradation. This simple metric can be used to estimate the geomorphic stability of proposed restoration designs. CSR values were calculated for each reach on South St Vrain Creek and a full discussion of the methods and details can be found in Otak (2016). Results relevant to this project are reproduced in Error! Reference source not found..
Table 7: South St. Vrain Capacity Supply Ratio at 2-yr Recurrence Interval Flow (adapted from Otak, 2016)

<table>
<thead>
<tr>
<th>Reach #</th>
<th>Expanded Area Study Reach ID</th>
<th>CSR at Q2</th>
</tr>
</thead>
<tbody>
<tr>
<td>R8</td>
<td>SSV-10</td>
<td>N/A</td>
</tr>
<tr>
<td>R7</td>
<td>SSV-09</td>
<td>N/A</td>
</tr>
<tr>
<td>R6</td>
<td>SSV-08</td>
<td>2.8</td>
</tr>
<tr>
<td>R5</td>
<td>SSV-07</td>
<td>0.4</td>
</tr>
<tr>
<td>R4</td>
<td>SSV-06</td>
<td>0.6</td>
</tr>
<tr>
<td>R3</td>
<td>SSV-05</td>
<td>1.9</td>
</tr>
<tr>
<td>R2</td>
<td>SSV-04</td>
<td>2.3</td>
</tr>
<tr>
<td>R1</td>
<td>SSV-03</td>
<td>1.2</td>
</tr>
<tr>
<td>-</td>
<td>SSV-02</td>
<td>0.2</td>
</tr>
<tr>
<td>-</td>
<td>SSV-01</td>
<td>3.4</td>
</tr>
</tbody>
</table>

As shown in the disparity of CSR values, the sediment balance on South St Vrain oscillates widely, with reaches that tend towards aggradation and reaches that tend towards degradation due to longitudinal discontinuities in sediment transport capacity. This indicates that the channel is still adjusting to the flood impacts more so than the other segments. At larger flood events, this oscillation from oversupply and undersupply is more evident, and is to be expected as very large, and infrequent flood events tend to reform channel geometry to account for this inter-reach transport capacity imbalance. Restoration designs should therefore seek to achieve continuity in CSR values from reach to reach, with values close to 1.

ii. Bed Mobility Analysis

Bed mobility is evaluated by considering the incipient motion, or the initiation of movement of sediment particles in the bed, for particular grain sizes in the bed. Incipient motion is calculated based on threshold conditions established when the flow forces (lift and drag) become greater than the particle weight and particle-to-particle contact forces (gravity and friction). The relationship between the driving forces of water flow and resisting forces of gravity and friction are summarized in the Shields dimensionless shear stress parameter ($\tau^*$). Values of this parameter, which scales with bed grain size and shear stress at a given discharge, can be compared to standard values of critical dimensionless shear stress which tend to range from 0.03 to 0.07 (Buffington and Montgomery 1997).

The boundary shear stress (typically obtained from hydraulic modeling) considers only a portion of this shear stress that acts directly on the stream bed to initiate sediment movement, shear stress partitioning is more appropriate to estimate grain size mobility. Shear stress available to mobilize bed grains (i.e., grain stress or skin friction) was calculated following Pitlick, et al. (2009).

Particle mobility was determined for each bed sediment size class, which varies by reach, by comparing $\tau^*$ against a critical dimensionless shear stress value ($\tau_{c}^*$). When $\tau^* > \tau_{c}^*$, the particle is considered mobile at the representative critical dimensionless shear and associated discharge value.

(To Do: Analysis is currently in progress and section will be updated)
iii. **Sediment Transport Capacity and Balance**

**Sediment Transport Capacity**

Sediment transport capacity is defined as the quantity and rate of sediment that a river is able to transport at a given flow. It is a function of the shear stress on the river bed and the range and relative quantities of sediment grain sizes on the bed surface available to transport downstream. Sediment transport capacity calculations rely on grain size distribution data collected by pebble counts, as described above. Grain size distributions from pebble count locations are associated with ranges of nearby modeled cross sections. Sediment transport capacity at each model cross section is then scaled based on the relative quantities of grain sizes on the bed (coarse sand, gravel, cobble, and up to small boulders). Using hydraulic modeling results and grain size distribution data, transport capacity is estimated using the Parker (1990) surface-based, bed material load equation for coarse bed rivers as described by Pitlick et al. (2009). Transport capacity is calculated for a given discharge for each grain size interval and then scaled based on the fraction of each grain size interval represented in the bed. We partition bed shear stress based on the approach outlined in Pitlick et al. (2009).

Sediment transport in rivers occurs over different time frames with sand and fine gravel-sized material able to travel longer distances and more frequently over the course of a year and larger gravel and cobble-sized material travelling shorter distances more episodically. Sediment yield in a river (sediment mass exported from a reach) is driven by the entire range of competent flows. Here, transport capacity at individual design floods is considered. Coarse bed rivers such as St. Vrain Creek tend to mobilize their bed during flood flows such as the annual flood and larger. Therefore, considering sediment continuity during these flood events allows one to consider the relative rate and quantity of sediment moving in each reach. In addition to calculating sediment transport capacity at each modeled cross section, transport capacity is averaged over a reach comprised of several cross sections.

**Sediment Transport Capacity Balance**

Sediment transport capacity balance is estimated as the difference between the transport capacity of an upstream reach and a downstream reach, where the upstream transport capacity is assumed to be the bed material supply to downstream. Positive transport capacity balance values in a given reach indicate that more sediment transport capacity (and more sediment) is coming from upstream than there is capacity to transport in the reach of interest. This means that this particular area may be subject to aggradation. Negative transport capacity balance values indicate degradational tendencies for a particular reach. However, some of the modeled sediment deficit will be in finer sediment classes (gravel to coarse sand), which may be supply limited. This means that the actual sediment deficit will be smaller than the modeled deficit. The large grain sizes (large gravel and cobble) encountered in the beds of South St. Vrain Creek indicates that many of these reaches are supply limited of finer sediment and have armored beds. Bed armoring tends to mitigate channel degradation.

A further simplification of this evaluation is through the use of the CSR, as discussed above.

(To Do: Analysis is currently in progress and section will be updated)
d. Effective Discharge

Design discharges used to size bankfull channel dimensions often rely on regional hydraulic geometry relations and/or flood frequency estimates such as the 1.5 or 2-year flood peaks. Consideration of the range of geomorphically-effective flows as well as the relationship between discharge and sediment movement can better inform channel design, especially in systems adjusting to a disturbance, such as post flood St. Vrain Creek (Doyle et al., 2007). The effective discharge, $Q_{\text{eff}}$, is that which transport the most sediment on average over time. It is calculated from a flow frequency distribution representing a long-term flow record (e.g., a flow duration curve) and a relationship between the flow rate and sediment transport rate for a given reach and bed material size distribution (Error! Reference source not found.a; Biedenharn et al., 2000). In gravel and cobble bed rivers such as St. Vrain Creek, $Q_{\text{eff}}$ tends to predict bankfull discharge well (Sholtes and Bledsoe, 2016). The half-yield discharge, $Q_h$, is the discharge associated with a cumulative 50% of sediment transport on the sorted flow (and sediment yield) record (Error! Reference source not found.b). Its calculation relies on the same data as $Q_{\text{eff}}$. It is also a good predictor of bankfull discharge in most river types and often corresponds with $Q_{\text{eff}}$ in coarse bed rivers.

Figure 21. a) Conceptual diagram of sediment yield effectiveness curve used to calculate the effective discharge. b) Cumulative sediment yield curve used to calculate the half-yield discharge (Otak, 2016)

These sediment yield-based design discharge metrics provide additional information about a river beyond flood frequency-based design discharges. By combining information from the entire flow regime and characteristics of the local sediment supply, these design metrics highlight other flows or a range of flows that are important to consider for sediment continuity and ultimately geomorphic stability. The effective and half-yield discharges were calculated for reaches on South St. Vrain Creek as part of the Expanded Study (Otak, 2016).
Resulting values of $Q_{\text{eff}}$ and $Q_h$ on South St. Vrain Creek are similar in magnitude to each other at approximately 230 and 280 cfs, respectively (Error! Reference source not found.). These values approximate the 1-year recurrence interval flood. Both $Q_{\text{eff}}$ and $Q_h$ are most influenced by flow variability, bed material grain size, and channel geometry. All things being equal, $Q_{\text{eff}}$ and $Q_h$ decrease with decreasing grain size and increasing channel entrenchment (Sholtes et al., 2014). For this study, $Q_{\text{eff}}$ and $Q_h$ were calculated based on post-flood channel geometry and bed material, both of which are likely still adjusting to this disturbance. In general, the flood created larger and deeper channels and brought in finer sediment from upstream bank erosion and hillslope failure. This may have resulted in producing estimates of $Q_{\text{eff}}$ and $Q_h$ that are smaller than their pre-flood values. This is likely the case for the South St Vrain, which exhibits finer sediment and the most geomorphic change relative to St. Vrain and North St. Vrain Creeks.

![Graph showing Sediment Yield vs. Discharge for South St. Vrain Creek](image1.png)

![Graph showing Cumulative Sediment Yield vs. Discharge for South St. Vrain Creek](image2.png)

*Figure 22. Effective discharge and cumulative sediment yield curves for South St. Vrain Creeks.*

e. Stream Evolution Model

Otak 2016 used the stream evolution model (SEM) presented in Cluer and Thorne (2013) to define the current stage of stream evolution of each reach along the South St Vrain. The SEM is a tool to assist with understanding morphological responses to disturbances within a stream system (e.g., base level change, channelization, alterations to the flow/sediment regimes) and can help determine channel trajectories and achievable restoration goals. A graphic showing the stages of the SEM is shown in Error! Reference source not found. below and the SEM trajectories identified in Otak, 2016 are reproduced in Error! Reference source not found. below.

All identified stages are adjustment stages, meaning that the South St Vrain can be expected to undergo further flood response. This table will be updated based on additional analyses of the proposed design.
Figure 23. Stream Evolution Model (Cluer and Thorne, 2013)

Table 8. Stream Evolution Trajectories
Reach # | Expanded Study Reach ID | River Style | Current Stream Evolution Stage<sup>a,b</sup> | Capacity/Supply Ratio @ Q<sub>2</sub> | Stream Evolution Trajectory<sup>a,b</sup>
--- | --- | --- | --- | --- | ---
8 | SSV-10 | Confined Valley w/ FP pockets | N/A | - | - | N/A
7 | SSV-09 | Partially Confined, Alluvial Valley | Stage 3 Degradation | - | - | Stage 4 Degradation and Widening
6 | SSV-08 | Partially Confined, Alluvial Valley | Stage 5 Aggradation and Widening | 2.8 | Degradational | Stage 3 Degradation
5 | SSV-07 | Partially Confined, Alluvial Valley | Stage 4 Degradation and Widening | 0.38 | Aggradational | Stage 5 Aggradation and Widening
4 | SSV-06 | Partially Confined, Alluvial Valley | Stage 5 Aggradation and Widening | 0.59 | Aggradational | Stage 6 Quasi Equilibrium<sup>c</sup>
3 | SSV-05 | Partially Confined, Alluvial Valley | Stage 4 Degradation and Widening | 1.9 | Degradational | Stage 5 Aggradation and Widening<sup>c</sup>
2 | SSV-04 | Partially Confined, Alluvial Valley | Stage 4 Degradation and Widening | 2.3 | Degradational | Stage 5 Aggradation and Widening<sup>c</sup>
1 | SSV-03 | Partially Confined, Alluvial Valley | Stage 5 Aggradation and Widening | 1.2 | Degradational | Stage 6 Quasi Equilibrium<sup>c</sup>

Notes:

<sup>a</sup> Based on (Cluer & Thorne, 2013)

<sup>b</sup> N/A=stream evolution model not applicable (e.g., step-pool reaches do not necessarily follow the same disturbance model)

<sup>c</sup> Potential for reach to move into Stage 3 - Degradation

The uppermost reach of South St. Vrain Creek (R8) has been categorized as confined with floodplain pocket (CFP) river styles. They have narrow valleys with roadways sharing the valley bottom with the channel.

The canyon opens up to the alluvial valley upstream of the Town of Lyons (R7 through R1), where alluvial valley refers to a valley bottom that has been formed over time by the river itself. This means that the channel footprint has occupied every part of these valleys during some point in the modern geologic era and is referred to as high geomorphic hazard areas with the potential for larger channel adjustments during large flood events. This concept was made evident by the river’s response to the flood. A combination of relatively large slopes and a rapid reduction in stream power from the steeper and confined reaches upstream resulted in vast amounts of sediment falling out of transport along these reaches and massive lateral channel migration and avulsion. In many cases in these reaches, channels are relatively unconfined and not entrenched, and as such, they moved from one side of the valley to the other. Channels widened and developed multiple threads. As summarized on Error! Reference source not found., stream evolution trajectories for these reaches along South St. Vrain Creek vary widely from Degradation to Aggradation/Widening to Quasi Equilibrium (with the potential to move back into the Degradation stage).
The Hall Meadows reaches (R2 and R3) were evaluated as Stage 4 – Degradation and Widening of the SEM. However, the application of the SEM to these reaches is anything but straightforward – at various locations throughout the reaches, properties of several stages of the SEM (Stage 3 – Degradation, Stage 5 – Aggradation and Widening) are evident, obscuring the application of the simplifying SEM model. Ultimately, Stage 4 was chosen for both reaches because the channel remains mostly disconnected from overflow channels and floodplain, has actively eroding banks and poorly formed hydrogeomorphic units that are likely to be re-worked or destroyed upon receipt of flows approaching the effective discharge rate (~2-year discharge, ~230 cfs) or even the annual flood event. Both reaches (R2 and R3) are likely to undergo substantial geomorphic adjustment in response to a net evacuation of sediment as the river seeks to establish equilibrium slopes and channel dimensions. However, the determination of the geomorphic trajectory is obscured by the issues noted above, wildly fluctuating balance calculation results through the range of design flows, and an uncertain sequence of flow events (meaning, while flow sequences are always uncertain, mild flow events will moderate geomorphic adjustment, while larger flow events may cause widespread destabilization). Fine sediments (i.e., sand) are prevalent throughout the reach which has the effect of increasing the geomorphic sensitivity of the reach, whereby small differences in shear stress produce large changes in transport capacity. At the effective discharge rate, CSR values suggest that both reaches are degradational. However, locations containing slackwater near the channel margins and substantial sediment supply suggest that the stream may begin to deposit material, narrowing the wetted channel, and building banks and functional geomorphic units. In light of these seemingly contradictory pieces of information and the fact that several restoration projects have been implemented and/or are forthcoming through the project reach, these reaches are assigned a trajectory of Stage 5 Aggradation and Widening with a significant chance of regressing into another round of degradation (Stage 3).

(To Do: Analysis is currently in progress and section will be updated)

a. Preliminary Results
   (To Do: Analysis is currently in progress and section will be updated)

b. Supporting Data
   (To Do: Analysis is currently in progress and section will be updated)

9. Aquatic and Terrestrial Species Habitat Requirements
Aquatic and terrestrial species habitat requirements were completed by ERO, THK and Blue Mountain Consultants.

a. Aquatic Species Habitat Requirements
   i. Fish Species Evaluated
      Below is a list of the species of concern throughout reach.

      - Brown Trout (*Salmo trutta*)
      - Rainbow Trout (*Oncorhyncus mykiss*)
      - Longnose Sucker (*Catostomus catostomus*)
      - Longnose Dace (*Rhinichthys cataractae*)
      - No T&E fish species present in project reach (per Matt Kondratieff, CP&W)

   ii. Fish Passage Aspects
No major concerns about fish passage in the project reach. Longmont pipeline check dam can prevent sucker and dace upstream movement but it poses no barrier to adult brown and rainbow trout movement.

- **Option 1** – Do nothing. Least costly, but check dam does negatively impact sediment transport and some fish movement, as it has historically done.
- **Option 2** – Install sand sluice on left bank of check dam. Would improve sediment transport through reach and allow upstream passage at certain times of the year for juvenile trout and perhaps suckers and dace. Cost and feasibility dependent on elevation of Longmont Pipeline through check dam.
- **Option 3** – Move diversion upstream and remove check dam all together. Best solution for both the physical and biological function of river reach but is the most costly.

### iii. Channel Function

The flood and flood recovery efforts have negatively impacted the pattern, profile and dimension of the South St. Vrain Creek through the project reach. Valley width is a major factor in determining what could, or should, be done in the project reach. The highway, infrastructure and private property concerns limit the potential for restoration at certain “choke” points in the valley while locations with ample belt width could certainly benefit, physically and biologically, from appropriate restoration techniques.

Factors to consider when developing conceptual design are:

- **Continuity** – biological access up and downstream over a range of flows
- **Conveyance** – account for water and sediment transport including:
  - Capacity – sediment load
  - Competence – particle size
- **Connectivity** – a well-connected floodplain will dissipate energy at flows greater than bankfull and promote a robust riparian community that will enhance the sustainability of any restoration.
- **Cover** – instream cover for fish, primarily trout. With the current state of the river we are looking at pool depth and spacing. Overhead and near-bank cover will come as the riparian vegetation recovers.
- **Carbon** – long term and short term carbon sources. The flood turned the river corridor into a cobble field but the cottonwood/willow/alder communities are coming back strong. Let’s encourage the natural recovery where we can and assist the areas that are lagging. Where river pattern requires realignment I would recommend using as much toewood/rootwads as practical. The wood provides an excellent long term carbon source and when installed properly should be more than sufficient to provide structural stability until the riparian recovers.

A multi-stage channel with a well-developed inner berm would be appropriate for this reach. The inner berm would enhance the biological continuity, particularly at low flows, and provides about 15% greater efficiency in bed load transport. The flood removed much of the substrate fines but subsequent flows will continue to add that component back into the system. Between the bedrock outcrops and the coarseness of the substrate, I don’t think you’re going to need a lot of large rock for grade control.
b. Terrestrial Species Habitat Requirements

ERO Resources Corporation (ERO) conducted a site visit on July 22, 2016 and assessed the project area for terrestrial species habitat. The sections below summarize terrestrial federally threatened and endangered species; state and local threatened, endangered, and species of concern; migratory birds and raptors; and other wildlife potentially found in the project area. Where applicable, recommendations for future actions are provided based on the current site conditions and federal, state, and local regulations.

i. Federally Threatened and Endangered Species

On July 22, 2016, ERO assessed the project area for suitable habitat for federally listed threatened and endangered species protected under the Endangered Species Act (ESA). The project area does not fall within U.S. Fish and Wildlife Service (Service) habitat or survey guidelines for the majority of the species listed by the Service as potentially being present in Boulder County (Table X). Because the project area falls within survey guidelines for Preble’s meadow jumping mouse (Zapus hudsonius preblei or Preble’s) and Ute ladies’-tresses orchid (Spiranthes diluvialis or ULTO), ERO assessed the project area for suitable habitat for both species. ERO also assessed the project area for Colorado butterfly plant (Gaura neomexicana ssp. coloradensis or CBP), a federally threatened species that has been documented in northern Colorado.

The proposed project would not directly impact the Canada lynx, Mexican spotted owl, or greenback cutthroat trout because of the lack of potentially suitable habitat in the project area. The interior least tern, piping plover, whooping crane, pallid sturgeon, and western prairie fringed orchid occur in Nebraska within the Platte River floodplain, and are potentially affected by water depletions from the Platte River watershed. Projects that include activities that deplete water in the South Platte River, such as diverting water from a stream or developing new water supplies, could potentially affect these species and consultation with the Service may be required.
Table 9. Federally threatened and endangered species potentially found in Boulder County or potentially affected by projects in Boulder County.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Status*</th>
<th>Habitat</th>
<th>Potential Habitat Present</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mammals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada lynx</td>
<td>Lynx canadensis</td>
<td>T</td>
<td>Climax boreal forest with a dense understory of thickets and windfalls</td>
<td>No</td>
</tr>
<tr>
<td>Preble’s meadow jumping mouse</td>
<td>Zapus hudsonius preblei</td>
<td>T</td>
<td>Shrub riparian/wet meadows</td>
<td>Potential</td>
</tr>
<tr>
<td><strong>Birds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior least tern**</td>
<td>Sterna antillarum athalassas</td>
<td>E</td>
<td>Sandy/pebble beaches on lakes, reservoirs, and rivers</td>
<td>No habitat and no depletions anticipated</td>
</tr>
<tr>
<td>Mexican spotted owl</td>
<td>Strix occidentalis</td>
<td>T</td>
<td>Closed canopy forests in steep canyons</td>
<td>No</td>
</tr>
<tr>
<td>Piping plover**</td>
<td>Charadrius melodus</td>
<td>T</td>
<td>Sandy lakeshore beaches and river sandbars</td>
<td>No habitat and no depletions anticipated</td>
</tr>
<tr>
<td>Whooping crane**</td>
<td>Grus americana</td>
<td>E</td>
<td>Mudflats around reservoirs and in agricultural areas</td>
<td>No habitat and no depletions anticipated</td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenback cutthroat trout</td>
<td>Oncorhynchus clarki stomias</td>
<td>T</td>
<td>Cold, clear, gravel headwater streams and mountain lakes</td>
<td>No</td>
</tr>
<tr>
<td>Pallid sturgeon**</td>
<td>Scaphirhynchus albus</td>
<td>E</td>
<td>Large, turbid, free-flowing rivers with a strong current and gravel or sandy substrate</td>
<td>No habitat and no depletions anticipated</td>
</tr>
<tr>
<td><strong>Plants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado butterfly plant</td>
<td>Gaura neomexicana ssp. coloradensis</td>
<td>T</td>
<td>Subirrigated, alluvial soils on level floodplains and drainage bottoms between 5,000 and 6,400 feet in elevation</td>
<td>No</td>
</tr>
<tr>
<td>Ute ladies’-tresses orchid</td>
<td>Spiranthes diluvialis</td>
<td>T</td>
<td>Moist to wet alluvial meadows, floodplains of perennial streams, and around springs and lakes below 6,500 feet in elevation</td>
<td>Potential</td>
</tr>
<tr>
<td>Western prairie-fringed orchid**</td>
<td>Platanthera praeclara</td>
<td>T</td>
<td>Mesic and wet prairies, and sedge meadows</td>
<td>No habitat and no depletions anticipated</td>
</tr>
</tbody>
</table>

* T = Federally Threatened Species, E = Federally Endangered Species.

**Water depletions in the South Platte River may impact the species and/or critical habitat in downstream reaches in other counties or states.

Source: Service 2016.

Potential habitat for Preble’s, CBP, and ULTO is generally more prevalent within areas across the Front Range. Because these species are more likely to be addressed by counties and regulatory agencies such as the Corps, a more detailed discussion is provided below.
Preble’s Meadow Jumping Mouse

Species Background
Preble’s was listed as a federally threatened subspecies under the ESA in May 1998 (63 FR 26517 (May 13, 1998)). On July 9, 2008, the Service issued a final ruling to amend the listing for Preble’s. The amended final rule states that Preble’s is a distinct subspecies and will remain listed as a federally threatened species in Colorado. The Service’s amended final rule states that because of development along Colorado’s Front Range, the long-term survival of the subspecies in Colorado remains threatened. The Service also announced that Preble’s will not remain protected in Wyoming because threats from development and other habitat-altering practices are not prevalent. On August 5, 2011, the Service reinstated ESA protection for Preble’s in Wyoming because of interpretations regarding the definition of a threatened species being “in danger of extinction throughout all or a significant portion of its range,” which was invalidated by two court rulings. The Service requested that the courts remand the Preble’s decision back to the Service. The court granted the request and the Service reinstated the listing of Preble’s as a federally threatened species in Wyoming. Previous critical habitat designation in Wyoming was not reinstated. In 2011, two petitions to delist Preble’s were filed to the Service. In May 2013, the Service completed a 12-month finding in response to the petitions and ruled that delisting was not warranted at the time. Therefore, Preble’s remains protected under the ESA.

Habitat
Along Colorado’s Front Range, Preble’s is found below 7,800 feet in elevation, generally in lowlands with medium to high moisture along permanent or intermittent streams. Preble’s typically inhabits areas characterized by well-developed plains riparian vegetation with relatively undisturbed grassland and a water source nearby. Previous studies have suggested that Preble’s may have a wider ecological tolerance than initially thought, and that the requirement for diverse vegetation and well-developed cover can be met under a variety of circumstances (Meaney et al. 1997). Radio-tracking studies conducted by the Colorado Parks and Wildlife (CPW) have documented Preble’s using upland habitat adjacent to wetlands and riparian areas (Shenk and Sivert 1999). Additional research by CPW has suggested that habitat quality for Preble’s can be predicted by the amount of shrub cover available at a site.

Critical Habitat
In June 2003, the Service designated critical Preble’s habitat (50 Code of Federal Regulations (CFR) 17). Critical habitat consists of specific areas that are designated for threatened and endangered species recovery. Critical habitat was designated along portions of the North Fork of the Cache la Poudre and Cache la Poudre Rivers in Larimer County, and along the South Platte River in portions of Douglas County. Critical habitat was also designated along portions of Ralston Creek in Jefferson County and Buckhorn Creek in Larimer County (Service 2003). In 2009, the Service proposed revision of designated Preble’s critical habitat (74 FR 52102 (October 8, 2009)). On December 14, 2010, the Service issued a final rule for revised critical habitat designation (50 FR 78430 (December 14, 2010)). The newly revised critical habitat includes 8 miles of streams within the South Boulder Creek watershed south of the project area limits and along the Cache la Poudre River north of the project area in Larimer County. There is no designated critical habitat along South St. Vrain Creek or within any portion of the project area.
**Potential Habitat within the Project Area**

The project area is within an area mapped as Preble’s overall range by the Colorado Natural Diversity Information System (NDIS 2016). Portions of the project area contain multilayered shrub habitat consisting of sandbar willow (*Salix exigua*), American plum (*Prunus americana*), chokecherry (*Prunus virginiana*), and snowberry (*Symphoricarpos albus*), which is suitable habitat for Preble’s. Trapping surveys have been conducted in previous years (1996, 2005 and 2015 (BCOS 1996; Meaney 2005; BCOS 2015)) in the project area. Trapping surveys conducted in 1996 and 2015 within the project area did not result in any Preble’s captures; however, in 2005 Preble’s was captured in the project area (Meaney 2005).

**Recommendations**

Riparian habitat within the project area provides adequate habitat for Preble’s. Areas currently devoid of vegetation due to sedimentation and scour from the 2013 flooding may be enhanced through construction of secondary channels, or other areas that are low enough to provide adequate hydrology for wetland and riparian vegetation. ERO recommends that Boulder County consult with the Service prior to construction activities to discuss the level of Section 7 consultation required for the project.

**Ute ladies’-tresses Orchid**

Species Background

ULTO is federally listed as threatened. Once thought to be fairly common in low-elevation riparian areas in the interior western United States, ULTO is now rare (Service 1992a).

In Colorado, the Service requires surveys in areas of suitable habitat on the 100-year floodplain of the South Platte River, Fountain Creek, and Yampa River, and their perennial tributaries; or in any area with suitable habitat in Boulder and Jefferson Counties (Service 1992a). ULTO does not bloom until late July to early September (depending on the year) and the timing of surveys must be synchronized with blooming (Service 1992b).

Habitat

ULTO occurs at elevations below 6,500 feet in moist to wet alluvial meadows, floodplains of perennial streams, and around springs and lakes where the soil is seasonally saturated within 18 inches of the surface. Generally, the species occurs where the vegetative cover is relatively open and not overly dense or overgrazed.

**Potential Habitat Within the Project Area**

The soils in the project area consist primarily of sand and cobble, which is typically associated with ULTO (Service 1992a). The wetland vegetation found within the project area is dominated by broadleaf cattail, common threesquare, Baltic rush, and dense stands of reed canarygrass and Emory’s sedge. Many of the plants in wetland areas within the project area are likely too dense for ULTO establishment. Additionally, there is no known seed source within the South St. Vrain Creek watershed. ULTO surveys have been conducted in previous years and no ULTO have been found during survey efforts (Hirt 2016).
Recommendations

The project area falls within the survey guidelines for potential ULTO habitat because of the presence of wetland vegetation and because the project area is in Boulder County. ERO recommends coordination with the Service prior to construction requesting the site be cleared from a presence/absence survey for ULTO due to the lack of suitable habitat and known populations. If the Service clears the site from a presence/absence survey, no further consultation would be needed for ULTO.

Colorado Butterfly Plant

Species Background

The CBP is federally listed as threatened and is found in small areas in southeastern Wyoming, western Nebraska, and north-central Colorado (Service 2004). The CBP flowers from June to September and produces fruit from July to October (Spackman et al. 1997). The Service has not established formal survey guidelines for CBP, but has indicated that areas similar to, and slightly drier than, ULTO habitat should be assessed.

Habitat

The CBP is a short-lived perennial herb found in moist areas of floodplains. It occurs on sub irrigated alluvial soils on level or slightly sloping floodplains and drainage bottoms at elevations from 5,000 to 6,400 feet. Colonies are often found in low depressions or along bends in wide, active, meandering stream channels that are periodically disturbed. Historically, the main cause of disturbance was probably flooding (Service 2004).

Potential Habitat within the Project Area

The project area is located outside of the known geographic range of CBP, which includes portions of Larimer and Weld Counties. While potential habitat exists within portions of the project area, no known populations or seed sources are known to occur within the South St. Vrain Creek watershed.

Recommendations

ERO recommends coordination with the Service prior to construction requesting the site be cleared from a presence/absence survey for CBP due to the lack of suitable habitat and known populations. If the Service clears the site from a presence/absence survey, no further consultation would be needed for CBP.

ii. State Threatened, Endangered, and Species of Concern

The project area contains potential habitat for threatened, endangered, and species of special concern protected under State Statute 33. Although State Statute 33 prohibits the take, possession, and sale of a state-listed species, it does not include protection of their habitat. The state lists several threatened, endangered, and species of special concern that are known to occur or have the potential to occur in Boulder County and are presented in Table X.
Table 10. State threatened, endangered, and species of concern potentially found in Boulder County or potentially affected by projects in Boulder County.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name (Status*)</th>
<th>Status</th>
<th>General Colorado Range</th>
<th>Suitable Habitat Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black-tailed prairie dog</td>
<td>Cynomys ludovicianus</td>
<td>SC</td>
<td>Eastern plains/urban</td>
<td>No</td>
</tr>
<tr>
<td>Northern pocket gopher</td>
<td>Thomomys talpoides ssp. macrotis</td>
<td>SC</td>
<td>Eastern Colorado – Douglas/Arapahoe Counties, northern El Paso County</td>
<td>No</td>
</tr>
<tr>
<td>Northern river otter</td>
<td>Lontra canadensis</td>
<td>ST</td>
<td>Colorado, Gunnison, Piedra, and Dolores Rivers and possibly the Poudre River</td>
<td>No</td>
</tr>
<tr>
<td>Townsend’s big-eared bat</td>
<td>Corynorhinus townsendii pallescens</td>
<td>SC</td>
<td>Western and mountain portions of eastern Colorado</td>
<td>Potential</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Birds</th>
</tr>
</thead>
<tbody>
<tr>
<td>American peregrine falcon</td>
</tr>
<tr>
<td>Bald eagle</td>
</tr>
<tr>
<td>Ferruginous hawk</td>
</tr>
<tr>
<td>Long-billed curlew</td>
</tr>
<tr>
<td>Western burrowing owl</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amphibians and Reptiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common garter snake</td>
</tr>
<tr>
<td>Northern leopard frog</td>
</tr>
</tbody>
</table>

* ST = Colorado Threatened Species, SC = Colorado Species of Special Concern.

Source: CPW 2016.

Of the species listed in Table X, the Townsend’s big-eared bat (TBEB), American peregrine falcon, bald eagle, common garter snake, and northern leopard frog have potential to occur in the project area. The black-tailed prairie dog, northern pocket gopher, northern river otter, ferruginous hawk, long-billed curlew, and western burrowing owl would not be affected by the proposed project because the project area is outside of the species’ known range, suitable habitat is not present, or potential habitat would not be impacted by the project and, therefore, these species are not discussed in the following sections.

**Townsend’s Big-Eared Bat**

Species Background

The TBEB is currently a species of special concern in Colorado (CPW 2016). The Colorado National Heritage Program (CNHP) ranks TBEB as S2, imperiled in the state because of rarity due to very restricted range, few populations, steep declines in population, or other factors making it vulnerable to extirpation. Threats to the species includes disturbance of roosting areas (Sherwin et al. 2000; Schmidt 2003).

The TBEB forages primarily for insects over water or along the margins of vegetation (Fitzgerald et al. 1994; Armstrong et al. 2011). The TBEB is found in the western United States, where it occurs in Idaho, Wyoming, Colorado, New Mexico, southern Kansas, Oklahoma, and Texas, with scattered populations in Arkansas, Missouri, Kentucky, Virginia, and West Virginia. In Colorado, the TBEB is found over most of the western two-thirds and the extreme southeastern parts of the state to elevations of approximately 9,500 feet (2,900 meters) (Armstrong et al. 2011). The abundance of the TBEB in Colorado is unknown.
Habitat
The TBEB uses a variety of habitats including coniferous forest, desert shrublands, piñon-juniper woodlands, and pine forests (Jones et al. 1983). Most of the accounts of this species focus on requirements of suitable roosts, which include caves, mines, rocky ledges, overhangs, buildings, and bridges (Sherwin et al. 2000; Adam and Hayes 2000; Keeley and Tuttle 1999; Jagnow 1998). Throughout this species’ range, it seems to be common in mesic habitats with coniferous and deciduous forests (Humphrey and Kunz 1976) or associated with dry ponderosa pine and Douglas fir (Holroyd et al. 1994).

Riparian areas and rock outcrops within the project area contain potential foraging and roosting habitat for the TBEB. An abandoned quarry and some structures in the western portion of the project area could provide potential roosting habitat for the TBEB.

Recommendations
The proposed project is unlikely to adversely affect the TBEB given the lack of suitable roost sites in areas where project activities would occur. The proposed project would not affect rocky outcrops or abandoned buildings within the project area; therefore no action is recommended for the TBEB.

American Peregrine Falcon
Species Background
The American peregrine falcon is currently a species of special concern in Colorado (CPW 2016). The peregrine falcon once ranged throughout North America (Service 1984). In 1970, after significant population declines due largely to the effects of organochloride pesticides (such as DDT) in the environment, the falcon was federally listed as endangered. In 1999, however, after a considerable population increase, the falcon was removed from listing under the ESA. Additional causes for the sharp population decline are also believed to include low breeding densities and reproductive isolation and reduced availability of foraging habitat and avian prey (Finch 1992). Peregrines remain protected under the Migratory Bird Treaty Act (MBTA) and the CPW recommends applying spatial and seasonal buffers around active nest sites.

Peregrines primarily prey on medium-size birds including jays, doves, flickers, shorebirds, and songbirds. Preferred hunting areas include cropland, meadows, river bottoms, marshes, and lakes that attract abundant bird life. Peregrines may travel up to 29 kilometers (17 miles) from nesting cliffs to hunting areas (Service 1984). Peregrine falcons can be found in downtown Denver, along the foothills, and all the way to the western border of Colorado. Peregrine falcons mate for life and usually breed in March and April.

Habitat
Peregrines use a variety of habitats for nesting, foraging, migrating, and wintering. Nest sites are usually constructed on rugged, remote cliffs generally from 60 to more than 100 meters (200 to 300 feet) in height with nearby water sources where prey is abundant (Service 1984; Craig and Enderson 2004). As peregrine populations have expanded, they have accepted cliffs as low as 30 meters (100 feet) as suitable nesting sites (Craig and Enderson 2004). In the Rocky Mountains, nests can be found at elevations up to 3,600 meters (11,811 feet) (White et al. 2002). Potential peregrine falcon habitat exists within some of the rocky outcrops located around the project area. No known nests occur in the project area.
Recommendations

No known peregrine falcon nests are known to occur in the vicinity of the project area. Additionally, proposed project activities would not affect potential peregrine falcon habitat; therefore, no action is necessary regarding peregrine falcons.

Bald Eagle

Species Background

The bald eagle is currently a species of special concern in Colorado (CPW 2016). The bald eagle is a large North American bird with a historical distribution throughout most of the U.S. The bald eagle was listed as a federally endangered species in 1978. Population declines were attributed to habitat loss, the use of organochloride pesticides, and mortality from shooting. Since its listing, the bald eagle population has been increasing. On July 9, 2007, the Service announced the delisting of the bald eagle from the threatened and endangered species list (Service 2007). Although removed from the list of threatened and endangered species, the bald eagle continues to be protected under the MBTA and Bald and Golden Eagle Protection Act.

Habitat

Most bald eagle nesting in Colorado occurs near lakes or reservoirs or along rivers. Typical bald eagle nesting habitat consists of forests or wooded areas that contain tall, aged, dying, and dead trees (Martell 1992). Bald eagles seek aquatic habitat for foraging and typically prefer fish, although they also feed on birds, mammals, and carrion, particularly in winter (Buehler 2000; Sharps and Uresk 1990). Prairie dogs provide a major food resource for bald eagles wintering along the Colorado Front Range (Environmental Science and Engineering 1988).

CPW recommends that construction activities remain at least ½ mile from active bald eagle nests. One historical bald eagle nest occurs within ½ mile of the project area in Lyons. The status of this nest is not known according to the NDIS (2016). The project area occurs within an area mapped as bald eagle winter range (NDIS 2016). Winter range typically refers to those areas where bald eagles have been observed between November 15 and April 1 (CPW 2014).

Recommendations

For any work conducted within areas mapped as bald eagle winter range, ERO recommends contacting the local CPW district manager to request concurrence that the proposed project would not likely affect wintering bald eagles. Because of the low level of human disturbance in the project area and surrounding area, ERO biologists conclude the project activities would not likely disturb eagles potentially using the winter range.

Common Garter Snake

Species Background
The common garter snake is currently a species of special concern in Colorado (CPW 2016). The subspecies of the common garter snake that occurs in Colorado is the red-sided garter snake (*Thamnophis sirtalis* ssp. *parietalis*), which is characterized by black and red sides with a pale yellow to white stripe down the center of the back. In Colorado, this species is found from southern Jefferson County north through Boulder and Larimer Counties and northeast through Nebraska and Wyoming (Hammerson 1999). The common garter snake inhabits the margins of streams, irrigation ditches, natural and artificial ponds, as well as open areas that are surprisingly far from water.

**Habitat**

This species has been known to inhabit riparian and wetland areas in the northeastern portion of the state (Hammerson 1999). It has been noted that in previous years, the populations of this species began to decline in Colorado (Hammerson 1999). The reasons for the population declines are currently unknown. However, periodic droughts, declines in local amphibian populations, and rapid development are suspected. Furthermore, rural communities north of Denver have undergone a rapid increase in human population. Many riparian and wetland areas that once contained high numbers of this species have been developed. In 2001, the Colorado Division of Wildlife (now CPW) listed the common garter snakes as a state species of special concern and has made it illegal to collect specimens without proper permitting (CPW 2016). The project area provides suitable habitat for the common garter snake and this species likely inhabits the project area, particularly in wet years. The proposed project could potentially affect common garter snakes if work is conducted within the wetland areas, primarily due to displacement from suitable habitat during construction.

**Recommendations**

ERO recommends implementing Conservation Measures (CMs) and Best Management Practices (BMPs) to avoid habitat and incidental take. Recommended CMs and BMPs include: 1) constructing the project during the winter when common garter snakes are inactive, minimizing the risk of incidental take of any random occurrence or movement of common garter snakes in the area; 2) confining clearing to the minimal area necessary to facilitate construction activities and confine movement of heavy equipment within designated areas and minimize impacts on habitat disturbance along stream and drainage channels and wetlands; 3) planning staging areas to be within nonnative upland areas; and 4) prior to construction activities, surveying the project area for common garter snakes. If a common garter snake is encountered during construction, ERO recommends activities cease until appropriate corrective measures have been completed or it has been determined that the common garter snake will not be harmed. After completion of construction activities, any temporary fill and construction debris should be removed and, wherever feasible, disturbed areas should be restored to pre-project conditions. Restoration work may include replanting species removed from impacted channels, banks, or wetland areas, or planting native vegetation in undisturbed areas for habitat enhancement. The listed CMs and BMPs would prevent long-term impacts on the species and minimize potential short-term impacts. If no activities would occur within the wetland areas, the proposed project would not likely adversely affect the common garter snake because suitable habitat would not be impacted.
Northern Leopard Frog

Species Background
The northern leopard frog is listed as a Colorado species of special concern (CPW 2016). This species typically inhabits the banks and shallow portions of wetlands, ponds, lakes, streams, and other permanent water bodies. The northern leopard frog occurs at elevations from 3,500 to 11,000 feet in Colorado (Hammerson 1999).

Habitat
Permanent water bodies including wetland and backwater areas are potential habitat for the northern leopard frog. During a site visit on July 22, 2016, several tadpoles were observed in a small backwater area in the western Emergency Watershed Protection (EWP) section of the project area. Although the tadpoles resembled those of northern leopard frogs, this could not be confirmed. Similar to the common garter snake, the proposed project could have potential short-term impacts on the northern leopard frog if construction activities occur within the wetland areas.

Recommendations
ERO recommends implementing the CMs and BMPs listed in the Common Garter Snake – Recommendations section to minimize adverse effects on the northern leopard frog. If no activities would occur within the wetland areas, the proposed project would not likely adversely affect leopard frogs because suitable habitat would not be impacted.

Locally Threatened, Endangered, and Species of Concern
Boulder County maintains a list of species of special concern (Boulder County 2013). The Boulder County Species of Special Concern List was created for the conservation and preservation of wildlife species and their habitat. Table X lists several species on the Boulder County Species of Special Concern List on which the proposed project could have potential impacts. It is likely that impacts on these species would be short-term because of the project goal to avoid and minimize impacts or enhance high-quality habitat, including wetland and riparian areas.
Table 11. Boulder County species of special concern potentially found in the project area or potentially affected by projects in the area.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Community Type¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mammals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gray Fox</td>
<td><em>Urocyon cinereoargenteus</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Least Shrew</td>
<td><em>Cryptotis parva</em></td>
<td>U, RC</td>
</tr>
<tr>
<td>Little Brown Myotis</td>
<td><em>Myotis lucifugus</em></td>
<td>RC</td>
</tr>
<tr>
<td>Meadow Vole</td>
<td><em>Microtus pennsylvanicus</em></td>
<td>RC, U, W</td>
</tr>
<tr>
<td>Myotis, Western Small-Footed</td>
<td><em>Myotis ciliolabrum</em></td>
<td>RC</td>
</tr>
<tr>
<td>Preblei’s Meadow Jumping Mouse</td>
<td><em>Preblei zapus hudsonius</em></td>
<td>RC</td>
</tr>
<tr>
<td>Uinta Chipmunk</td>
<td><em>Neotamias umbrinus</em></td>
<td>RC</td>
</tr>
<tr>
<td><strong>Birds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Bittern</td>
<td><em>Botaurus lentigenosus</em></td>
<td>W</td>
</tr>
<tr>
<td>American Redstart</td>
<td><em>Setophaga ruticilla</em></td>
<td>RC</td>
</tr>
<tr>
<td>Bald Eagle</td>
<td><em>Haliaeetus leucocephalus</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Band-Tailed Pigeon</td>
<td><em>Patagioenas fasciata</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Bobolink</td>
<td><em>Dolichonyx oryzivorus</em></td>
<td>W, U</td>
</tr>
<tr>
<td>Bushtit</td>
<td><em>Psaltria pratincola</em></td>
<td>RC</td>
</tr>
<tr>
<td>Cedar Waxwing</td>
<td><em>Bombycilla cedrorum</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Golden Eagle</td>
<td><em>Aquila chrysaetos</em></td>
<td>U</td>
</tr>
<tr>
<td>Golden-Crowned Kinglet</td>
<td><em>Regulus satrapa</em></td>
<td>RC, U, W</td>
</tr>
<tr>
<td>Lark Bunting</td>
<td><em>Calamospiza melanocorys</em></td>
<td>W, U</td>
</tr>
<tr>
<td>Lazuli Bunting</td>
<td><em>Passerina amoena</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Least Bitter</td>
<td><em>Ixobrychus exilis</em></td>
<td>W</td>
</tr>
<tr>
<td>Long-Eared Owl</td>
<td><em>Asio otus</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Northern Flicker</td>
<td><em>Colaptes auratus</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Northern Harrier</td>
<td><em>Circus cyaneus</em></td>
<td>W, U</td>
</tr>
<tr>
<td>Northern Mockingbird</td>
<td><em>Mimus polyglottos</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Ovenbird</td>
<td><em>Seiurus aurocapilla</em></td>
<td>RC</td>
</tr>
<tr>
<td>Pine Siskin</td>
<td><em>Spinus pinus</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Prairie Falcon</td>
<td><em>Falco mexicanus</em></td>
<td>U</td>
</tr>
<tr>
<td>Rough-Legged Hawk</td>
<td><em>Buteo lagopus</em></td>
<td>RC, U, W</td>
</tr>
<tr>
<td>Short-Eared Owl</td>
<td><em>Asio flammeus</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Veery</td>
<td><em>Catharus fusciscens</em></td>
<td>RC</td>
</tr>
<tr>
<td>Western Scrub Jay</td>
<td><em>Aphelocoma californica</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Willow Flycatcher</td>
<td><em>Empidonax traillii</em></td>
<td>W, RC</td>
</tr>
<tr>
<td>Wilson’s Warbler</td>
<td><em>Cardellina pusilla</em></td>
<td>RC, U</td>
</tr>
<tr>
<td>Yellow-Headed Blackbird</td>
<td><em>Xanthocephalus xanthocephalus</em></td>
<td>W, U</td>
</tr>
<tr>
<td><strong>Insects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Bumble Bee</td>
<td><em>Bombus pensylvanicus</em></td>
<td>U</td>
</tr>
<tr>
<td>American Emerald</td>
<td><em>Cordula shurtleff</em></td>
<td>W</td>
</tr>
<tr>
<td>Black and Gold Bumble Bee</td>
<td><em>Bombus auricomus</em></td>
<td>U</td>
</tr>
<tr>
<td>Cross-Line Skipper</td>
<td><em>Polites orijenes</em></td>
<td>U, RC</td>
</tr>
<tr>
<td>Dusted Skipper</td>
<td><em>Atrytonopsis hianna</em></td>
<td>U</td>
</tr>
<tr>
<td>Western Bumble Bee</td>
<td><em>Bombus occidentalis</em></td>
<td>U</td>
</tr>
<tr>
<td><strong>Reptiles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Garter Snake</td>
<td><em>Thamnophis sirtalis</em></td>
<td>RC, U, W</td>
</tr>
<tr>
<td><strong>Amphibians</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chorus Frog</td>
<td><em>Pseudacris triseriata</em></td>
<td>W</td>
</tr>
<tr>
<td>Northern Leopard Frog</td>
<td><em>Rana pipiens</em></td>
<td>W</td>
</tr>
<tr>
<td>Plains Spadefoot Toad</td>
<td><em>Spea bombifrons</em></td>
<td>U, W</td>
</tr>
</tbody>
</table>

¹U= Uplands; RC = Riparian Corridor; W = Wetlands.
iv. **Raptors and Migratory Birds**

**Regulatory Background**

Migratory birds, as well as their eggs and nests, are protected under the MBTA. While destruction of a nest by itself is not prohibited under the MBTA, nest destruction that results in the unpermitted take of migratory birds or their eggs is illegal (Service 2003). The regulatory definition of a take means to pursue, hunt, shoot, wound, kill, trap, capture, or collect; or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect (50 CFR 10.12).

Under the MBTA, the Service may issue nest depredation permits, which allow a permittee to remove an active nest. The Service, however, issues few permits and only under specific circumstances, usually related to human health and safety. Obtaining a nest depredation permit is unlikely and involves a process that takes from four to eight weeks at a minimum. The best way to avoid a violation of the MBTA is to remove vegetation outside of the active breeding season, which typically falls between March and August, depending on the species. Public awareness of the MBTA has grown in recent years, and most MBTA enforcement actions are the result of a concerned member of the community reporting a violation.

**Potential Habitat and Effects**

A wide variety of bird species use different habitat types in the upland, riparian, and wetland habitat along South St. Vrain Creek for shelter, breeding, wintering, and foraging at various times during the year. Riparian vegetation, wetlands, and upland grasslands and shrublands within and adjacent to the project area are potential nesting habitat for migratory birds.

Some of the most common birds observed in the region include cliff swallow, red-winged blackbird, mallard, American robin, and mourning dove.

Wetland habitats typically support and provide nesting habitat for common yellowthroat, song sparrow, red-winged blackbird, and yellow-headed blackbird. Riparian vegetation supports several avian species including the yellow warbler, western wood-pewee, Bullock’s oriole, American goldfinch, house finch, and American robin. Shorebirds and waterfowl species such as the killdeer, mallard, double-crested cormorant, and great blue heron are common around lakes and rivers.

Raptors potentially occurring in or adjacent to the project area include the red-tailed hawk, great horned owl, Northern harrier, American kestrel, osprey, rough-legged hawk, merlin, sharp-shinned hawk, and Swainson’s hawk (Boulder County 2013).

**Recommendations**
To avoid destruction of potential migratory bird nests, vegetation including grasslands, riparian vegetation, and wetlands should be removed outside of the April 1 through August 31 breeding season. If active nests are identified within or near the project area, activities that would directly affect the nest should be restricted. Habitat-disturbing activities (e.g., tree removal, grading, scraping, and grubbing) should be conducted in the nonbreeding season to avoid disturbing active nests or to avoid a “take” of the migratory bird nests within the project area. Nests can be removed during the nonbreeding season, September 1 through March 31, to preclude future nesting and avoid violations of the MBTA. There is no process for removing nests during the nonbreeding season; however, nests may not be collected under MBTA regulations. *If the construction schedule does not allow vegetation removal outside of the breeding season, a nest survey should be conducted prior to vegetation removal to determine if the nests are active and by which species.*

Should an active raptor nest occur on or within ⅓ mile of the project area, ERO recommends compliance with the CPW temporal and spatial recommendations. Activities that would directly impact an active nest, or that would encroach close enough to cause adult birds to abandon the nest during the breeding season, should be restricted. Consultation with CPW or the Service may be required if construction is proposed within a buffer zone of an active raptor nest. *Although there is no CPW buffer designated for great horned owls, any active owl nests should be left undisturbed until the birds have left the nest.*

### v. Other Sensitive Species Habitat and Natural Resources

#### Mule Deer and Elk

Although mule deer and elk are most commonly found in upland or riparian shrublands, both species are known to occur within almost all available habitat types including open grasslands. The project area is within the overall ranges of mule deer and elk. Mule deer change their habitat use patterns. Although elk are less common than mule deer at lower elevations, they are known to occur along foothill riparian corridors.

The project area is located in mule deer overall range as well as summer range, winter range, and winter concentration areas and elk winter range (NDIS 2016). It is likely that mule deer and elk forage or migrate through the project area; however, no designated wildlife corridors were mapped in the project area (NDIS 2016). No deer or elk were observed during the July 22, 2016 site visit.

#### Other Mammals

The project area provides habitat for a variety of small mammals such as cottontail rabbits (*Sylvilagus* sp.), deer mice, voles, and pocket gophers. Carnivores such as coyotes, raccoons (*Procyon lotor*), red and grey foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), and striped skunks (*Mephitis mephitis*) are also likely to occur in the project area. These species are typically observed in open grasslands and close to riparian corridors. Additionally, the project area is within the overall range of mountain lion (*Puma concolor*) and black bear (*Ursa americanus*) (NDIS 2016). It is likely that impacts on these species would be short-term because of the project goal to avoid and minimize impacts or enhance habitat, especially in wetland and riparian areas.
10. Alternatives, Alternative Analysis and Preferred Alternative

a. Alternatives

The alternatives developed as part of this project have been developed by using multiple constraints and criteria. These constraints and criteria were developed into a Decision Making Process Diagram and Decision Matrix that was presented at the June 30 public meeting and is also attached in Appendix X – Decision Making Process Diagram and Decision Matrix.

Numerous visits with the landowners and members of the Coalition have taken place to develop the alternatives for this project, including one-on-one, on site meetings with landowners throughout the corridor. The design team has attended a Coalition supported working group meeting (May 11, 2016) along with two presentations to the Coalition (May 25, 2016 and June 29, 2016) and two presentations to the public (May 24, 2016 and June 30, 2016) with regard to this project.

Having two to three “alternatives” for the entire 3.2 mile reach would not meet the goals of this project, nor would it propose a resilient design that can be implemented. The fact that this project is composed of a 3.2 mile reach of the South St Vrain Creek from above the andesite quarry down to the eastern Old South St. Vrain Road Bridge means that to develop an implementable preferred alternative it is essential to first look at the system as a whole and develop a strategy to prioritize the most important improvements the entire system.

The alternatives developed as part of this prioritization process can then be broken down further into sub-reach sections of the of the project and individual elements can be evaluated based on the overall approach for the entire 3.2 miles.

Therefore our team developed issue and reach based alternatives that addressed the specific concerns for various sub-reaches and the system as a whole. The main issues facing the corridor are dis-connection of the floodplain from the channel, minimal instream structures for geomorphically effective bedforms and habit, lack of vegetation to support a diverse ecosystem, and risk of infrastructure to future flooding. The four alternatives developed to address each of the aforementioned issues are Floodplain Connectivity, Channel Complexity, Revegetation and Infrastructure Protection, respectively.

Floodplain connectivity involves activating the floodplain at frequent intervals to enable critical floodplain functions, including:

- Sediment storage
- Reduction of erosive forces in main channel
- Nutrient transfer
- Healthy riparian/wetland ecosystem

Strategies used to illustrate floodplain connectivity in the alternative include:

- Activating overflow channels
- Incorporating channel/floodplain benching (sediment removal)
Channel complexity refers to channel features that contribute to geomorphically effective bedforms, as well as habitat quality and diversity. These features include:

- Low Flow Channel
- Pools, riffles, steps
- Bars (point, lateral, mid-channel)
- Large woody material (bank protection/habitat enhancement)
- Roughened channels/boulder clusters

Revegetation will provide the framework for increased ecosystem function and aesthetic appeal along the corridor. Our team presented strategies that include:

- Protecting and preserving existing stands of vegetation.
- Incorporating bioengineering measures to increase habitat maturation and resiliency.
- Planting a diverse palette of native plant species.

Infrastructure Protection includes the protection of key infrastructure elements and onsite item that are considered “assets” to the corridor. Infrastructure elements include:

- Roads
- Bridges
- Houses
- Ditches

Strategies presented for infrastructure projection include:

- Bank Stabilization
- Bioengineering
- Buried Rootwads
- Offset Buried Natural/Structural Aspects
- Buried Riprap Revetment
- Buried Boulders
- Structural Walls
- Channel Alignment: In-depth Analysis Required
- Slope, Sinuosity, Wavelength, Belt Width
- Detention
- Cost

These alternatives and the location of each alternative were presented at the public meeting on June 30th with a PowerPoint presentation to explain each alternative and the benefit of each alternative along with their location on aerial roll maps, which were available for the public to view. Meeting participants had an opportunity to ask questions and comment on each alternative and its location. These comments were compiled into Addendum X (South St. Vrain Comments) and recommendations were incorporated into the preferred alternative.
Following the public meeting on June 30th, a robust alternative analysis process analyzed both qualitative input from the public and quantitative technical data to prioritize aspects of each of the alternatives. By using the alternative analysis process and prioritization methods, the design team was able to place emphasis on the aspects of each alternative that most closely represented the desires of the public and stakeholders to produce a resilient preferred alternative.

b. Alternative Analysis

i. Decision Making Process

To develop and analyze the initial alternatives the design team first synthesized the goals laid out in the RFP, Grant Request and Masterplan into a project goals statement that can be found in Section 3.b of this document.

Six core values were identified from this project goals statement and they formed the categories in which the public comments were organized. The six core values for this project are:

- Community
- Resiliency
- Safety
- Environment
- Implementation
- Schedule

An intensive public outreach took place to gather public and stakeholder input for the project as well as to compile comments that had been collected prior to the beginning of this project. Almost two hundred comments had been collected during this process and they are attached in Addendum X (South St. Vrain Comments). The comments that were collected were then distilled into critical issues that represent the key concerns and desires the public and stakeholders have for this project. It was these critical issues that ultimately drove the development of seventeen questions that created the prioritization criteria.

The prioritization criteria are a series of questions that best encapsulated the critical issues for the public and stakeholders. These questions were incorporated into a Decision Matrix that allowed the design team to determine how each alternative address the concerns public and stakeholders.

Together the project goals statement, core values, critical issues from stakeholder comments and the prioritization criteria were developed as a tool to allow the public and stakeholder process impact the strategies that ultimately made up the preferred alternative. The decision making process was critical to the design team developing a design that incorporated the most important public and stakeholder issues into a technically sound and implementable design.

c. Prioritization of Projects/Alternatives

i. Decision Matrix

A decision matrix was developed as a prioritization tool used to determine the amount of emphasis that should be placed on each of the alternatives that were developed. This system has been used successfully on multiple complicated and high profile projects in the past, including the I-70 Mountain Corridor Context Sensitive Solutions, the Upper Fountain and Cheyenne Creek Watershed Masterplan and the Monument Creek Watershed Masterplan.
The decision matrix allowed the design team to use the prioritization criteria that was developed as part of the decision making process to rank each of the alternatives on a scale of “best, better and fair”. Each alternative was analyzed by the design team, with input from Boulder County, and given a ranking and description based on how they applied to the prioritization criteria. The alternative that had the most “best” answers represented the alternative that met the majority goals developed during the public process.

For this project, floodplain connectivity ranked the “best”. That means that the majority of the design emphasis and funding allocation was placed on strategies that reconnect the floodplain because that is the approach that best met the goals of the project and provided the greatest impact for restoration and resiliency. While floodplain connectivity received the most emphasis for the development of the preferred alternative aspects of channel complexity, revegetation and infrastructure protection were also included in the preferred alternative but were not emphasize to the degree that floodplain connectivity was.

d. Preferred Alternative

Based on the alternative analysis presented in the previous section, an emphasis for the preferred alternative was placed primarily on floodplain connectivity, secondarily on revegetation, thirdly on channel complexity, and infrastructure protection was incorporated in select areas. The main channel alignment will remain in its existing flow path for the majority of the project reach, with the exception of three locations (vicinity of the quarry, vicinity of Hall property, and vicinity of Redmond property). Given the dynamic nature of the project reach, as discussed in Section 7 Geomorphology, in most locations there is not necessarily a preferred alignment from a geomorphic standpoint, the channel will move laterally across the valley as it adjusts to the incoming discharge and sediment load. In the locations where infrastructure is at stake, the channel alignment can be located to minimize the risk the infrastructure, but with the inherent understanding that in larger flows the channel will adjust. Additionally, design calculations suggested that it is possible to achieve equilibrium channel dimensions with the current alignment. Therefore, considerable construction budget can be re-purposed for other aspects of the restoration.

The biggest component of the proposed design to increase floodplain connectivity is the incorporation of overflow channels. These channels are activated at frequent flows (1.5-yr recurrence interval flows) and moderate flows (5-yr recurrence interval flows), for multiple purposes including reducing erosive forces within the main channel, activating the adjacent floodplain, and functioning as depositional areas for the sediment loads coming from upstream. Establishing connections to existing overflow channel paths that are disconnected at frequent recurrence intervals will restore the sediment storage function of the alluvial valley considering the mainstem alignment is disconnected from the floodplain in many locations in the project area. The proposed overflow channel alignments were selected almost exclusively based on existing flow paths, which will limit the amount of grading and vegetation disturbance and conserve construction funds. A summary of key features of the preferred alternative for the entire project reach is presented below (broken out by subreach) starting with upstream and moving downstream.

(To Do: Section to be expanded to discuss managing sediment, revegetation, and channel complexity)

i. Upstream Reach (R8)
   o Minor regrading of right floodplain at inside of bend, and revegetation
   o Addition of wood structures to aid in bank stability and initiation of pool formation
o Keep pre-flood alignment as overflow channel (minimal grading necessary, considering channel is already at a low elevation)

ii. Vicinity of Quarry (R7 and R6)
   o Main channel will be realigned to mimic historical alignment pre-mining (upstream portion) and pre-flood alignment (downstream portion)
     - Existing flow paths through floodplain will be utilized to minimize grading
     - Other existing flow paths will be utilized as overflow channels (activated at approximately 1.5- and 5-yr flows), including existing channel (some fill will be necessary, and potential for grade control to initiate natural sediment deposition)
   o Addition of wood structures to aid in bank stability and to initiate pool formation
   o Extensive floodplain grading – especially in the upstream portion of the reach. Excess fill may be place in the current channel alignment and perhaps utilized in the mine reclamation effort.
   o Extensive revegetation
   o Potential offset buried riprap for the private parcel (depending on buy-out situation)
   o Potential reestablishment of Otto diversion at base of vertical andesite walls

iii. Vicinity of Bedrock Bend (R5):
   o Addition of wood structures to aid in bank stability, initiate pool formation, and direct flow toward overflow channel
   o Create overflow channel to activate the extensive left floodplain (at approximately 5-yr flows) and reduce hydraulic forces near the proposed road alignment at higher flows.
   o Grade right and left banks to create floodplain benches

iv. Vicinity of Hall Property (R4)
   o Reactivate pre-flood channel as main channel and keep existing alignment as overflow channel (activated at approximately 5-yr flows)
     - The pre-flood channel, at the upstream end, has already started recovering with a young riparian corridor – would need to widen existing channel, but will minimize amount of disturbance to existing vegetation
     - Enhance pool-riffle morphology in pre-flood channel with grading and the addition of wood structures to aid in the initiation of pool formation
   o Grade the vertical left bank upstream of structures and revegetate
   o Utilize the existing riprap on the left bank as offset protection – bury and revegetate
   o Overflow channel (activated at approximately 5-yr flows) in the left floodplain requires some grading at the upstream end to activate the existing flow path at the downstream end
   o Grading and removal of floodplain deposits to create benching
   o Extensive revegetation
   o Addition of wood structures in specific locations to aid in initiation of pool formation

v. Vicinity of Proposed Bridge (upstream R3)
   o Upstream of proposed bridge, an existing group of downed trees has created a functioning pool (with a riffle up and downstream of the pool), enhancement and stabilization of the existing wood
structure is proposed, as well as an additional structure further upstream on outside of channel bend
  o Grading/removal of excess flood deposits to create lower elevation floodplain benching (mostly on right floodplain)
  o In the existing eroded bank/scar area downstream of the proposed bridge, coarse fill should be pushed up against the toe of the existing bank (and larger boulder material) and grading/revegetating the area

vi. Vicinity of Redmond/Blackwell (downstream R3)
  o In upstream portion of reach, enhance instream complexity and address over widened condition with boulder clusters and enhanced riffles
  o Reactivate the pre-flood channel and keep the existing alignment as an overflow channel (active at approximately 1.5-yr flows); grade/enhance pool-riffle morphology in the re-activated channel. It should be noted that the work limits of the EWP project may require that the main channel remain in place.
  o Activate an overflow channel through the right floodplain (activated at approximately 5-yr flows)
  o Addition of wood structures in specific locations to aid in bank stability and initiation of pool formation
  o Grading of both right and left floodplain areas to remove excess sediment and create floodplain benching

vii. EWP Reach 1 (R2)
  o Across from Hall Ranch trailhead – grade right bank to alleviate confinement in this portion of the reach (repurpose existing andesite boulders)
  o Addition of wood structures are proposed in specific locations to aid in bank stability and initiate pool formation
  o Overflow channel on the left floodplain, upstream of the private parcels, is an existing overflow that will be activated at the approximately 5-yr flow. There is an existing berm on the left bank of the overflow channel that will not be modified.
  o Overflow channels in the right floodplain were selected based on existing flow paths, therefore grading will be minimal, although some grade control will be necessary
    ▪ The southernmost overflow channel activates previous flow path and routes through wetland area. Flow would exit wetland area into several existing flow paths and into the existing ditch/flow path adjacent to Old S St. Vrain Rd. during an approximately 1.5-yr event. The ditch adjacent to the road has some existing bedforms/grade control created as part of the South Ledge/Meadows ditch project – to hold grade where the pipe crosses under the channel, but additional controls should be added in the upstream portions of the alignment.
      ▪ Multiple activation points on the upstream end of overflow channels provides alternative flow paths if one path plugs with sediment
    ▪ The middle overflow path skirts around the wetland area and would be activated at approximately the 1.5-yr flow events)
- The northernmost (downstream) overflow channels (close to the main channel alignment) follow existing flow paths and would be activated at the approximately 1.5-yr flow events
  - Minor riffle enhancement is necessary mid-reach, but otherwise riffles already exist within most of this reach and will be supplemented by the addition of wood structures in specific locations to initiate pool formation (Stability of riffles will be analyzed and riffle crests will be enhanced with larger rock to provide bed grade control, if necessary)
  - Existing main channel split flow alignment will remain
    - At bend – bank protection would be needed (does not exist at this point – need to modify note in dwg)
  - Just downstream of South Ledge/Meadows diversion, an additional wood structure is recommended for bank stabilization

viii. Vicinity of the Longmont Diversion (upstream R1)
  - Upstream of diversion, the main channel will remain in existing alignment and abandoned main channel will become an overflow channel (activated at approximately 5-yr flow). Minimal grading will be needed for the majority of the overflow channel with the exception of the upstream approximate 8-foot tall sediment plug (which will need to be removed and regraded/revegetated)
    - Bank protection will be necessary at outside bend of overflow channel (adjacent to Hwy), currently the bank consists of unstable riprap. Recommend benching and revegetating
  - Right bank upstream of diversion (adjacent to Old South St. Vrain Rd) consists of riprap (and some other debris still buried), vegetation has started to establish, but could be supplemented with additional willow staking.
  - Left bank upstream of diversion is mostly bedrock, but upstream of the bedrock the bank is currently unstable and will require bank stabilization
  - Existing channel downstream of diversion will remain as the low flow channel.
    - Wood structures are being proposed in specific locations to aid in bank stability, but also to initiate pool formation
  - Overflow channel on the outside of the bend (downstream of the diversion; activated at approximately 5-yr flow) will only need minor grading (flow path already exists throughout most of this alignment).
    - Existing underground pipe on the downstream end of the overflow channel will need to be located to ensure protection
  - Grading of the remaining floodplain to allow for lower elevation benching and revegetation.
  - Buried offset protection is recommended for the existing ditch infrastructure just downstream of diversion (box and ditch)
  - A berm exists on the outside of the bend, therefore no additional offset protection is necessary on the outside of the bend, besides some additional revegetation along portions of the berm.

ix. EWP Reach 2 (downstream R1)
  - Wood structures proposed at upstream end to initiate pool formation
  - Regrade the bar upstream of the bridge (remove sediment and create benches) and revegetate as necessary
o Potential for channel realignment upstream of bridge (flow path already exists in this location)
 o Riprap embankment on right bank is pushed out into the flow causing even more of a constriction, it is recommended to pull back the riprap and a portion of the upstream fill to increase conveyance through the bridge
 o Potential overflow channel on downstream side of Old S St. Vrain Rd that could return to the creek downstream, if capacity exists (construction of overflow channel would not covered under EWP funding and would need coordination with the EWP project downstream).
 o (To Do: Section to be evaluated further)
e. Prioritization of Projects/Alternatives

While a portion of the proposed plan will be implemented under the EWP program funding, prioritization of other potential projects along the reach have been conducted to allow for a plan to move forward once the EWP construction is complete. Evaluations at this level are very much qualitative.

(To Do: Priority Areas to be evaluated : Andesite Quarry, Longmont Diversion, Reach Between Old St Vrain Bridge Repair and EWP #1, Reach Between EWP #1 and EWP #2)

11. Meeting Notes

The design team engaged in two public meetings to receive input from the public and stakeholders about key project elements at different phases of the design.

This first public meeting, on May 24, 2016, was for the purpose of providing information to the community about the project team and project process. The project team facilitated an open discussion for the public to voice concerns and issues that they would like to see addressed by this project. These issues were be categorized to form the decision making process information and the evaluation criteria the design team used to evaluate the alternative design strategies for the restoration of the creek.

The purpose of the second public meeting, on June 30th, 2016, was to present the public with four alternatives and explain the prioritization process by which the design team developed each alternative and how they will be evaluated and combined into a final preferred alternative.

For a full overview of both meetings please see Appendix X – Public Meeting Minutes

12. 30% Design Plan Set

A set of plans evaluating the entire 3.2 mile reach of South St Vrain Creek has been developed to the 30% design level as part of this project. Design guidelines from DOLA, BCPOS, SVCC, and NRCS were followed as the basis for these designs. Review of these plans were completed by BCPOS, DOLA, SVCC, and the EWP at a 15% level to get approval on the major design elements prior to finalizing the drat 30% plans. Draft 30% plans were also submitted to DOLA, EWP and BCPOS for acceptance prior to final design.

These plans include existing conditions as surveyed in the field along with information acquired from BCPOS and other sources. Exiting conditions plans took into account existing projects along this reach along with including proposed design elements through other projects that will be constructed in the near future. Existing topography was developed from LiDAR and ground survey from multiple sources. Existing channel thalweg was evaluated and used in this design from actual ground survey.

From the existing conditions plans, proposed conditions plan elements were designed. These proposed elements include overflow channels at various recurrence intervals, floodplain benching, bank stabilization, buried riprap revetment, and channel complexity aspects to name a few. The design plans also include revegetation aspects in the form of a planting plan. A proposed conditions grading plan was developed based upon multiple new channel alignments and profiles along with various cross sections that were modeled with the use of 3D computer aided drafting techniques. The entire 3.2 mile extents of our project are shown in plan and profile views at a 1”=50’ scale.
Main Channel Planform

As described in Section Error! Reference source not found. (Geomorphology), the majority of South St. Vrain Creek through the project reach can be characterized as a single-thread channel with a meandering planform. A few short segments have split flow paths and minor braiding. The 2013 flood event resulted in significant modifications to the planform throughout the project area, but previous emergency stream improvements have already returned much of the creek to its pre-flood position.

The proposed planform is very similar to the existing condition through most sub-reaches. In some areas, the main channel has been realigned to increase channel sinuosity. Multiple overbank flow paths have also been proposed to significantly improve floodplain connectivity during higher flow events, as described in the Overflow Channel Design section below. These alterations are expected to decrease the risk to critical infrastructure by reducing the shear stresses on the banks. The channel realignment also helps to shape channel structure, which will improve habitat and increase sediment storage in the stream corridor.

Main Channel Profile

The South St. Vrain Creek project reaches have average existing bed gradients ranging between 1.0% and 2.35%. An equilibrium bed slope analysis was performed to assess the stability of the existing channel and determine if longitudinal profile adjustments were needed. The equilibrium bed slope was predicted for each design reach using Shields method for incipient motion for the median grain size. The equilibrium bed slope methodology is detailed in Technical Supplement 14B of the National Engineering Handbook part 654 from the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS, 2007). The design calculations for these analyses can be found in Appendix X. The results of the equilibrium bed slope analysis, coupled with the findings from the sediment transport analysis completed as part of the Expanded Study (Otak, 2016), informed the profile design for the proposed alignment.

Channel and Floodplain Dimensions

The proposed cross-section geometry will be modified in select locations to improve river function, flood conveyance, aquatic habitat, and facilitate fish passage. A multi-stage channel cross section was designed for a large portion of the project area to restore river processes (i.e., increase flood frequency in the overbank and bench areas, deposit sediment along the margins of the channel) and accommodate flows from low flow to moderate flood events. To limit channel impacts, instream grading is generally only proposed for realigned segments of channels and in the vicinity of proposed riffle-pool structures.

To the extent possible, the channel geometry was designed so the 1.5-year discharge could be conveyed by the bankfull channel. Hydraulic geometry equations for streams in Colorado (Andrews, 1984) and elsewhere (Hey and Thorne, 1986) were compared and used for estimating bankfull geometry—width and mean depth. The formula for bankfull width is a power equation in the form w=aQ^b. The variable “a” depends on factors such bank vegetation, bank cohesion, and sediment load. Given the characteristics of the project site, the bankfull geometry was calculated with the assumption of relatively thin bank vegetation. The variable “b” is a fixed value with a narrow range between 0.48 and 0.50.
A range of bankfull widths and depths were calculated for straight segments of channels, meanders, and transition reaches, using both sets of equations. The results are shown in Error! Reference source not found.. The equations and calculations for these analyses can be found in Appendix X.

**Table 12. Proposed Bankfull Channel Geometry**

<table>
<thead>
<tr>
<th>Description</th>
<th>Top Width (ft)</th>
<th>Bed Width (ft)</th>
<th>Max. Depth (ft)</th>
<th>Bank Slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight Reach</td>
<td>40 - 55</td>
<td>31 - 44</td>
<td>2.1 - 2.5</td>
<td>3:1 - 5:1</td>
</tr>
<tr>
<td>Transition Reach</td>
<td>40 - 55</td>
<td>N/A</td>
<td>2.1 – 4.4</td>
<td>3:1 - 5:1</td>
</tr>
<tr>
<td>Meander Reach</td>
<td>40 - 55</td>
<td>N/A</td>
<td>3.6 – 4.4</td>
<td>3:1 - 5:1</td>
</tr>
</tbody>
</table>
The bankfull channel was designed to include a “low flow” channel that concentrates stream flow to improve habitat quality and facilitate fish passage during periods with lower discharge. The low flow channel was sized to convey the baseflow (~25 cfs), and the geometry is summarized in Error! Reference source not found..

Proposed design elements also include floodplain benches along one or both banks to maximize flow conveyance. These benches will typically be activated at the 1.5-year design flow. The floodplain benches were proposed to be graded at a 50:1 h:v slope and the bench widths will vary depending on the space available. The upper slopes would have a typical grade of 4:1 h:v slope to tie into the existing ground.

<table>
<thead>
<tr>
<th>Description</th>
<th>Top Width (ft)</th>
<th>Typ. Depth in Straight Reach (ft)</th>
<th>Typ. Depth in Meander Reach (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Flow Channel</td>
<td>26 - 32</td>
<td>0.76</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Table 13. Proposed Low Flow Channel Geometry**

**d. Bed Morphology/Riffle Structure Design**

As described in Section Error! Reference source not found. (Geomorphology), the bed morphology in the existing project reach was dominated by long extended riffles followed by few shallow pools. The stream design aimed to improve hydraulic complexity with the creation of pool-riffle morphology in specific locations with more pronounced riffles and deeper pools. This type of morphology is commonly found in natural coarse-bed systems with similar bed gradients. The riffle and pool sequences are expected to improve aquatic habitat, stabilize the longitudinal bed slope, and dissipate instream energy, which ultimately reduces erosive forces on the banks.

Riffles consist of channel-wide accumulations of larger cobbles and boulders, and transitions into either a lower gradient run or directly into a pool. Water depth is relatively shallow over the riffle, and the slope is steeper than the average channel slope. At low flow, water accelerates over the riffle, mobilizing finer sediments, keeping interstitial spaces in the channel substrate clean, and oxygenating the water. Energy is dissipated through tumbling flow and grain roughness.

Riffles are generally spaced at 5-7 bankfull channel widths apart in natural channels (NRCS, 2007). Given the average design width of 48 ft for the bankfull channel (Error! Reference source not found.), riffle spacing was calculated to be between 240 to 336 ft for this reach of South St. Vrain Creek, with an average spacing of 288 ft. When feasible, existing riffles will be enhanced to minimize earthwork and locate the structures in areas they would be more likely to naturally persist.
The design of each riffle structure includes three distinct sections: a ramp, a boulder crest, and the riffle face. Short ramps are constructed on the upstream end of the riffle to transition the bed grade between the existing channel elevation and the proposed riffle crest elevation. The structure accommodates ramp slope adjustment over time as additional substrate is trapped immediately upstream of the constructed riffle. The crest of the riffle consists of a collection of larger boulders that serve as grade control and help shape the flow path through the riffle. The crest has a “V-shape” that points slightly upstream and slopes towards a low flow path in the center of the channel. This geometry directs flow away from the bank and helps maintain the shape of the riffle. The crest rock is keyed into the bed, floodplain benches, and upper banks to reduce the risk of the stream avulsing to a new flow path and/or flanking the structure. The riffle face was designed to have a bed gradient ranging from 3 to 4%, defaulting to shorter, steeper riffle faces that would scour deeper pool habitat at the base of the riffle face.

Pools are proposed downstream of the riffles in areas where a pool is expected to form naturally. These pools are designed to have deeper water depth than the average channel and have a water surface with very little slope at low flow. The pools will likely shift position slightly in the future as the pool geometry will continuously be shaped by bed scour during high flows. At low flow, the pools will act as a depositional feature, temporarily storing fines, sediments, and organic matter. Depth and slope increase over the pools during larger flow events, increasing shear stress, initiating scour that mobilizes fine materials.

Each riffle crest will be designed to remain stable during a 100-year design flow. The limited supply of boulders from the upper watershed may not be able to replenish the necessary size rock to fill in voids in the riffle crest if these larger rocks are mobilized. To reduce future maintenance requirements, and increase the probability of long-term stability in the riffle structures, the minimum rock size in each riffle crest was designed to remain stable using Shield’s method of incipient motion (NRCS, 2007) with a factor of safety of 1.5. The hydraulic design parameters at each riffle will be based on the SRH-2D model of the proposed conditions. The proposed riffle crest boulders for the riffles located between Sta XX+XX and Sta XX+XX will range in diameter from XX to XX inches, with a median grain size of XX inches. The riffle crest boulders for the proposed riffle at Sta XX+XX ranged in diameter from XX to XX inches, with a median grain size of XX inches.

(To Do: Section to be update with applicable information not shown)

A summary of the design parameters and median grain sizes for each section of the riffle are shown in Table 14.
**Table 14 Proposed Riffle Design Parameters**

<table>
<thead>
<tr>
<th>Section</th>
<th>Length (ft)</th>
<th>Longitudinal Bed Slope</th>
<th>Width</th>
<th>Rock Depth (ft)</th>
<th>Median Grain Size (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp</td>
<td>5 - 10</td>
<td>10 - 20% up</td>
<td>Bankfull Channel</td>
<td>2</td>
<td>TBD</td>
</tr>
<tr>
<td>Crest</td>
<td>3 - 4</td>
<td>0%</td>
<td>Tie 5 ft into bank</td>
<td>3 - 4</td>
<td>TBD</td>
</tr>
<tr>
<td>Riffle Face</td>
<td>TBD</td>
<td>2 - 5% down</td>
<td>Bankfull Channel</td>
<td>2</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Larger habitat boulders are proposed to be placed in the riffles and pools to increase channel roughness and provide alternate migration paths and resting areas for a variety of fish species and sizes. It is expected that the habitat boulders will shift slightly but not move any appreciable distance during a flood event with a recurrence interval of 100 years. The required size of the boulders was determined using Shield’s method of incipient motion (NRCS, 2007) with a factor of safety of 1.5. The proposed habitat boulders ranged in size from 2 to 4 ft in diameter. A minimum of one-third of each boulder will be embedded in the channel bed to increase sliding resistance. In several areas, clusters of boulders may be appropriate to encourage stream flow to either diverge or converge, depending on the water depth, to increase the presence of micro habitat.

The remaining segments of the channel that are adjacent to the riffles and pools will function as runs. In general, minimal in-channel earthwork is proposed in these sections other than the construction of a low flow channel. Most runs have a longitudinal bed slope similar the existing channel, which was predicted to be stable, therefore the available sediment supply is expected to replenish the substrates that will be periodically transported out of the runs. Fine sediments will either deposit along the channel margins or will be able to pass through the stream as wash load.

Detailed riffle design formulas and calculations are included in Appendix X, and additional details are shown on the design plan set in Appendix X. The methods for rock sizing are further described in the National Engineering Handbook part 654, Technical Supplement 14C, from the Natural Resources Conservation Service (NRCS 2007).

(To Do: Analysis and design are still in progress and section will be update.)

e. **Overflow Channel Design**

Overflow channels were designed to re-establish the overbank area as functioning floodplain and better protect assets in the vicinity. Planform alignment and channel dimensions were chosen as a function of available space and where flow paths currently exist. The elevation of the overflow channels were set to engage between the 1.5- and 5-year flows, with a minimum width of 20 feet. Typical overflow channel bed gradients are similar to the existing floodplain gradient along the chose path, although adjustments were made to further improve floodplain connectivity where possible. Bank heights were minimized to provide flood flow relief into the floodplain.
Incipient motion analyses and riprap sizing calculations will be completed to evaluate and select the appropriate size of rock to line the bed and banks of the overflow channels. Where necessary, grade control will be provided in the form of bed sills in areas that may be susceptible to erosion that may result in an unacceptable risk to adjacent infrastructure, private property, or wetlands.

(To Do: Bed sill rock gradation methods will be added prior to final deliverable)

f. Large Wood Structure Design

Nearly sixty large wood structures are being proposed throughout the project area to enhance aquatic habitat and deflect flows away from actively eroding banks. Two types of log configurations, referred to as Type A and Type B structures, are being proposed in locations suitable for large wood accumulations, with the purposes of scouring pool habitat and deflecting flows. The Type B structure is designed with bank protection as a primary goal, and the Type A structure is intended to increase hydraulic diversity downstream of the riffle. These structures are proposed in areas where pools are expected to form naturally, and these structures are expected to encourage bed scour to increase the pool depth.

Despite the restricted access for recreational users in the reach, safety concerns for river users were considered during the design of all large wood structures. Most logs will be positioned close to the bank so there is a low probability that the structures will recruit other mobile logs in the future which could act as “strainer” logs.

Type A structure (pool scouring) is designed with nine logs stacked in two levels, and a footer log placed at the toe of the bank to reduce the risk of the structure being undermined by scour. The logs have rootwads that are exposed to flow with stems embedded in the bank. The rootwads will be set flush with the streambank to reduce the hazard to boaters.

Type B structures could be placed next to each other in order to deflect flows away from bank on the outside meander bend. Type B structures consist of eight logs stacked in three levels. The rootwads of all eight logs project into the flow to maximize the area of the bank that will be protected. The Type B structure is designed to allow some flexibility when selecting individual log sizes in the field.

The identified source of logs for this project is a stockpile of cottonwood trees. Cottonwood is considered to have a short engineering design life, particularly when the wood goes through a repetitive wetting and drying cycle. Although the logs will likely decay within a few years, they are expected to provide bank protection long enough for mature woody vegetation to establish. Rock toe protection is proposed in the vicinity of the wood structures to provide additional long-term bank protection.

Each type of log structures will be designed to remain stable during a storm event with a XX-year recurrence interval. In order to resist hydrodynamic forces, the logs will be primarily stabilized using soil ballast through partial burial. Where necessary, boulders can be added as a secondary measure to provide additional resistance to buoyancy. Each structure type will be designed to have a minimum factor of safety of 1.5 for vertical, horizontal, and moment forces. The stability evaluation calculations follow the methodology described in USFS Technical Note 103.1 (Rafferty, 2016). Detailed log stability calculations are included in Appendix XX, and additional details are shown on the design plan sets in Appendix XX.

(To Do: Analysis and design are still in progress and section will be update.)
g. Emergency Watershed Protection Program

Included with the entire 3.2 mile reach are plan sets focusing on the EWP eligible project areas. These plans are at a scale of 1"=30’ to allow for greater detail and easier transition to construction. Some elements included with the 3.2 mile reach evaluation might be removed or modified due to the limitation of funding on certain aspects or the limits within the corridor of approved permitting through the EWP team.

(To Do: Further guidance and design information on the EWP reaches will be developed)

h. Bank Stabilization Aspects

(To Do: Analysis and design are still in progress and section will be updated.)

i. Revegetation Recommendations

The design team recommends strategies that will preserve the existing stands of healthy vegetation on site, re-establish denuded areas and mitigate for future flood events through grading measures and bio-engineering solutions.

Existing healthy stands of mature vegetation will be preserved by limiting large disturbances measures in their immediate proximity. Special care will be given to minimize grading efforts in these “areas of preservation” and design solutions will be developed around the pre-existing habitat. This will not be possible in all cases but a site specific approach will be taken to preserve areas that survived the floods and continue to hold ecologic value.

The plant communities that survived the 2013 floods will also be expanded to increase habitat corridors and create linkages for plant communities and terrestrial species to spread throughout the site. Revegetation efforts will focus on identifying and growing the areas to increase these productive ecosystem into denudes or disturbed areas.

Revegetation efforts will be primarily determined by the plantings proximity to the water table. No supplemental irrigation will be provided as part of the restoration effort so it is essential that the plants used for revegetation have access to enough natural water sources to meet their water needs. This is why the design team will use creative grading techniques to form a series of riparian benches that steps up from the channel and provides varying plant communities access to the water that they need.

Wetland plants will be located closer to the limits of the base flow. Riparian plants will be planted at varying bench heights, depending on their water needs. Willows and cottonwoods can be planted in the riparian zones but can also be driven into the ground to access the water table at a further distance from the base flow and act as transitional planting between riparian and upland habitats.
Revegetation efforts should include: upland and riparian seeding, willow stakes and cottonwood pole plantings, tree and shrub planting and installation of wetland/riparian sod.

**Upland Seeding:** The design team is working with David Hirt at Boulder County Parks and Open Space (BCPOS) to determine what herbaceous upland plants exist on the site and what seeding measures had been successful in the past. David informed members of the design team that they had not had much luck with reseeding over areas with high concentrations of cobble but have had good success seeding certain varieties in more sandy and alluvial areas. Many varieties of upland species have been successfully reseeded are incorporated in the South St. Vrain Bridge Seed Mix and were provided to the design team by BCPOS. Boulder County gave the design team additional recommendations for this seed mix and those recommendations have been incorporated into the 30% Draft Submittal.

The upland seeding will only be applied to areas that are twenty four inches or more above the water table.

**Riparian Seeding:** The design team also worked with David to identify onsite riparian and wetland plants that were currently thriving. Based on these observations and extensive experience in the area, David will be recommending a revised mesic/wetland mix for the project. This mix will not be incorporated in the 30% Draft Submittal but will be included as part of the final design.

The riparian seeding will be applied at elevations up to twenty four inches above the bankfull water surface elevation. Riparian seeding will also be applied in conjunction with other riparian revegetation measures.

**Willow Stakes:** Willow stakes will be harvested onsite and will be predominantly Coyote Willows. The stakes can be installed in a variety of locations including cobble areas and sandy alluvial soils. They can also be inserted into existing and proposed bank stabilization structures to create a living grid of organic matter that will make stabilization measures more resilient and ecologically rich.

Willow stakes can either be installed by hand or machinery depending on their application. However, all willow stakes must be inserted so that the bottom end of the willow stake is submerged in the water table.

**Cottonwood Poles:** Cottonwood poles will be a key revegetation element for this project. Poles can be harvested onsite and there are plenty of sapling cottonwoods that are beginning to colonize since the floods. These saplings are congregated in dense clusters primarily around historic wetland areas. By transplanting saplings or using them as poles, the design team will be able to disperse these native eco-types into the productive areas of the site, reducing the competition and congestion in the areas of secondary succession.

Cottonwood poles are also an affordable revegetation option. If they are able to be harvested onsite, their cost will only include their removal and installation. The installation is similar to the willow stakes in that the most important factor for their survival is access to the water table.

**Tree and Shrub plantings:** Tree and shrub plantings will most likely be less widespread than other revegetation measures on this project. These plantings will be either container grown plants or B&B plants. The benefits of planting large individual trees and shrubs are great, however there could also be a large cost associated with them. The majority of our revegetation efforts will also consist of wetland and riparian plantings which alternative revegetation measures are usually more successful than traditional tree and shrub plantings.

Tree and shrub plantings may occur in the upland ecosystem and will be installed per the details provided in the 30% design plans.
**Wetland/Riparian Sod:** The design team will use wetland/riparian sod as part of this project. This sod is made from native plant material grown in a matrix of coconut fiber matt that can be grown from local seed and installed along the creek channel for immediate revegetation. Seed can be harvested from the site itself and grown specifically for this project. That will provide an eco-type planting that will have immediate growth and be naturally adapted to this area.

The wetland/riparian sod does cost more than traditional revegetation measures’. However, its application on this project has been discussed with David Hirt (BCPOS) and there are strategies that could be employed to maximize its success and impact, while keeping cost reasonable.

The design team recommends installing wetland/riparian sod in areas of high visibility. Often times, the success of a project is judged by how it looks. By installing wetland/riparian sod our, team will give the surrounding area an immediate aesthetic improvement and showcase successful revegetation months after the improvements have been made.
Figure 25 Wetland/Riparian Sod during installation: May, 2016

Figure 26 Wetland/Riparian Sod: July, 2016
Bio-engineering Measures: Bio-engineering is a method of engineering natural materials and living systems to stabilize streambanks to in a manner that is conducive with natural stream processes.

On this project a variety of bio-engineering measures will be used. Willow stakes will be incorporated with boulder toes to provide a matrix of living material within the rigid boulder structure, willow facines will be used to stabilize riparian benches and allow for plants to establish and mature, vegetated riprap can be used to provide bank protection with a softer aesthetic appeal and vegetated geogrids can improve eroded cutbanks and provide a platform in which riparian shrubs can take hold in steep environments. Other examples of bio-engineering include:

<table>
<thead>
<tr>
<th>Bioengineering Treatment</th>
<th>Permissible shear stress (lb./ft²)</th>
<th>Permissible velocity (ft./s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Live poles</strong></td>
<td>Initial: 0.5 to 2</td>
<td>Initial: 1 to 2.5</td>
</tr>
<tr>
<td>(Dependent on length of poles &amp; nature of the soil)</td>
<td>Established: 2 to 5+</td>
<td>Established: 3 to 10</td>
</tr>
<tr>
<td><strong>Live poles in woven coir TRM</strong></td>
<td>Initial: 2 to 2.5</td>
<td>Initial: 3 to 5</td>
</tr>
<tr>
<td>(Dependent on installation &amp; anchoring of coir)</td>
<td>Established: 3 to 5+</td>
<td>Established: 3 to 10</td>
</tr>
<tr>
<td><strong>Live poles in riprap (joint planting)</strong></td>
<td>Initial: 3+</td>
<td>Initial: 5 to 10+</td>
</tr>
<tr>
<td>(Dependent on riprap stability)</td>
<td>Established: 6 to 8+</td>
<td>Established: 12+</td>
</tr>
<tr>
<td><strong>Live brush slabs with rock</strong></td>
<td>Initial: 3+</td>
<td>Initial: 5 to 10+</td>
</tr>
<tr>
<td>(Dependent on soil conditions &amp; anchoring)</td>
<td>Established: 6+</td>
<td>Established: 12+</td>
</tr>
<tr>
<td><strong>Brush mattress</strong></td>
<td>Initial: 0.4 to 4.2</td>
<td>Initial: 3 to 4</td>
</tr>
<tr>
<td>(Dependent on soil conditions &amp; anchoring)</td>
<td>Established: 2.8 to 8+</td>
<td>Established: 10+</td>
</tr>
<tr>
<td><strong>Live fascine</strong></td>
<td>Initial: 1.2 to 3.1</td>
<td>Initial: 5 to 8</td>
</tr>
<tr>
<td>(Very dependent on anchoring)</td>
<td>Established: 1.4 to 3+</td>
<td>Established: 8 to 10+</td>
</tr>
<tr>
<td><strong>Brush layer / branch packing</strong></td>
<td>Initial: 0.2 to 1</td>
<td>Initial: 2 to 4</td>
</tr>
<tr>
<td>(Dependent on soil conditions)</td>
<td>Established: 2.9 to 6+</td>
<td>Established: 10+</td>
</tr>
<tr>
<td><strong>Live crib wall</strong></td>
<td>Initial: 2 to 4+</td>
<td>Initial: 3 to 6</td>
</tr>
<tr>
<td>[Dependent on nature of the fill (rock or earth), compaction &amp; anchoring]</td>
<td>Established: 5 to 6+</td>
<td>Established: 10 to 12</td>
</tr>
<tr>
<td><strong>Vegetated reinforced soil slopes (VRSS)</strong></td>
<td>Initial: 3 to 5</td>
<td>Initial: 4 to 9</td>
</tr>
<tr>
<td>(Dependent on soil conditions &amp; anchoring)</td>
<td>Established: 7+</td>
<td>Established: 10+</td>
</tr>
<tr>
<td><strong>Grass turf - Bermuda grass, excellent stand</strong></td>
<td>Established: 3.2</td>
<td>Established: 3 to 8</td>
</tr>
<tr>
<td>(Dependent on vegetation type &amp; condition)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Live brush wattle fence</strong></td>
<td>Initial: 0.2 to 2</td>
<td>Initial: 1 to 2.5</td>
</tr>
<tr>
<td>(Dependent on soil conditions &amp; depth of stakes)</td>
<td>Established: 1.0 to 5+</td>
<td>Established: 3 to 10</td>
</tr>
<tr>
<td><strong>Vertical bundles</strong></td>
<td>Initial: 1.2 to 3</td>
<td>Initial: 5 to 8</td>
</tr>
<tr>
<td>(Dependent on bank conditions, anchoring, &amp; vegetation)</td>
<td>Established: 1.4 to 3+</td>
<td>Established: 6 to 10+</td>
</tr>
</tbody>
</table>

*Figure 27 Bioengineering Treatments*
13. Additional Design Elements
There are a few design elements that have been developed based upon comments received from stakeholders. The majority of these items are outside the scope of this project and furthermore are not eligible for funding under the current EWP projects. None the less the Design Team evaluated these areas and have provided design recommendations that can be evaluated further under different planning and design projects.

a. Large Woody Material
Discussions with the project team and BCPOS staff along with the Boulder Office of Emergency Management have taken place to ensure the designs as part of this project address woody vegetation management as possible under this contract. Site evaluations throughout the entire 3.2 mile reach evaluated potential woody vegetation that might meet requirements to be removed. It is noted though that further investigations by the Boulder Office of Emergency Management (OEM) are required to ensure a safe riverine corridor and that County guidelines are followed.

Woody vegetation management along the corridor has already taken place prior to the project. Emergency debris removal, which was funded by FEMA, removed debris within the post-flood channel below the 5-year flow event. This occurred primarily near the Andesite Bridge, the Old St. Vrain Bridge, and along the southern high flow channel where it was constrained within existing vegetation. The OEM also conducted site visits and evaluations of woody vegetation along the South St Vrain Creek with coalition members and homeowners.

Following the guidelines below the Design Team evaluated the 3.2 mile stretch of South St Vrain Creek for potential locations of woody vegetation management. Included on the plans are locations where woody vegetation might need to be evaluated by OEM for potential removal. Below are discussions about large woody material including the natural benefits in the corridor along with management guidance from Boulder County and EWP.

i. Benefits
Understanding that woody vegetation in a creek corridor is a natural process and evident along most creeks is paramount. Woody vegetation accumulates in rivers through biological and physical process. Accumulation of vegetation generally occurs at specific sites along the corridor. Woody material can play an important role in the ecological processes of a stream by providing habitat structure and food sources for a variety of organisms, aquatic and terrestrial. Woody vegetation can also provide ecological benefits at an ecosystem level outside of the creek environment. The amount of nutrient cycling and energy transfer in a stream ecosystem is often related to the amount of wood present in the stream (Wallace et al., 1993). By retaining the debris, macroinvertebrates are able to process it into a form, through shredding and filtering, that can be used as a food resource and incorporated into the food web. If retention of this woody vegetation did not occur, the nutrients and energy in the organic debris would be transported downstream.
Large woody vegetation can also influence the geomorphology of a stream through alteration of sediment transport and storage, channel dynamics and processes. At the channel unit scale, wood affects bed and bank erosion and influences the size and type of individual pools, bars, and steps. Large woody vegetation diversifies the velocity of water within a stream channel (Rutherford et al., 2002). Localized increases and decreases in velocity near LWD cause scour and deposition, respectively. Directly downstream from a channel spanning log, water velocity increases due to the flow being constricted. Upstream of a channel spanning log, velocity can decrease, creating sediment bars. Typically, erosion will occur directly downstream of LWD due to increased water velocity and scour, whereas deposition is more likely on the upstream end of LWD due to the decreased water velocity (JF New, 2007).

ii. Boulder Office of Emergency Management Guidance

Through project discussions with homeowners and stakeholders it has been determined there are concerns with some of the woody vegetation along the South St Vrain Creek corridor. And while woody vegetation can be a benefit to the ecology and biology of a riverine corridor woody vegetation under certain situations can cause flood risks. Understanding this risk Boulder County lead a significant effort to identify high hazard locations along all creeks and rivers in Boulder County. With this the Boulder Office of Emergency Management released a report titled Threat Hazard Identification and Risk Assessment (THIRA). This report provides guidance to the county, coalitions and other officials about the steps that need to take place to manage wood vegetation in river corridors.

This report outlined that FEMA supplied funding that reimbursed vegetation clearing activities prior to the 2014 spring runoff. Currently issues related to woody vegetation are addressed in the long term recovery projects of the watershed coalitions and the County’s; Emergency High Hazard River and Creek Program. The Emergency High Hazard program is designed to act once a report is made into the Boulder Sheriff’s Communications Center by a resident or business owner. Deputies and road crews are dispatched to evaluate the problem and if required act to stabilize the incident.

The aforementioned THIRA report documents criteria to evaluate the potential negative impacts of large woody material in a riverine corridor:

**Tree Criteria**
- The fallen tree is in an identified hazard polygon.
- The tree is ¾ or completely spanning the river channel.
- The fall attitude is orthogonal within 70-110 degrees of creek or river flow.

**Multiple Tree Removal Criteria**
- The fallen tree is in an identified hazard polygon.
- The trees are 1/2 or completely spanning the river channel.
- The fall attitude is orthogonal within 70-110 degrees of creek or river flow.
- There are multiple trees (2 or more additional trees) within the visual observation area of the tree site upstream or downstream.
- There are signs of vegetation collection within the river or creek at the review site location.

**Debris Dam Removal Criteria**
- The debris dam is spanning ½ to 100% of the river or creek channel width.
The debris dam is already or going to cause a change in flow around the dam causing erosion or cause water to back up.

Further collection of woody vegetation is going to create a complete dam.

Is this a potential flash flood CFS release situation?

The recommended solution advised by the Boulder Office of Emergency Management is a multi-year mitigation program that complements the watershed coalition activities moving forward. The program should be funded based on yearly assessments of hazard mitigation sites. This program if implemented addresses the gap that the longer term watershed coalition projects and emergency programs do not. In the meantime citizens are recommended to call Boulder OEM offices when they see vegetation that might be of concern. The OEM office will then send out a representative to document the site conditions using a new program called Crisis Track that can document these site conditions on a smart phone with pictures and text.

A site visit the Director of the Boulder OEM was completed by Design Team members. This site visit took place to evaluate the 3.2 mile reach of the South St Vrain to note areas that meet the OEM guidelines for removal or warrants continued observations. (To Do: Discuss findings of site visit and map aspects)

iii. EWP Program Woody Vegetation Guidance

The fact that EWP has potential funding for two reaches along the 3.2 mile corridor requires evaluation of EWP’s guidance with regard to large woody material. In the EWP Program Project Engineering Guidance it outlines the various removal aspects of woody vegetation in an EWP eligible project. NRCS EWP funds may be used to remove all flood deposited anthropogenic vegetation (structural material, vehicles, appliances, etc.) and sediment (sand, gravel, cobble, boulders, etc.) where necessary to reduce threats to life or property by restoring the pre-flood hydraulic capacity of channels and floodplains (EWP, 2016).

NRCS recognizes the value of natural woody material in the riparian corridor where it supports ecological functions retains sediment and contributes to channel stability. Therefore NRCS will not use funds from the EWP program to remove large woody material (4 or more inches in diameter) from impaired channels and floodplains, except where it is necessary to:

- Reduce threats to life or property by restoring the pre-flood hydraulic capacity of channels and floodplains.
- Reduce potential for large wood to accumulate at bridges, culverts, and other in-channel infrastructure in quantities that could cause damage or impair functions of those structures; or
- Facilitate construction of other in-channel recovery measures.

Clearing and snagging should only remove as much large wood as needed to reestablish the pre-flood capacity of the channel and floodplain. Leave large wood in the riparian zone where it does not create a risk to life or property, and where possible consider using logs to construct channel and bank stabilization measures. The following are some additional guidelines with regard to large woody vegetation:

- To the extent possible, leave logs with a diameter greater than 1/3 the flow depth that are aligned or can be realigned at an angle less than 30 degrees with the direction of flow.
- Large wood with a diameter of less than 1/3 the flow depth left in the floodplain should be anchored.
• All flood deposited woody vegetation within 20 channel bankfull widths upstream from a bridge, culvert, or other infrastructure at risk may be removed to reduce potential for damaging or impairing the functions of the structure.
• During mobilization to the construction site, minimize disturbance to the primary stream channel, side channels, and streambanks.

b. **Longmont Diversion Structure**

The Longmont diversion structure located near the downstream extents of our project has been an area of concern for homeowners and stakeholders throughout the South St Vrain Creek. The diversion structure is under the jurisdiction of the City of Longmont and the property is owned by the City of Longmont. The existing diversion structure underwent repairs as discussed earlier and had planned a sloping grouted drop structure at the downstream side of the diversion. Since the sloping structure was removed from the project, stakeholders have requested further design elements be evaluated as part of this project. The premise for the 30% construction designs as part of this project were to evaluate stream restoration techniques as if existing infrastructure, like the diversion, would remain in place.

A few members of the public have suggested the relocation of the Longmont Diversion, which is owned and managed by the City of Longmont, to situate it in a location that may work better with the existing floodplain and stream flows. The idea has been called out in the preferred alternative and will continue to be included in the plan. It has been referred to as “master plan” level recommendations. This is due to the complexities associated with potential changes to this structures, the vetting of which is well beyond the scope of the current grant funding and contract. These issues include but are not limited to the need for high level engineering for design, legal ramifications with regard to water and property rights, permitting constraints, and the need to find the necessary funds for engineering and implementation of such projects. In addition, allocating additional time and resources to this level of analysis without the buy-in of the controlling agencies is a poor use of the current funds, as no recommendations, regardless of how thorough they are, will move forward without their consent. Therefore, they will remain as potential future projects in the current plan, but the project team will also continue to work within the existing conditions.

With that being said the Design Team took the initiative to evaluate potential alternatives that could be emplaced in this location under future projects. One of the major concerns from these stakeholders is that the 3’ drop after the cross channel diversion has safety concerns along with potential influences on fish passage. Low head dams are known to cause safety risks due to the ‘washing-machine’ effect that takes place on the downstream side of these drops that can trap people under water. While this area is closed to public recreational uses it is known to be used by kayakers and fisherman, therefore design aspects are presented below to address both of these issues. It was also determined by our fishery biologist that only smaller species of fish are unable to pass this drop structure under various flow regimes.

Another concern with regard to the diversion structure is the possibility of the channel diverting around the structure to the south. In this location during flood the water scoured the inside of the bank where the concrete dam interfaced with the creek banks. The existing vegetation upstream of the diversion helped to stabilize the banks and floodplains so that the flood didn’t scour the bank further upstream, which could have caused more damage. Design elements will be evaluated to help preclude the banks from eroding in this location and activate the floodplain bench at the appropriate level.
i. **Sloping Drop Structure or Stepped Drops**
One recommendation the Design Team has is to install the sloping drop structure that was previously planned for this area. Design plans currently existing that could be implemented with minor modifications based upon this stream restoration project. By allowing for a sloping drop recreational uses through this area would not be limited by a safety concern. While it will also allow for a greater range of fish passage. It should be noted though that by increasing the elevation of the channel bed there might be floodplain implications that need to be evaluated to ensure there isn’t a rise in the base flood elevations through this reach.

A series of stepped drop structures could also be designed to reach the same goals. By stepping the larger 4’ impoundment down to a series of multiple smaller drops the drop height at each drop could be reduced to a safer height. This would allow for fish passage by more species while also not causing a low head dam scenario that could be unsafe.

ii. **Fish Passage Channel or Sediment Sluice**
It has been noted in conversations with stakeholders that sediment does accumulate on the upstream side of this diversion and has to be removed periodically. With that being said a sediment bypass channel or sediment sluice might be a way to alleviate the buildup of this sediment. This would constitute designing a small channel that could be designed to convey flow around the diversion structure itself to remove the buildup of sediment. The secondary feature of this channel is that it could also be used by fish to move upstream past the diversion. This channel would require some grading and potential vegetation removal to allow a stable slope that could catch grade upstream beyond the diversion.

iii. **Relocation of Diversion Structure**
The next recommendation would be to install a new diversion structure further upstream than its current location. This diversion structure could be moved upstream at a location where a cross channel impoundment would not be required, but could still deliver water to its intended use. This is known as chasing grade upstream. The relocation of the diversion structure would allow recreationalists to safely pass this area while it also would also remove any aspects to preclude fish passage. The location of the proposed diversion structure could be on the straight segment of the creek about 300’ upstream and along the right bank of the river.

c. **South Ledge / Meadows Ditch Diversion Structure**
As discussed previously it has been brought to our attention that there is sediment building up in the newly combined diversion of the South Ledge and Meadows Ditch. From field visits to the site it can be seen that sediment is building within the diversion structure itself beyond where the sediment sluice can clear the sediment. During one of our site visits there was anywhere from 1’-3’ of sediment in the diversion. Due to the sediment sluice being located at the front of the structure there is no way for the sediment to be removed from the back of the diversion itself expect for by physically shoveling sediment out of the structure.

There are a couple ways to address this issues. The first way would be to either relocate the sediment sluice further in the diversion itself or allow for a secondary sediment sluice that could be activated to allow sediment to wash out of the diversion back to the creek. Also an in channel drop structure could be used to help promote clear water to enter the diversion by allowing the sediment to deposit on the upstream side of the drop structure.
d. Matthews / Holcomb Diversion Structure

One of the proposed future project that currently has founding from FEMA is the relocation and combining of
the Matthews and Holcomb diversion structures. Both of these diversion structure provide water to ditches that
irrigate fields along the South St Vrain. Both of these structures were also washed away or damaged in the flood.
It is from our understanding that the diversions will be combined and located in the vicinity of the Hall Ranch 2
Road Repair and Hazard Mitigation project.

This location for the combined diversion is a good location due to its position on the outside of a river bend that
will preclude sediment from entering the diversion, while there is also a good amount of bedrock outcrops that
can be used to anchor this diversion in place. Design aspects with regard to this combined diversion were evaluated as part of this project. Ensuring that the creek is in a location where water can be diverted both horizontally and vertically is paramount to coordinate future designs. The 30% design plans call out the approximate horizontal and vertical location of the proposed features and ensure delivery of water the ditch.

Under the Old St Vrain Road Bridge project there currently are plans to install a 12” reinforced concrete pipe in the abutment so that the future alignment of the proposed ditch can convey water through the bridge safely. The vertical location of the diversion was evaluated based upon the invert of this 12” pipe at a minimum slope of 0.5% to the newly proposed location of the combined diversion. Bank stabilization aspects along with buried riprap revetment are included with this design to protect the ditch infrastructure in critical locations.

Figure 28. Cross Vane with Diversion

e. Otto Diversion

The Otto Diversion was another water right diversion that was impacted by the 2013 flood. The diversion for the
Otto Ditch was damaged during the flood and remnants of it are thought to have been washed downstream. The
pre-flood location of this diversion is along an andesite rock outcrop on the outside of a river bend near the
Andesite Quarry. An evaluation of the pre-flood grade in the vicinity of the diversion compared to a post flood
evaluation show that the area has actually degraded since the flood. This could because the of bed rock outcrop increased velocities around this bend and scoured bed material.

The proposed design for the stream restoration in this area is align the creek back to its pre-flood location so that a new diversion structure can be built in the future. The diversion might need to be relocated upstream further in order to catch grade with the diversion, which is allowed within 500’ without having to go to Water Court. The actual ditch alignment itself also needs to be monitored due to its proximity of a sloughing bank near the downstream Hall property where exigent NRCS work was completed.

f. Old St Vrain Road Bridge
A few members of the public have suggested the replacement of the Old South St. Vrain Road Bridge, which is under the jurisdiction of Boulder County Transportation, to increase its capacity. The idea has been called out in the preferred alternative and will continue to be included in the plan. It has been referred to as “master plan” level recommendations. This is due to the complexities associated with potential changes to this structures, the vetting of which is well beyond the scope of the current grant funding and contract. These issues include but are not limited to the need for high level engineering for design, legal ramifications with regard to property rights, permitting constraints, and the need to find the necessary funds for engineering and implementation of such projects. In addition, allocating additional time and resources to this level of analysis without the buy-in of the controlling agencies is a poor use of the current funds, as no recommendations, regardless of how thorough they are, will move forward without their consent. Therefore, they will remain as potential future projects in the current plan, but the project team will also continue to work within the existing conditions.

It is understood that the existing capacity of the bridge near the downstream extents of our project on Old St Vrain Road is very limited when compared to the new 100 year hydrology. Our HEC RAS model of this bridge verifies that it cannot pass any storm greater than the 25 year event, 3,168 cfs. The current capacity of the bridge is about 4,200 cfs, which is about 3,000 cfs less than the revised 100 year hydrology of 7,234 cfs. Furthermore this shows that the bridge could not pass the pre-flood hydrology 100 year event either.

The bridge has approximately 1 foot of overtopping during the 50 year event and about 1.5 feet of overtopping during the 100 year event. It also should be noted that the majority of the overtopping in the HEC-RAS model takes place actually at the low point in the road, south of the bridge crossing. The existing opening for the bridge is about 403 square feet. In order to convey the entire 100 year storm through the bridge the opening would need to be approximately 700 square feet, therefore increasing the size by about 75%.

The increase in needed area for conveyance could be completed by either increasing the vertical profile of the bridge and/or increasing the span of the bridge. Increasing the vertical profile of the bridge would require considerable grading to the south, but would need to be ensured that the low point of the crossing is just not moving more towards the south. Consequently, Increasing the span of the bridge could lead to issues in the downstream channel where the existing bridge span does mimic the downstream channel width. Furthermore, reevaluation of the horizontal alignment of the bridge and where the Old St Vrain Road ties into Highway 7 could be engineered to allow for a more perpendicular crossing of South St Vrain Creek and a safer intersection junction.

Consequently though in this scenario the bridge is not the limiting factor when evaluating floodplain aspects. Even if the capacity of the bridge is increased, the downstream capacity of the channel is still less than adequate to convey the entire 100 year storm. The channel downstream of the bridge can’t even convey the 25 year storm adequately in the some of the downstream reaches. Therefore during a 50 year storm and greater (in some places at a 25 year event) the floodwave spills out of its banks, inundating the properties along the corridor. This means that backwater could potentially affect the conveyance capacity of the bridge, which means that even increasing the size of the bridge to convey to 100 year event, overtopping would still occur due to backwater and conveyance limitations of the downstream channel.

i. Connection of Overflow over Old St Vrain Road towards Bohn Park
It is understood that due to the lack of conveyance capacity of the Old St Vrain Road bridge at the downstream extents of our project and the channel downstream of that bridge, floodwaters overtop Old St Vrain Road south of the bridge. This split flow was not unexpected based on the volume of water that occurred during the flood, and it will very likely flow in this path again in future floods of this magnitude regardless of the size of the bridge. This flow path was evident during the 2013 flood and was validated in our hydraulic modeling. While our project scope is limited to upstream of Old St Vrain Road at this location the Design Team evaluated potential channel aspects to convey the flow that overtops the at this location back to the creek.

The project team developed an alternative to deal with this split flow, which was an overflow channel that would direct the flow in a safe and resilient manner into Lyons. However, this alternative was adamantly opposed by members of the public even though the Design Team conveyed the information that whether we recommend a channel or not the flood wave will travel that direction in the future.

Therefore, this alternative, which occurs outside the planning area for the current study, was removed from further consideration, and the project team continues to look at a modified alternative, which is an overflow channel that parallels the east side of Old South St. Vrain Road. This overflow channel would return this flow back to South St. Vrain Creek on the downstream side of the bridge. Ultimately, projects downstream of Old South St. Vrain Road will need to be coordinated with Lyons and the EWP SSV 3 project teams. Matrix has met with these teams and will continue to provide the necessary information from the current study to determine if a viable and publically acceptable alternative exists.

g. Detention Along the Corridor

Many discussions have taken place with regard to potential detention options available throughout the corridor. This consideration was vetted and evaluated by the Michael Baker team that produced the St Vrain Creek Master Plan (Baker, 2014). The St Vrain Creek Master Plan evaluated potential detention in the vicinity of the Andesite Quarry. It was determined that there is a lack of significant reduction in downstream flood risk with the design of a detention facility in this area. It also determined that such a facility would not be cost beneficial as a result of the large cost of designing, building, maintaining, and operating such a facility with limited public benefit.

The St. Vrain Creek Master Plan evaluated two different dam locations in vicinity of the Andesite Quarry to provide flood storage and peak flow attenuation. For the purposes of their evaluation, the maximum dam height was set to an elevation such that Highway 7 would not be inundated during maximum storage conditions. Highway 7 is a major highway that needs to remain operable for emergency service vehicles. There is a potential future evaluation that could look at realigning Highway 7 so that is located at a higher elevation to provide more storage, but is beyond the scope of this project. The Michael Baker Team evaluated the benefit for flood attenuation by comparing the maximum storage capacity of each dam alternative with the volume of the inflow hydrograph.

It was determined that neither detention alternative would be feasible to implement. Placing a dam at either location would inundate infrastructure upstream and would likely not provide enough peak flow attenuation to alleviate flooding downstream. For each alternative is was determined that only 7% and 18% of the 100 year peak flow would be attenuated at Site 1 and Site 2, respectively. The dam at Site 1 would be 320 feet wide and 38 feet deep, while the dam at Site 2 would be 680 feet wide and 56 feet tall.
Considering such a massive structure would cost a considerable amount of money in design, construction and maintenance, while not provided a significant amount of relief for the peak flood, at this time the idea is considered unfeasible. Also the impoundment would cause significant loss of ecological and biological benefits throughout the corridor. Furthermore, the idea of a detention in this area does not fit with the purpose or vision of county open space.

### h. Andesite Quarry

Currently the Andesite Quarry, managed by Aggregate Industries, is in the process of submitting the mine reclamation plans to the state after a 5 year cessation since mining. Our Design Team met with stakeholders with regard to the plans for the mine to coordinate design aspects. Our Design Team was able to provide comments and inform Aggregate Industries of our plans for this area while also learning theirs.

In evaluation of the mine reclamation plans, it is understood that the existing toe of slope along the quarry wall will remain where it is at and fill will be used to balance the slope to the top of the quarry. This will allow the proposed stream restoration design as part of this project be implemented in the future. The ultimate final plan for the mine reclamation has not been approved and is currently being reviewed by the State. The final mine reclamation plan should be evaluated once complete to ensure designs as part of this plan have not been affected.

Our Design Team coordinated on available fill material either from the EWP projects or other projects in the County that could lead to an advantageous scenario for both parties. Furthermore ideas of revegetating the corridor and implementing potential designs from this plan as part of their project for future funding applications was discussed. Incorporating elements from our stream restoration plan might allow Aggregate Industries to apply for various grants to help fund the project.

### 14. Benefits of the Project

The resiliency objectives of the project have been to restore the stream channel in a way that both protects and increases the ability of critical infrastructure and environmental and cultural resources to withstand future disaster, while reducing future recovery time by mitigating risk and assisting in local community disaster preparedness.

Sustainability objectives have focused on reconstructing the channel in a way that protects the existing homes and built environment, while also improving the local economic, social and natural environments.

Resilience metrics for critical infrastructure included:

- Mitigation of flood erosion hazard upon roads and bridges through bank revetments and bioengineering.
• Increased sediment transport ability at ditch diversions and headgates which increases structural stability and function during flood.
• Re-direction of creek flows away from existing homes and roads using a geomorphic approach.
• Reduction of maximum stream flow velocity and erosion potential through increased floodplain connectivity and designed natural channel sinuosity.

Resilience metrics for environmental and cultural resources included:
• Using a natural channel design to increase bank and channel stability and to reduce restoration and regeneration time following future flooding.
• Providing in-stream habitat including riffles, pools, large wood, and point bars to restore and enhance the biological productivity of the creek.
• Reducing or eliminating hard engineering in the creek corridor where possible that will reduce stream velocity and increase long-term bank stability and ecological health.
• Promoting floodplain connectivity which alleviates erosion, speeds ecological regeneration and reduces impact on cultural resources within the floodplain by reducing flood velocities and avulsion hazards (such as at historic agricultural homes).

Sustainability metrics considered future home and business reconstruction, as well as economic, social and environmental revitalization, and must not compromise the needs of future generations. These include:
• Restoration of riparian and in-stream habitats.
• Construction of a native fish passageway for two ditch diversions which will significantly improve long-term stream habitat health.
• Planning the natural channel design of the stream to sustain long-term ecological health and reduce “hard” engineering features (i.e. using existing tree shade, increasing sinuosity, improving water quality, and large wood placement).
• Providing economic and social value to the surrounding community (i.e. enhanced trout fishery, Open Space aesthetics, and property values).
• Protecting homes and infrastructure in a way that considers the future (i.e. distanced channel alignments, reduced flow velocity, and sediment transportation).

The overall economic health of the corridor will also benefit from this project. The design and eventual restoration and recovery of the St. Vrain Creek Watershed will foster the resilience and resurgence of the local economy surrounding St. Vrain Creek. The flood event caused millions of dollars in damages to area homes, businesses, and infrastructure. Damage to area roads and bridges led to a stoppage or reduction in business traffic and operations. The design plans contribute to improving the resiliency of the public roads and corresponding infrastructure that the community relies on for economic and personal welfare activities, as well as for emergency response vehicles. Restoring roads, bridges, creeks, parks and trails quickly and in a manner that mitigates against future hazards will help regenerate economic activity in the area.

15. Dewatering and Erosion Control Plan
(To Do: Discuss requirements of 30% design to determine level of planning necessary)

16. Map and Acres of Areas Requiring Revegetation
Maps identifying the areas of revegetation can be found in the 30% Design Plans and can be provided by the design team upon request. (Exhibits of the areas requiring revegetation can be provided in this document prior to the next submittal).

The total area of requiring revegetation is 41.86 acres.

17. Cut/Fill Estimates
(To Do: Cut Fill estimates will be updated with final design due to iterations required in design surface and 2D SRH Modeling)

18. Permit Plan
a. Summary of Permits
   i. Section 404 of the Clean Water Act

South St. Vrain Creek is considered a jurisdictional water of the U.S. The proposed project would likely affect wetlands associated with South St. Vrain Creek. Two levels of Section 404 permitting are possible:

- Authorization under a Nationwide Permit (NWP) – based on specific activities and have thresholds. Generally allow up to ½ acre of impacts on waters of the U.S. including wetlands.
- Authorization under an Individual Permit (IP) – based on larger projects and generally do not have impact thresholds. IPs can take up to a year to authorize and go out for public comment.

Proposed work within identified EWP project areas will likely be permitted under NWP 37 for Emergency Watershed Protection and Rehabilitation. The description and limits for NWP 37 are listed below (taken from the Corps Omaha District website).

“NWP authorized work funded by:

- The Natural Resources Conservation Service for a situation requiring immediate action under its emergency Watershed Protection Program (7 CFR part 624);
- The U.S. Forest Service under its Burned-Area Emergency Rehabilitation Handbook (FSH 2509.13);
- The Department of the Interior for wildland fire management burned area emergency stabilization and rehabilitation (DOI Manual part 620, Ch. 3);
- The Office of Surface Mining, or states with approved programs, for abandoned mine land reclamation activities under Title IV of the Surface Mining Control and Reclamation Act (30 CFR Subchapter R), where the activity does not involve coal extraction; or 21
- The Farm Service Agency under its Emergency Conservation Program (7 CFR part 701).
- In general, the prospective permittee should wait until the district engineer issues an NWP verification or 45 calendar days have passed before proceeding with the watershed protection and rehabilitation activity. However, in cases where there is an unacceptable hazard to life or a significant loss of property or economic hardship will occur, the emergency watershed protection and rehabilitation activity may proceed immediately and the district engineer will consider the information in the pre-construction notification and any comments received as a result of agency coordination to decide whether the NWP 37 authorization should be modified, suspended, or revoked in accordance with the procedures at 33 CFR 330.5.
**Notification:** Except in cases where there is an unacceptable hazard to life or a significant loss of property or economic hardship will occur, the permittee must submit a pre-construction notification to the district engineer prior to commencing the activity.

Impacts on South St. Vrain Creek outside of the EWP areas would likely require authorization under a separate Section 404 permit. Depending on the nature and scale of future activities, authorization under one or more NWPs or IPs will likely be required.

### ii. Endangered Species Act (ESA) Consultation (Section 7 of the ESA)

The project area is located in the overall range for federally listed threatened or endangered species that potentially occur in Boulder County – particularly ULTO, CBP, and Preble’s. Trapping surveys for Preble’s conducted in 1997 and 2015 yielded no captures; however, a capture in 2005 at Hall Meadows did yield a capture (Meaney 2005). It is possible the Service would consider portions of the project area as “occupied” habitat for Preble’s and request formal consultation under Section 7 of the ESA. According to conversations with Boulder County Open Space staff, ULTO surveys have been conducted. No ULTOs have been found, and there are no known seed sources along South St. Vrain Creek (Hirt 2016). Additionally, no habitat for the CBP exists in the project area. The majority of the vegetation in wetland and riparian areas is possibly too dense to allow establishment of these species. Nonetheless, ERO recommends that Boulder County Open Space coordinate with the Service prior to construction.

### iii. National Historic Preservation Act (Section 106 of the NHPA)

As part of the federal process (i.e., Section 404 permitting), Section 106 (which requires an assessment of cultural or historic resources in the project area) must be addressed. It is possible that cultural resources or historic properties eligible for listing on the National Register of Historic Places occur in the project area. In addition to prehistoric artifacts, structures (e.g., railroads and bridges), irrigation ditches, and historic districts more than 50 years old are potentially eligible for listing. A cultural resource file search and Class III pedestrian survey would likely be necessary for the project area if a Section 404 permit were required.

The project team recommends coordination with the permitting agencies during the conceptual project development phase. Early coordination with the agencies typically allows for more of a streamlined permitting process. Contracting a permitting specialist is recommended to help facilitate the environmental permitting process. The current project team is capable of supporting these needs.

### iv. Land Use Permit

(To Do: Information to be added)

### v. Floodplain Development Permit

(To Do: Information to be added)

### b. Contacts
c. Estimated Schedule
(To Do: Need to discuss anticipated permitting schedule with BCPOS and EWP)

19. Implementation Plan and Timeline
(To Do: Schedule to be developed with input from BCPOS to determine next steps and timing of various aspects.)

Now that 30% designs have been developed for the entire 3.2 mile reach these designs can be used to implement Design-Build contracts to build the proposed restoration aspects.

Timeline to Include:
- Final Design Plans and Specificaitons
- Submittal to EWP
  - Approval or Modifications of Design
- Submittal of Permitting Document
- Design Build RFP
  - Development of RFP
  - Proposal Process
  - Selection of Contractor
- Permits Received
- Construction
- Monitoring
20. Opinion Probable Construction Costs

Below are anticipated construction costs at this draft stage.

(To Do: Break out EWP areas. Refine revegetation costs based upon new designs)

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<td>$3,500</td>
</tr>
<tr>
<td>Wetland Sod</td>
<td>217,800</td>
<td>43,560</td>
<td>SF</td>
<td>$6.00</td>
<td>$1,306,800</td>
<td>$261,360</td>
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<td>Subtotal</td>
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<td></td>
<td>$7,945,887.37</td>
<td>$1,581,009.50</td>
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<tr>
<td>Contingency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
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<td></td>
<td></td>
<td>$9,535,064.84</td>
<td>$1,897,211.40</td>
</tr>
</tbody>
</table>
21. References


d. USDA NRCS. 2015. Damage Survey Report


h. CWCB. 2014. Guidance for Hydrologic and Hydraulic Analysis


m. Lawlor, Sean; Determination of Channel-Morphology Characteristics, Bankfull Discharge, and Various Design-Peak Discharges in Western Montana; USGS 2004


22. Appendices
   a. Meeting Minutes
   b. Applicable Sections of St Vrain Creek Master Plan
   c. EWP Damage Survey Report
   d. HEC-RAS Hydraulic Model Output
   e. SRH Hydraulic Model Output
Appendix X:
Decision Making Process Diagram and Decision Matrix
South St. Vrain Creek Restoration at Hall Ranch Decision Making Process:

**Project Goals**

- Communicates with the residents
- Incorporate residents needs in alternative analysis
- Be mindful of impact of property value
- Consider the affects work will have downstream
- Consider recreational opportunities
- Increase aesthetic appeal
- Consider existing water rights
- Minimize impact to cultural and historic features

**Core Values**

- **Community**
  - Communicates with the residents
  - Incorporate residents needs in alternative analysis
  - Be mindful of impact of property value
  - Consider the affects work will have downstream
  - Consider recreational opportunities
  - Increase aesthetic appeal
  - Consider existing water rights
  - Minimize impact to cultural and historic features

- **Resiliency**
  - Improve “Creek Conveyance”
  - Provide smarter infrastructure solutions
  - Improve creek stability
  - Reduce risk to critical infrastructure
  - Restore natural ecosystem process
  - Reconnect the floodplain

- **Safety**
  - Reduce the impacts to private property
  - Reduce potential flood risk
  - Make public safety top priority

- **Environment**
  - Assess existing environmental conditions
  - Reduce sedimentation in general
  - Improve wildlife habitat (banking opportunities)
  - Increased channel capacity to accommodate future flooding
  - Work with natural systems
  - Improve fish passage and habitat
  - Remove and recycle onsite materials
  - Avoid highly-engineered solutions
  - Re-establish natural condition of the channel and adjacent stream bank
  - Increase revegetation efforts
  - Concerned about movement of potential debris both short and long term
  - Concerned about ground water and the rise in the creek bed elevation
  - Concerned about interim berm condition along creek
  - Consider new 100 year hydrologic volumes

- **Implementation**
  - Work with existing project initiatives and ongoing projects
  - Find funding for future implementation
  - Include fiscally responsible costs
  - Continue longterm planning for future projects
  - Meet the goals for EWP funding
  - Consider elements of the master plan
  - Be consistent with land use regulations and management
  - Consider phasing

- **Schedule**
  - Prioritize strategies as critical, necessary or desired

**Critical Issues Paraphrased from Stakeholder Comments**

- 1. Protect critical public and private infrastructure?
- 2. Avoids negative impacts to downstream infrastructure, channel and stormwater systems?
- 3. Improves aesthetics to the creek corridor?
- 4. Consider recreation where allowed?
- 5. Benefits larger area of creek corridor?
- 6. Re-establishes floodplain connectivity?
- 7. Restores affected areas of the South St. Vrain Creek channel and surrounding areas to stable, resilient and ecologically rich habitats?
- 8. Reduces future recovery time?
- 9. Moderates conveyance of sediment?
- 10. Reduce flood risk to the public and residents by providing long term solutions that increase resiliency?
- 11. Natural ecosystem processes restored?
- 12. Protects or improves existing habitat and significant ecological resources?
- 13. Incorporates locally available materials and environmentally friendly processes?
- 14. Protects and improves water quality and the geomorphology of the creek?
- 15. Creates infrastructure investments that are reasonable to construct and provides the best value for their life-cycle, function and purpose?
- 16. Can be supported by current land use regulations or revised land use regulations?
- 17. Provides funding, partnering and collaboration opportunities by meeting multiple stakeholder objectives?

**Prioritization Criteria**

- Assess existing environmental conditions
- Reduce sedimentation in general
- Improve wildlife habitat (banking opportunities)
- Increased channel capacity to accommodate future flooding
- Work with natural systems
- Improve fish passage and habitat
- Remove and recycle onsite materials
- Avoid highly-engineered solutions
- Re-establish natural condition of the channel and adjacent stream bank
- Increase revegetation efforts
- Concerned about movement of potential debris both short and long term
- Concerned about ground water and the rise in the creek bed elevation
- Concerned about interim berm condition along creek
- Consider new 100 year hydrologic volumes

- Prioritize strategies as critical, necessary or desired
## SOUTH ST. VRAIN CREEK RESTORATION AT HALL RANCH DECISION MATRIX - FOR THE PRIORITIZATION OF THE PREFERRED ALTERNATIVE

### 7/12/2016

<table>
<thead>
<tr>
<th>ID</th>
<th>Critical Issues</th>
<th>Prioritization Criteria</th>
<th>Alternatives Evaluation</th>
<th>Implementation</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Floodplain Connectivity</td>
<td>Channel Complexity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Revitalization</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Infrastructure Protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Community</td>
<td>Protect critical public and private infrastructure?</td>
<td>The best way to increase flood volume and reduce flood energy throughout the system. Note: Detention ponds cannot provide enough volume to mitigate flood impacts. Water rights are needed to detain water. Detention ponds would fill full of sediment. There is physically not enough room to detain the appropriate amount of water needed.</td>
<td>Can provide some channel stability.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Community</td>
<td>Avoids negative impacts to downstream infrastructure, channel and storm water systems?</td>
<td>Returns the river corridor to a more natural channel condition with minimal downstream impacts.</td>
<td>Minimal downstream negative impacts.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Community</td>
<td>Improves aesthetics to the creek corridor?</td>
<td>Returns the river corridor to a more natural channel condition. Time needed for naturalization of vegetation.</td>
<td>Improves the aesthetics of the channel.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resiliency</td>
<td>Benefits larger area of creek corridor?</td>
<td>Benefits the larger creek corridor by jump starting the natural systems.</td>
<td>Benefits the larger reach corridor but without floodplain connectivity the results will be diminished.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resiliency</td>
<td>Re-establishes floodplain connectivity?</td>
<td>Yes. Floodplain connectivity is the most holistic approach to re-establishing functioning floodplain.</td>
<td>Yes. Channel complexity would contribute to inundation of floodplain benches.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resiliency</td>
<td>Restores affected areas of the South St. Vrain Creek channel and surrounding areas to stable, resident and ecologically rich habitats?</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Community</td>
<td>Consider recreation where allowed?</td>
<td>Improves the quality of the recreational experience. Provides inset stream structures that could act as a recreational amenity to hikers and fishermen.</td>
<td>Improves the quality of the recreational experience. Recreational objectives could be included with infrastructure protection.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Resiliency</td>
<td>Benefits larger area of creek corridor?</td>
<td>Benefits the larger creek corridor by jump starting the natural systems.</td>
<td>Benefits the larger reach corridor but without floodplain connectivity the results will be diminished.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resiliency</td>
<td>Re-establishes floodplain connectivity?</td>
<td>Yes. Floodplain connectivity is the most holistic approach to re-establishing functioning floodplain.</td>
<td>Yes. Channel complexity would contribute to inundation of floodplain benches.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Resiliency</td>
<td>Restores affected areas of the South St. Vrain Creek channel and surrounding areas to stable, resident and ecologically rich habitats?</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Resiliency</td>
<td>Reduces future recovery time?</td>
<td>Jump starts the natural systems of the corridor most holistic approach.</td>
<td>Not a holistic approach, focuses on channel.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Resiliency</td>
<td>Reduces future recovery time?</td>
<td>Jump starts the natural systems of the corridor most holistic approach.</td>
<td>Not a holistic approach, focuses on channel.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resiliency</td>
<td>Moderates conveyed of sediment?</td>
<td>Yes for the entire reach.</td>
<td>Yes for the entire reach.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Traps sediment during a flood and minimizes erosion.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Could be part of the strategy at diversions, bridges and culverts.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Safety</td>
<td>Reduce flood risk to the public and residents by providing long term solutions that increase resiliency?</td>
<td>Increases flood storage volume and reduces flood energy throughout the system.</td>
<td>Provides some creek channel resiliency.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Natural ecosystem processes restored?</td>
<td>Most holistic approach. Partial approach, not all ecosystems addressed.</td>
<td>Partial approach, not all ecosystems addressed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Protects or improves existing habitat and significant ecological resources?</td>
<td>Improves both terrestrial and aquatic habitat.</td>
<td>Improves aquatic habitat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Natural ecosystem processes restored?</td>
<td>Most holistic approach. Partial approach, not all ecosystems addressed.</td>
<td>Partial approach, not all ecosystems addressed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td>Improves both terrestrial and aquatic habitat.</td>
<td>Improves aquatic habitat.</td>
<td>Improves terrestrial and riparian habitat</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Environment</td>
<td>Incorporates locally available materials and environmentally friendly processes?</td>
<td>Not a differentiator. All alternatives can incorporate locally available materials and environmentally friendly processes.</td>
<td>Not a differentiator.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Implementation</td>
<td>Creates infrastructure investments that are reasonable to construct and provides the best value for their lifecycle, function and purpose?</td>
<td>Protects geomorphology and jump starts natural systems of the corridor.</td>
<td>Protects geomorphology and jump starts natural systems of the creek.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Implementation</td>
<td>Can be supported by current land use regulations or revised land use regulations?</td>
<td>Not a differentiator. All alternatives can be supported by the current land use regulations.</td>
<td>Not a differentiator.</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Implementation</td>
<td>Provides funding, partnering and collaboration opportunities by involving multiple stakeholder objectives?</td>
<td>Not a differentiator. There are opportunities with all alternatives for partnering.</td>
<td>Not a differentiator.</td>
<td></td>
</tr>
</tbody>
</table>

### Definitions:
- **Fair** - What is thought to be right acceptable
- **Better** - Higher in quality
- **Best** - Better than all others in quality or value
Appendix X:
South St. Vrain Comments
**South St. Vrain Comments**

<table>
<thead>
<tr>
<th>Comment</th>
<th>Source</th>
<th>Safety</th>
<th>Habitat</th>
<th>Conveyance</th>
<th>Recreation</th>
<th>Environmental</th>
<th>Stabilization</th>
<th>Coordination</th>
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<tbody>
<tr>
<td>&quot;Creek conveyance&quot; should be the most important design component</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How closely will the alignment and design match the alignment and objectives that were presented in the Master Plan?</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Need coordination amongst various entities on repairs throughout the reach (e.g. creek restoration, ditches, bridges, etc.)</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How do we handle historic channel changes, especially within and above Hall Meadows area</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>County open space was protected primarily for the natural resource and open space values that the creek and floodplain provide.</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project should be focused on creek restoration design, not general land management planning for the county's open space lands. General land management (e.g. recreation, agriculture, etc.) is provided in the St. Vrain Creek Corridor Open Space Management Plan and North Foothills Open Space Management Plan.</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restoring the natural process is more important than existing or pre-flood conditions (e.g. think about system first).</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Look at potential for multi-stage channel with floodplain bench to provide both ecological and public safety benefits</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimize hardscape as much as possible. Instead, use soft engineering, while protecting infrastructure.</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How will this project be a partnership amongst BCPOS, residents, and SVCC?</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>County open space was protected primarily for the natural resource and open space values that the creek and floodplain provide.</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>County open space was protected primarily for the natural resource and open space values that the creek and floodplain provide.</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project should be focused on creek restoration design, not general land management planning for the county's open space lands. General land management (e.g. recreation, agriculture, etc.) is provided in the St. Vrain Creek Corridor Open Space Management Plan and North Foothills Open Space Management Plan.</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restoring the natural process is more important than existing or pre-flood conditions (e.g. think about system first).</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Look at potential for multi-stage channel with floodplain bench to provide both ecological and public safety benefits</td>
<td>BCPOS</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Minimize hardscape as much as possible. Instead, use soft engineering, while protecting infrastructure.</td>
<td>BCPOS</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How will this project be a partnership amongst BCPOS, residents, and SVCC?</td>
<td>BCPOS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Count</td>
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</tbody>
</table>

<table>
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<tr>
<th>Comment</th>
<th>Source</th>
<th>Safety</th>
<th>Habitat</th>
<th>Conveyance</th>
<th>Recreation</th>
<th>Environmental</th>
<th>Stabilization</th>
<th>Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now we appear to be proceeding with “conceptual design plans” for improvements in this area without an overall planning process or public involvement in the concepts. Boulder County is currently in process of approving Longmont water intake improvements in this segment also. It appears to me that the Longmont intake project coupled with the BCPOS design will fix the corridor without the type of integrated and collaborative process that our expanded SVCC is promoting. The types of overall flood mitigation and potentially detention alternatives that were requested in the Lyons PDGs are being ignored.</td>
<td>Larry Quinn</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would like to reinforce the comments of Ron Gosnell on the need to integrate the thoughts and ideas of the SS Vrain residents in this Hall Meadows planning. Boulder County made verbal commitments to the residents during the walking tour completed during the master plan preparation. (see notes in Appendix A of Master Plan)</td>
<td>Larry Quinn</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This is a very important stretch of river for boaters and as a revenue generator for Lyons. Fish passages does not always equal passable by boat or similar. Whenever in-channel structures are installed, safe navigable boating structures, in addition to plans for fish passage, should also be installed. In channel rehabilitation should create in-channel features such as eddies, pools and drops, consistent with a natural river bed, that promote in stream recreation including boating and angling. Plans for public and private access for recreation should be considered, as appropriate, in all locations where floodplain rehabilitation will occur.</td>
<td>Matt Booth</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>After the recent deluge of rain, we had water coming into our crawl space for the last several days and requiring some round-the-clock vigilance on our part. We think that the flooding occurred for at least 3 reasons:</td>
<td>Bonnie Richards &amp; Sam Miller</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Before the flood, the river was at a lower elevation in our backyard. Water went easily down from the yard and drained into the river. Now that the river is at a higher elevation, and further away, we have a berm helping to keep the river from flowing into the yard. However, we have pools of water collecting in the basin that was the old river bed.</td>
<td>Bonnie Richards &amp; Sam Miller</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. To further complicate matters, we have natural springs in the vicinity around our house. These never caused flooding before the flood, as when the springs were running on the surface, they drained directly into the river. Now these springs are releasing into the backyard in the old riverbed and helping to create pools of standing water in the back yard.</td>
<td>Bonnie Richards &amp; Sam Miller</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Finally, we have noticed a great deal of standing water on Boulder County Open Space land across the street from us on Highway 7. Before the flood, there was a ditch on the other side of the road that carried water into a culvert that fed back into the river. The ditch was filled in by sand after the flood and is no longer feeding directly into the riverbed. The water has been collecting through April and May and gets worse with each new rain. We believe that some of this water is moving into our yard and contributing to the flooding in our crawl space. We now hear a chorus of frogs living in the open space pools and singing day and night. In the 27 years I have lived in this house, there have never been frogs anywhere near us. Charming as their song may be, the presence of frogs in the area signals a change in the landscape that also features the more unfortunate result of having water directed toward our hour that ultimately ends up with us having to pump water from our crawl space.</td>
<td>Bonnie Richards &amp; Sam Miller</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comment</td>
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<td>Regarding concern about water in crawl space and emergency repairs in Hall Meadows, which they felt caused the problem: There are three easy fixes that would stop the water from coming through the berm:</td>
<td>Bonnie Richards &amp; Sam Miller</td>
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<td>1. Correct the mistakes that were made when the second channel was shut off. This is the root cause of the new problems we have seen since then. Correcting the problem would require several hours of stone relocation and re-building the weir further downstream, but it would be the best possible solution.</td>
<td>Bonnie Richards &amp; Sam Miller X X</td>
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<td>2. Deepen the channel that exists now. This channel was originally opened over a year ago with a 1 foot depth, and has scrubbed deep enough that it has never been a problem until the dam was put in place. The dam increased the water level, but did not lower the river bed. Fixing this problem would require digging and moving a lot of stone and sand, which could be used to rebuild the field (which is part of the Flood Recovery Plan already).</td>
<td>Bonnie Richards &amp; Sam Miller X X</td>
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<td>3. The simplest solution, that should help somewhat with the problem is to clear the blockages in the river that are holding the water artificially high. There are very obvious rapids around woody debris just East of John Dabbs and Karen Libin’s house (next door). The post-flood river was cleaned of debris before the current channel was opened. The local channel has not been cleared of deepened, like the rest of the local river, because it is part of Open Space land. This is the easiest solution, but may not stop the water coming through the berm.</td>
<td>Bonnie Richards &amp; Sam Miller X X</td>
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<td>There is still a stream running through my basement, and I am running two sump pumps to keep up with it. This high water problem will not solve itself. The solutions all involve working on the river, and on Open Space property. Open Space has created a problem that cannot be fixed without their involvement. I have already added a lot of dirt to try to cover the standing water in my yard, but the ponds, puddles, and streams still run through the yard, they just run at a higher level.</td>
<td>Bonnie Richards &amp; Sam Miller X X</td>
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<td>Notes from an e-mail from POS staff based on site visit with Ms. Libin in February 20, 2014: Their 2 biggest concerns appear to be:</td>
<td>Karen Liblin</td>
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<td>1. They have a water right to pump 1 acre-foot of water out of the creek. They said they used to pump directly out of the creek. Now their pump is buried 8 – 10 feet down (by their estimate) and of course the river is too far away to pump from and on county property. They also mentioned groundwater and uncertainty on how it would fluctuate in the coming years, so they may also be able to pump groundwater too to access their water.</td>
<td>Karen Liblin X</td>
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<td>2. They also mentioned that they have lost $250,000 in equity from their home because the river is no longer right behind their house, and they are concerned about the aesthetic and financial losses. At a minimum, they are hoping to have the creek moved closer to their home to be able to get their water. They feel the creek could be put back just south of the cottonwoods where a secondary channel formed during the flood.</td>
<td>Karen Liblin X</td>
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<td>Our concerns are that until something definitive is concluded, we are not in a position to move forward with our planning and recovery process. The three main issues that are related to the river location that we, ourselves, need to consider are:</td>
<td>Jason Dabbs</td>
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<td>1. removal of the tons of debris and protection of the trees whose roots are currently smothered</td>
<td>Jason Dabbs X X</td>
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<td>2. long term viability of our well with a remote location of the river</td>
<td>Jason Dabbs X</td>
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<td>3. rehabilitation of our septic system</td>
<td>Jason Dabbs X</td>
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<td>Previously, above our 457 Old Saint Vrain Road location, the creek was pushed next to highway 7 with a large rock rip rap walled barrier on the south side of the stream. This was done after the 1969 flood. This action resulted in a long straight path followed by two very sharp right angle turns for the stream. The first sharp turn was at an easterly tributary diversion culvert installed to limit flows to the South Ledge Ditch head gate. The main stream flow here was directed North. The second right angle turn was where the stream then headed sharply east toward the County road and our property, before it again was redirected north along the west side of County road. This former main streambed with the two sharp right angle turns (north and then east) is now dry.</td>
<td>Ron Gosnell X</td>
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<td>The flood broke from the artificial rip-rap walled confines above and spread out. As the creek subsided after about a week of flood flows, there were several minor channels being formed and flowing. Now, after a meandering shallow flow over the meadow, there is one relatively distinct gathering with a single flow location near a cottonwood grove. That single flow takes the stream through a swale that existed before this flood and to a location South of the South Ledge Ditch head gate. Here the former muskrat pond was cut five feet deeper and breached.</td>
<td>Ron Gosnell X</td>
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<td>It is my opinion that the stream below the meadow is closer to an earlier pre-1969 flood location just above our property. And because of its present location above us and its widened breadth near us, the stream can better accommodate high water flows than before this flood. I understand, neighbors above us want the stream restored to its former location north of the pasture across from Dean and Elaine Readmond, and reestablished at a location just south of the two homes adjacent to Highway 7 that previously had stream front property. I think that this is a reasonable action and still enables the present downstream location to be enhanced and approximate its present path above the South Ledge Ditch head gate.</td>
<td>Ron Gosnell X</td>
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<td>That is my preference. Namely to NOT RESTORE any long straight steam paths and sharp angle turns and instead allow gradual stream bed turns to put the stream on a northerly course near the South Ledge Ditch head gate and along side the County Road, instead of being directed at it. Furthermore, encouraging the stream to spread out somewhat where there is space for it to do so without threatening structures, rather than attempting confinement with rip-rapped walls, seems to me to be a reasonable strategy for flood mitigation. I think that my stated preference is consistent with the City of Longmont’s need to supply their municipal water intake, and the South Ledge Ditch Company and Meadow Ditch Company needs to lift a portion of the stream flow above its present deep cut depth and feed their head gates. Because the flood deepened the channel so greatly, near the South Ledge Ditch and Meadow Ditch head gates, some engineered work will be necessary to gravity feed these two head gates/ditches. ... I do not claim expertise but I think it is appropriate to express my preference and opinion after I have observed the river’s behavior over 40 years and during several flood events.</td>
<td>Ron Gosnell</td>
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<td><strong>DEBRIS</strong></td>
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<td>Overall concern about woody debris throughout reach including short- and long-term plans for its management</td>
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<td>Concerned about log jams at bridges in future floods</td>
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<td><strong>LYONS QUARRY</strong></td>
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<td>What are the reclamation plans and timeline for reclamation at Lyons Quarry</td>
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<td>Is there anything that can be done in the quarry that would reduce flood risks?</td>
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<td>During Master Plan process, flood detention at Lyons Quarry was discussed, but deemed infeasible by the Michael Baker Jr. consulting team</td>
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<td><strong>PRIVATE RESIDENCES ALONG HWY 7</strong></td>
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<td>Concerned about groundwater levels and its impact on adjacent homes</td>
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<td><strong>HALL MEADOWS/ SPLIT FLOW</strong></td>
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<td>Following the flood, neighbors had a lot of concern about the split flow that occurred in Hall Meadows, including potential impacts to Old St. Vrain Road during spring run-off. Temporary repairs were completed in spring 2014 and fixed again in spring 2016. A long-term plan needs to be developed for this area.</td>
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<td>Need to consider interaction of creek and road</td>
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<td>Need planning that can determine specific strategies and mitigations to address the flooding that occurred due to the breach in this area</td>
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<td><strong>LONGMONT PIPELINE/ DIVERSION</strong></td>
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<td>A number of issues identified including channel capacity downstream, root wads remaining on bank, revegetation, future plans for post-flood channel to the south</td>
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<td>How will the stream alignment be determined and how does this affect private land and Boulder County open space land?</td>
<td>Larry Quinn</td>
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<td>What will be in regard to conveyance capacity of the stream in this reach alongside the new pipeline? Will the pre-flood capacity be restored or merely a 5-year channel as was done downstream of the bridge?</td>
<td>Larry Quinn</td>
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<td>Will the diversion structure include fish passage design elements as has been mentioned verbally by Longmont staff to neighbors?</td>
<td>Larry Quinn</td>
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<td>Can the proposed fill on the east side of the SSV channel proposed in the draft basin plan be included in this project?</td>
<td>Larry Quinn</td>
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<td>What are the Boulder County Open Space plans for the triangular section of Hall open space upstream of the bridge?</td>
<td>Larry Quinn</td>
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<td>How do the new 100-year hydrology figures in the draft SVCC affect the hydraulics of the existing bridge?</td>
<td>Larry Quinn</td>
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<td>The Longmont diversion should be modified to address life safety issues that are created by the current low head dam that exists. A downstream sloping retrofit is an easy way to address this problem. This section of creek is boated during runoff and is considered a run for beginner intermediate boaters. This structure is life threatening and also allows no route for fish to migrate up stream. Please do not harvest large boulders from the riverbed or banks to use as materials for other areas.</td>
<td>Matt Booth</td>
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<td>The Longmont South Pipeline flood repair project is funded by FEMA to “restore the function of the water utility” including compliance with permit requirements. The pipeline project has seeded the construction area to comply with the United States Army Corps of Engineers authorization, Colorado Department of Public Health and Environment permit for storm water discharges associated with construction activities, and the Boulder County grading permit.</td>
<td>Jon Robb</td>
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<td><strong>OLD SOUTH ROAD BRIDGES</strong></td>
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<td>Ability of existing intact downstream bridge to handle future floods – concern about how creek is angled at bridge</td>
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<td>Potentially look at increasing capacity for water and debris</td>
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<td>Need coordination of creek restoration with replacement of destroyed upstream bridge</td>
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<td><strong>DITCHES</strong></td>
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<td>Want to ensure ditch representatives are involved in the planning</td>
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<td>What are plans for replacing diversions?</td>
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<td>South Ledge / Meadows was rebuilt – concern about how this was designed / constructed</td>
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<td>Need fish passages</td>
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<td><strong>COMMUNITY</strong></td>
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<td>Does this project affect only private or only public entities along the creek? How are we determining the extent of who and what is affected by these alternatives?</td>
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<td>Adjacent recreational trails and public creek access should be considered. It is important to create connections to existing trail systems and to provide new opportunities for this experience.</td>
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<td>Consideration should be given to how the work done on this reach will affect the homes and amenities downstream.</td>
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<td><strong>RESILIENCY</strong></td>
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<td>The type and size of material used to re-establish the creek channel should be considered and applied in context to the surrounding area. Debris and large rocks have proven to be unstable and movable</td>
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<td>The current rise of the creek bed should be addressed. The project should take into account sediment deposition that will continue to make the creek bed shallower.</td>
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<td>The current increase in creek velocity should be addressed. The project should aim to decrease velocity and to make sure this does not continue to be a hazard in the future.</td>
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<td>Should the stream be put into a single channel or into multiple channels at different places along the reach? The stream should be allowed to take its path of least resistance.</td>
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<td>The flood plain should be altered or expanded in certain areas of the project to afford seasonal increased flows and provide room for flood events.</td>
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<td>The project should aim to reduce future flood impacts and damage risk.</td>
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<td>The project should evaluate existing engineered elements currently in place along the creek and utilize smarter infrastructure concepts.</td>
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<td><strong>SAFETY</strong></td>
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<td>Human life and safety should be a top priority for the project, for those in the immediate surroundings of the creek and others who will interact with the creek.</td>
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<td>The project should take into consideration the safety of recreational users of the creek, eg: kayakers. Large rocks and woody debris putting out incorrectly or placed in improper places can prove harmful and devastating.</td>
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<td>There is specific interest in modifying the current Longmont Diversion dam to create a passable structure for personal watercraft and fish.</td>
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<td>New infrastructure used to control the creek should not include any new dams. Proposed dams should be safe for recreation, even if they are in an area along the creek that is not sanctioned as such.</td>
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<td>Please recommend diversion structures that are safe for personal watercraft to pass over.</td>
<td>Chris Cope</td>
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<tr>
<td>Please keep the rivers safe for kayaks, tubes, and swimmers! Please do not create any new low head dams and modify the existing low head dams to allow safe passage. Even if it's an area where recreation is not sanctioned, all it takes is for someone to fall in the river or to lose control of a boat, and it could be deadly. Please, the river claims enough lives, make the dams safe.</td>
<td>Pam Stone</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>ENVIRONMENT</strong></td>
<td></td>
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<td>The project should ensure the creek channel allows for the passage of key fish species.</td>
<td>Public</td>
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</tr>
<tr>
<td>The creek and associated flood plain should provide aquatic and terrestrial habitat that allows for many different types of plant and animal species to thrive within the corridor.</td>
<td>Public</td>
<td></td>
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</tr>
<tr>
<td>The channel and adjacent stream bank should be re-established to a natural state and avoid highly-engineered solutions to the reach. A terraced bank system can be utilized to provide a space where native plant and animal species can thrive.</td>
<td>Public</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>The project should follow a natural model to mimic the conditions that would occur as the creek restores itself to a healthy condition. The creek should be as Mother Nature intended.</td>
<td>Public</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Criteria should be established for future mitigation of natural disasters. There should be planned vegetation control with awareness of the potential future hazard posed by large woody debris during flooding conditions.</td>
<td>Public</td>
<td></td>
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</tr>
<tr>
<td>There is a need for an assessment of the environmental consequences, positive or negative, of the proposed alternatives.</td>
<td>Public</td>
<td></td>
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</tr>
<tr>
<td><strong>PROJECT IMPLEMENTATION</strong></td>
<td></td>
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</tr>
<tr>
<td>The Andesite Quarry storm water management plan significantly impacts the adjacent stream channel. The operation of the Andesite Quarry reclamation is an important part of the corridor and something should be done to mitigate current negative impacts. The design team should review the Andesite Quarry reclamation and storm water management plans and push to work in conjunction with the reclamation of the Quarry site to help expedite and coordinate mutual positive outcomes such as flood risk reduction.</td>
<td>Public</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
### Comment

<table>
<thead>
<tr>
<th>Where are key / funded sections and how has the allocation of funds been determined for this reach? The project should not just focus on key / funded reaches but address the complete creek system.</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>The project should provide an understanding of the current grant money opportunities and strategize ways to continue to receive funds for recovery and maintenance.</td>
<td>Public</td>
</tr>
</tbody>
</table>

#### PUBLIC MEETING #1

**Community:**

- Does this project affect only private or only public entities along the creek? How are we determining the extent of who and what is affected by these alternatives?  
  - Public

- Adjacent recreational trails and public creek access should be considered. It is important to create connections to existing trail systems and to provide new opportunities for this experience.  
  - Public

- Consideration should be given to how the work done on this reach will affect the homes and amenities downstream.  
  - Public

**Resilience:**

- The type and size of material used to re-establish the creek channel should be considered and applied in context to the surrounding area. Debris and large rocks have proven to be unstable and movable during flood events.  
  - Public

- The current rise of the creek bed should be addressed. The project should take into account sediment deposition that will continue to make the creek bed shallower.  
  - Public

- The current increase in creek velocity should be addressed. The project should aim to decrease velocity and to make sure this does not continue to be a hazard in the future.  
  - Public

- Should the stream be put into a single channel or into multiple channels at different places along the reach? The stream should be allowed to take its path of least resistance.  
  - Public

- The flood plain should be altered or expanded in certain areas of the project to afford seasonal increased flows and provide room for flood events.  
  - Public

- Affects that may take place outside the project limits from creek stormwater runoff and diverted debris flow should be considered.  
  - Public

- The project should evaluate existing engineered elements currently in place along the creek and utilize smarter infrastructure concepts.  
  - Public

**Safety:**

- Human life and safety should be a top priority for the project, for those in the immediate surroundings of the creek and others who will interact with the creek.  
  - Public

- The project should take into consideration the safety of recreational users of the creek, eg: kayakers. Large rocks and woody debris jutting out incorrectly or placed in improper places can prove harmful and devastating.  
  - Public

**Environment:**

- The project should ensure the creek channel allows for the passage of key fish species.  
  - Public

- The creek and associated flood plain should provide aquatic and terrestrial habitat that allows for many different types of plant and animal species to thrive within the corridor.  
  - Public

- The channel and adjacent stream bank should be re-established to a natural state and avoid highly-engineered solutions to the reach. A terraced bank system can be utilized to provide a space where native plant and animal species can thrive.  
  - Public

- The project should follow a natural model to mimic the conditions that would occur as the creek restores itself to a healthy condition. The creek should be as Mother Nature intended.  
  - Public

- Criteria should be established for future mitigation of natural disasters. There should be planned vegetation control with awareness of the potential future hazard posed by large woody debris during flooding conditions.  
  - Public

- There is a need for an assessment of the environmental consequences, positive or negative, of the proposed alternatives.  
  - Public

**Project Implementation:**

- The Andesite Quarry stormwater management plan significantly impacts the adjacent stream channel. The operation of the Andesite Quarry reclamation is an important part of the corridor and something should be done to mitigate current negative impacts. The design team should review the Andesite Quarry reclamation and stormwater management plans and push to work in conjunction with the reclamation of the Quarry site to help expedite and coordinate mutual positive outcomes such as flood risk reduction.  
  - Public

- Where are key / funded sections and how has the allocation of funds been determined for this reach? The project should not just focus on key / funded reaches but address the complete creek system.  
  - Public

- The project should provide an understanding of the current grant money opportunities and strategize ways to continue to receive funds for recovery and maintenance.  
  - Public
<table>
<thead>
<tr>
<th>Comment</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Habitat</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Conveyance</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Recreation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Stabilization</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Coordination</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PUBLIC MEETING #2</strong></td>
<td></td>
</tr>
<tr>
<td>Summary of Alternatives Presented and Comments Received:</td>
<td></td>
</tr>
<tr>
<td><strong>Floodplain Connectivity:</strong></td>
<td></td>
</tr>
<tr>
<td>Hall 2 deed restrictions may preclude use of onsite materials – BCPOS to investigate</td>
<td>Public</td>
</tr>
<tr>
<td>Concern for wood removal maintenance (“to keep channel clear”) – who is responsible?</td>
<td>Public</td>
</tr>
<tr>
<td>Take into consideration where the river wants to go.</td>
<td>Public</td>
</tr>
<tr>
<td>Consider using excess cut at quarry for fill as part of their reclamation area</td>
<td>Public</td>
</tr>
<tr>
<td>Could take it from the area adjacent to the quarry and stream to lower floodplain</td>
<td>Public</td>
</tr>
<tr>
<td>Add sinuosity to reach downstream of quarry/upstream of bedrock bend?</td>
<td>Public</td>
</tr>
<tr>
<td>New road/embankment design includes benching on the inside (2-yr, 25-yr flow), does not include instream structures – proposed slope ~0.6%</td>
<td>Public</td>
</tr>
<tr>
<td>Public suggestion to move road to improve conveyance</td>
<td>Public</td>
</tr>
<tr>
<td>Move channel further west to take pressure off road</td>
<td>Public</td>
</tr>
<tr>
<td>Matthews and Holcombe combined diversion (across from John Hall’s property): Include proposed location in our design</td>
<td>Public</td>
</tr>
<tr>
<td>Matthews and Holcombe combined diversion (across from John Hall’s property): New location in stream – 2 ft. high (+/-)</td>
<td>Public</td>
</tr>
<tr>
<td>Matthews and Holcombe combined diversion (across from John Hall’s property): Potentially move diversion upstream to bedrock bend</td>
<td>Public</td>
</tr>
<tr>
<td>Andesite bridge: 2x wider, need to coordinate design</td>
<td>Public</td>
</tr>
<tr>
<td>Andesite bridge: Pipe for diversion tied into design</td>
<td>Public</td>
</tr>
<tr>
<td>Andesite bridge: Addition of floodplain culvert(s) on left bank, may not be feasible given wider span</td>
<td>Public</td>
</tr>
<tr>
<td>Andesite bridge: Need to stabilize area on right bank downstream of bridge (river was in this location, but the County moved it back)</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Illegal levee built on the upstream side of the 2 houses in the floodplain, expand floodplain benching to include removal of the levee? Or keep?</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Some folks want to keep plug so overflow does not occur</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Concern with avulsion potential (re: overflow channel at plug)... can the overflow channel be moved further downstream?</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Downstream of plug, improve channel/floodplain connection to provide “slow” crest over into floodplain</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Concern expressed over overflow channels near road – worried about flow moving over the road again. Would like to see different options (away from road)</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Maybe utilize “pilot channels” to encourage flow in floodplain without having a defined channel</td>
<td>Public</td>
</tr>
<tr>
<td>Plug area: Plug area is very important in terms of what the channel does downstream at the diversion</td>
<td>Public</td>
</tr>
<tr>
<td>South Ledge/Meadows Diversion: Is anything planned in this area? Floodplain grading? Overflow channels?</td>
<td>Public</td>
</tr>
<tr>
<td>Longmont Diversion: Would like to see sediment removed downstream of diversion (concerned that Longmont filled in the channel alignments, instead of just leaving as overflow</td>
<td>Public</td>
</tr>
<tr>
<td>Old South St. Vrain Bridge area: A lot of concern re: overflow channel that comes off of main channel upstream of bridge, crosses road and runs through private properties (house proposed on one of the parcels).</td>
<td>Public</td>
</tr>
<tr>
<td>Old South St. Vrain Bridge area: Interested in another option that sends flow around and back to the main channel without going very far into private property</td>
<td>Public</td>
</tr>
<tr>
<td>Old South St. Vrain Bridge area: Can the flow be optimized through bridge? What is the current capacity</td>
<td>Public</td>
</tr>
<tr>
<td>Old South St. Vrain Bridge area: Reroute channel to improve flow through bridge</td>
<td>Public</td>
</tr>
<tr>
<td>Channel Complexity:</td>
<td></td>
</tr>
<tr>
<td>BCPOS is combining two points of diversion into one structure – looking for guidance on placement and structure type. Proposed location circled on map</td>
<td>Public</td>
</tr>
<tr>
<td>BCPOS wants our survey data as they need to get out and collect more data but don’t want to duplicate effort</td>
<td>Public</td>
</tr>
<tr>
<td>BCPOS can send bridge drawings if we still need them</td>
<td>Public</td>
</tr>
<tr>
<td>Received one random comment to re-visit the suggestions in the master plan for the Old SSV Bridge and Longmont diversion. I suspect this mostly refers to replacing the current structure with a fish passable structure.</td>
<td>Public</td>
</tr>
<tr>
<td>Revegetation:</td>
<td></td>
</tr>
</tbody>
</table>
A long conversation took place between Brandon Parsons (THK), Vince Zounek and Ron Gosnell. Mr. Parsons (THK) was asked to consider revegetation measures along the embankment of Old St. Vrain Road, across the street from Vince’s property. This area used to be heavily vegetated but pre-flood work eliminated both upland vegetation and willows in this area. Specific revegetation measures discussed include: Installing coyote willows into the rip-rap, re-seeding the upland area currently used for parking, incorporating new bio-engineering measures along the embankment to establish more robust riparian zone.

Brandon (THK) explained to Cecily Mui, from the St. Vrain Creek Coalition (SVCC), the methods behind the revegetation alternative. Ms. Mui (SVCC) inquired as to the exact location of the EPW project boundaries. Erst Strenge (BCPOS), drew the project limits on the map of the alternative and a brief discussion arose regarding their placement and connection to one another.

Ms. Mui (SVCC) asked if a reference reach had been used to develop the revegetation plan and methods. Mr. Parsons (THK) explained that while a healthy reference reach had not been identified our experience in similar river systems helped guide the approach. David Hirt (BCPOS) stepped in to share his expertise on the native plant species and the approach we will be taking to revegetate this corridor based on his experience in this area.

Mr. Gosnell, asked the design team and BCPOS to consider a maintenance strategy and criteria to prevent woody debris from causing an issue. Ron, would like to develop a way to understand at what point mature vegetation could become a hazard during a flood. A discussion arose between Tim Shafer (BCPOS), Mr. Parsons (THK) and Mr. Gosnell regarding this issue.

Mr. Gosnell, identified areas along the stretch where woody debris gathered during the floods. It was discussed that a way to decrease obstructions caused of woody debris would be to open up these “choke points” along the creek.

**Infrastructure Protection:**

- Moth Mullein: State priority list B along the roadside
- Approximate 2:1 Slope for Mine reclamation
- New combined ditch location for Matthews and Holcomb near Hall property
- Will need to protect new diversion pipeline by Old South St Vrain Bridge
- Box culvert will be provided for Holcomb Matthews Ditch at Old South St Vrain Bridge
- Might need to protect diversion pipeline near Redmond’s
- Ok to move South Ledge and Meadows diversion as part of this project
- Vince Property: Parking along street, killing vegetation, need to plant willows
- Option to move Longmont diversion upstream
- Important to combine Longmont diversion into the EWP project limits.
- Sediment is starting to fill in downstream of Longmont Diversion.
- Option to straighten Highway 7 crossings should be evaluated
- Create Low Flow Channel Throughout Reach
- Do Not Harvest Boulders Or Break Boulders Greater than 3’ diameter
- Place Large Instream Boulders In The Channel
- Provide Boat And Fish Passage
Appendix X:
SSVC Plant List – Site Walk Observations
<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>National Wetland Indicator</th>
<th>Plant Type</th>
<th>Native Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panicum virgatum</td>
<td>Switchgrass</td>
<td>FACW</td>
<td>grass</td>
<td>Native</td>
</tr>
<tr>
<td>Asclepias syriaca</td>
<td>Milkweed</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td>Toxicodendron rydbergii</td>
<td>Poison Ivy</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Carduus nutans</td>
<td>Musk Thistle</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td>Cirsium arvense</td>
<td>Canadian Thistle</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td>Festuca arundinacea</td>
<td>Tall fescue</td>
<td>FACU</td>
<td>for</td>
<td>Introduced</td>
</tr>
<tr>
<td>Arctium minus</td>
<td>Common Burdock (noxious weed)</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td>Equisetum arvense</td>
<td>Common Horsetail</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Ambrosia artemisifolia</td>
<td>Common Ragweed</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td>Heterotheca villosa</td>
<td>Hairy Golden Aster</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Liatris punctata</td>
<td>Blazing Star</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Solidago canaensis</td>
<td>Goldenrod</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Elymus lanceolatus</td>
<td>Thickspike wheatgrass</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Elymus trachycaulus</td>
<td>Slender wheatgrass</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Elymus dahluricus</td>
<td>Wildrye wheatgrass</td>
<td>FACU</td>
<td>forb</td>
<td>Non-native</td>
</tr>
<tr>
<td>Amorpha canescens</td>
<td>Leadplant amorpha</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Astragalus glycyphyllos</td>
<td>Wild liquorice</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Ratibida pinnata</td>
<td>Yellow coneflower</td>
<td>FACU</td>
<td>shrub</td>
<td>Non-native</td>
</tr>
<tr>
<td>Nepeta cataria</td>
<td>Catnip</td>
<td>FACU</td>
<td>forb</td>
<td>Introduced</td>
</tr>
<tr>
<td>Helianthus annuus</td>
<td>Sunflower</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Thermopsis divaricarpa</td>
<td>Goldenbarker</td>
<td>FACU</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Veronica anagallis</td>
<td>Speedwell</td>
<td>OBL</td>
<td>forb</td>
<td>Native</td>
</tr>
<tr>
<td>Glycyrrhiza grandis</td>
<td>American mannagrass</td>
<td>OBL</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Hypericum perforatum</td>
<td>St. John’s-wort</td>
<td>FACU</td>
<td>for</td>
<td>Introduced</td>
</tr>
<tr>
<td>Rumex crispus</td>
<td>Curly dock</td>
<td>FACU</td>
<td>for</td>
<td>Introduced</td>
</tr>
<tr>
<td>Verbena officinalis</td>
<td>Blue verbena</td>
<td>FACU</td>
<td>for</td>
<td>Introduced</td>
</tr>
<tr>
<td>Primula vulgaris</td>
<td>Primrose</td>
<td>FACU</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Carex nebrascensis</td>
<td>Nebraska Sedge</td>
<td>OBL</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Leucanthemum vulgare</td>
<td>Oxeye daisy</td>
<td>OPL</td>
<td>for</td>
<td>Introduced</td>
</tr>
<tr>
<td>Salvia tragus</td>
<td>Russian thistle</td>
<td>FACU</td>
<td>for</td>
<td>Introduced</td>
</tr>
<tr>
<td>Juncus arcticus</td>
<td>Arctic rush</td>
<td>FACU</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Hippuris vulgaris</td>
<td>Mare’s tail</td>
<td>OBL</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Grindelia squarrose</td>
<td>Gum weed</td>
<td>FACU</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Apocynum cannabinum</td>
<td>Dogbane</td>
<td>FACU</td>
<td>for</td>
<td>Native</td>
</tr>
<tr>
<td>Ericameria nauseosa</td>
<td>Rabbitbrush</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Prunus virginiana</td>
<td>Chokecherry</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Salix exigua</td>
<td>Coyote Willow</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Rosa woodsii</td>
<td>Woods rose</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Asparagus officinalis</td>
<td>Wild asparagus</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Populus angustifolia</td>
<td>Narrow leaf cotton woods</td>
<td>FACU</td>
<td>tree</td>
<td>Native</td>
</tr>
<tr>
<td>Populus deltoides</td>
<td>Plains cottonwoods</td>
<td>FACU</td>
<td>tree</td>
<td>Native</td>
</tr>
<tr>
<td>Rhus trilobata</td>
<td>Three leaf sumac</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Malus domestica</td>
<td>Apple tree</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Physocarpus monogynus</td>
<td>ninebark</td>
<td>UPL</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Prunus americana</td>
<td>Wild plum</td>
<td>FACU</td>
<td>shrub</td>
<td>Native</td>
</tr>
<tr>
<td>Acer negundo</td>
<td>Boxelder</td>
<td>FACU</td>
<td>tree</td>
<td>Native</td>
</tr>
<tr>
<td>Alnus incana</td>
<td>Alders</td>
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Appendix X:
Public Meeting Minutes
South St. Vrain Creek Restoration at Hall Ranch

Meeting Minutes

Public Meeting #1

Date: May 24, 2016, 5:00-6:30 pm
Location: Rogers Hall
4th and High Street
Lyons, Colorado 80540
Attendees: 16 members of the public present. See Attached Sign In Sheet.

Project Team Members Present:
Matrix: Scott Schrieber – Project Manager
       Robert Krehbiel – Senior Civil / Quality Control
THK: Kevin Shanks – Revegetation and Public Involvement
Otak: Julie Ash – Senior / Quality Control

Meeting Purpose

This first public meeting was for the purpose of providing information to the community about the project team and project process. The project team facilitated an open discussion for the public to voice concerns and issues that they would like to see addressed by this project. These issues will be categorized to form the evaluation criteria the design team will use to evaluate the alternative design strategies for the restoration of the creek.

This meeting addressed these specific topics:

1. Introduce the design team
2. Explain the project funding and objective
3. Collect important input from the public and stakeholders

Summary of Discussion

The following is a collated list of critical issues and concerns voiced by the public and stakeholders at the first public meeting. These issues are grouped by topic to better organize and understand the key values that were discussed at this meeting.
Community

- Does this project affect only private or only public entities along the creek? How are we determining the extent of who and what is affected by these alternatives?

- Adjacent recreational trails and public creek access should be considered. It is important to create connections to existing trail systems and to provide new opportunities for this experience.

- Consideration should be given to how the work done on this reach will affect the homes and amenities downstream.

Resiliency

- The type and size of material used to re-establish the creek channel should be considered and applied in context to the surrounding area. Debris and large rocks have proven to be unstable and movable during flood events.

- The current rise of the creek bed should be addressed. The project should take into account sediment deposition that will continue to make the creek bed shallower.

- The current increase in creek velocity should be addressed. The project should aim to decrease velocity and to make sure this does not continue to be a hazard in the future.

- Should the stream be put into a single channel or into multiple channels at different places along the reach? The stream should be allowed to take its path of least resistance.

- The flood plain should be altered or expanded in certain areas of the project to afford seasonal increased flows and provide room for flood events.

- Affects that may take place outside the project limits from creek stormwater runoff and diverted debris flow should be considered.

- The project should aim to reduce future flood impacts and damage risk.

- The project should evaluate existing engineered elements currently in place along the creek and utilize smarter infrastructure concepts.

Safety

- Human life and safety should be a top priority for the project, for those in the immediate surroundings of the creek and others who will interact with the creek.
• The project should take into consideration the safety of recreational users of the creek, eg: kayakers. Large rocks and woody debris jutting out incorrectly or placed in improper places can prove harmful and devastating.

Environment

• The project should ensure the creek channel allows for the passage of key fish species.

• The creek and associated flood plain should provide aquatic and terrestrial habitat that allows for many different types of plant and animal species to thrive within the corridor.

• The channel and adjacent stream bank should be re-established to a natural state and avoid highly-engineered solutions to the reach. A terraced bank system can be utilized to provide a space where native plant and animal species can thrive.

• The project should follow a natural model to mimic the conditions that would occur as the creek restores itself to a healthy condition. The creek should be as Mother Nature intended.

• Criteria should be established for future mitigation of natural disasters. There should be planned vegetation control with awareness of the potential future hazard posed by large woody debris during flooding conditions.

• There is a need for an assessment of the environmental consequences, positive or negative, of the proposed alternatives.

Project Implementation

• The Andesite Quarry stormwater management plan significantly impacts the adjacent stream channel. The operation of the Andesite Quarry reclamation is an important part of the corridor and something should be done to mitigate current negative impacts. The design team should review the Andesite Quarry reclamation and stormwater management plans and push to work in conjunction with the reclamation of the Quarry site to help expedite and coordinate mutual positive outcomes such as flood risk reduction.

• Where are key / funded sections and how has the allocation of funds been determined for this reach? The project should not just focus on key / funded reaches but address the complete creek system.

• The project should provide an understanding of the current grant money opportunities and strategize ways to continue to receive funds for recovery and maintenance.
Continued Discussion

After the public meeting, the public and stakeholders were invited to continue to send any comments addressing critical issues and concerns of this project. See attached for the recorded comments. The following is a summary of the extended commentary:

Safety

- There is specific interest in modifying the current Longmont Diversion dam to create a passable structure for personal watercraft and fish.

- New infrastructure used to control the creek should not include any new dams. Proposed dams should be safe for recreation, even if they are in an area along the creek that is not sanctioned as such.
South St. Vrain Creek Restoration at Hall Ranch
Public Comment – By Email / Website

Sent to: Ernst Strenge
Date sent: 05-26-2016, 4:30 pm
Subject: South St. Vrain Creek Comments (#1)

Name: Matt Booth
Email: georgiavet1@gmail.com
Comments:

The Longmont diversion should be modified to address life safety issues that are created by the current low head dam that exists. A downstream sloping retrofit is an easy way to address this problem. This section of creek is boated during runoff and is considered a run for beginner intermediate boaters. This structure is life threatening and also allows no route for fish to migrate up stream
Please do not harvest large boulders from the riverbed or banks to use as materials for other areas.

Sent to: Ernst Strenge
Date sent: 05-26-2016, 5:39 pm
Subject: South St. Vrain Creek Comments (#2)

Name: Chris Cope
Email: chris@purecope.com
Address: 340 Vasquez Rd PO Box 608 Lyons, CO 80540
Phone: (3030)817-9037
Comments:

Please recommend diversion structures that are safe for personal watercraft to pass over.
Sent to: Ernst Strenge
Date sent: 05-26-2016, 8:11 pm
Subject: South St. Vrain Creek Comments (#3)
Name: Pam Stone
Email: pgand3@gmail.com
Address: Lyons, CO 80540
Comments:

Please keep the rivers safe for kayaks, tubes, and swimmers! Please do not create any new low head dams and modify the existing low head dams to allow safe passage. Even if it’s an area where recreation is not sanctioned, all it takes is for someone to fall in the river or to lose control of a boat, and it could be deadly. Please, the river claims enough lives, make the dams safe.
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<td><a href="mailto:prcgbouldervangen@gmail.com">prcgbouldervangen@gmail.com</a></td>
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<td>Darrell Beck</td>
<td>S.V. Creek Coal.</td>
<td>davelevy@TwnفسOffc.Net</td>
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<tr>
<td>Dave Levy &amp; Bob</td>
<td>Resident/ SVCC</td>
<td>davlevy@TwnفسOffc.Net</td>
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<td>Jim Kerr</td>
<td>Town of Lyons/Resident</td>
<td><a href="mailto:KerrJamesRe@gmail.com">KerrJamesRe@gmail.com</a></td>
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<tr>
<td>Vince Zonnek</td>
<td>South St Vrain</td>
<td><a href="mailto:VZeolhek@msn.com">VZeolhek@msn.com</a></td>
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<td>Wanda Griest</td>
<td>12500 Rd 69 Lyons</td>
<td><a href="mailto:Wgriest@gmail.com">Wgriest@gmail.com</a></td>
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<td>Roy Griest</td>
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<tr>
<td>Bob Snell</td>
<td>2643 Riverside Dr</td>
<td><a href="mailto:rnsnell@msn.com">rnsnell@msn.com</a></td>
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<tr>
<td>Julee Snell</td>
<td></td>
<td><a href="mailto:juleesnell1@msn.com">juleesnell1@msn.com</a></td>
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<tr>
<td>Matt Jacekei</td>
<td>31820 S. St Vrain</td>
<td><a href="mailto:Matt-Jacekei@Yahoomail.com">Matt-Jacekei@Yahoomail.com</a></td>
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<td>Nathen Werner</td>
<td>Local Engineer</td>
<td><a href="mailto:nathan@sz0d67.com">nathan@sz0d67.com</a></td>
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<td>Shera Sumnerford</td>
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<td>Laken Johnson</td>
<td>Lyons P&amp;R</td>
<td><a href="mailto:Laken921@comcast.com">Laken921@comcast.com</a></td>
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# South St. Vrain Creek Restoration Project
Planning and Preliminary Design
May 24, 2016

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<tr>
<td>Larry Quinn</td>
<td>Emas WNN</td>
<td><a href="mailto:lwunnn1134@gmai.com">lwunnn1134@gmai.com</a></td>
<td>89 C Rd 69 Lyons 80540</td>
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<tr>
<td>John Hall</td>
<td>Property Owner</td>
<td><a href="mailto:jhallcattke@gmail.com">jhallcattke@gmail.com</a></td>
<td>7901 Woodland Rd Longmont 80503</td>
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South St. Vrain Creek Restoration at Hall Ranch
Meeting Minutes
Public Meeting #2

Date:       June 30, 2016, 5:00-6:30 pm
Location:   Rogers Hall
            4th and High Street
            Lyons, Colorado 80540
Attendees:  19 members of the public present. See Attached Sign In Sheet.

Project Team Members Present:
Matrix:     Scott Schrieber – Project Manager
            Robert Krehbiel – Senior Civil / Quality Control
THK:        Kevin Shanks – Revegetation and Public Involvement
            Brandon Parsons – Revegetation and Public Involvement
OTAK:       Tracy Emmanuel – Fluvial Geomorphologist
            Luke – Fluvial Geomorphologist

Meeting Purpose
The purpose of the second public meeting for the South St. Vrain Creek Restoration at Hall Ranch was to present the public with four alternatives and explain the prioritization process by which the design team developed each alternative and how they will be evaluated and combined into a final preferred alternative.

Meeting Summary
The design team gave a presentation which summarized the work the design team had done to date and outlined the goals for the meeting and next steps for the project moving forward.

Scott Schreiber (Matrix) introduced the team, and summarized the progress of the project since the last public meeting. Mr. Schreiber discussed how the design team had continued to gather public input, through meeting with private landowners and progressed the design approach based on the input and technical observations they have received to date.

Kevin Shanks (THK) gave an in depth explanation of how the input received from stakeholder groups and the public had been distilled and incorporated into a set of prioritization criteria that would be used to place emphasis on aspects the four alternatives. This process was presented to the public in the form of a flow chart showing how the design team used public and stakeholder input to develop the prioritization criteria (Decisions Making Process) and how this criteria will be used to evaluate the alternatives (Decision Matrix).
The design team presented each of the four alternatives. Tracey Emmanuel (OTAK) presented Floodplain Connectivity, Luck Swan (OTAK) presented Channel Complexity, Brandon Parsons (THK) presented Revegetation and Scott Schreiber (Matrix) presented Infrastructure protection.

Following the presentations, each member of the design team was stationed at a table where maps showing each alternative was presented and explained in more detail. The public was encouraged to visit each table, ask questions and provide comments about each alternative to the design team. These comments were written directly on the maps of each alternative and compiled for consideration in the preferred alternative.

**Summary of Alternatives Presented and Comments Received:**

**Floodplain Connectivity:**

Floodplain connectivity involves activating the floodplain at frequent intervals to enable critical floodplain functions, including:

- Sediment storage
- Reduction of erosive forces in main channel
- Nutrient transfer
- Healthy riparian/wetland ecosystem

Strategies that were presented to illustrate floodplain connectivity include:

- Activating overflow channels
- Incorporating channel/floodplain benching (sediment removal)

**Comments:**

**General comments:**

- Hall 2 deed restrictions may preclude use of onsite materials – BCPOS to investigate
- Concern for wood removal maintenance (“to keep channel clear”) – who is responsible?
- Take into consideration where the river wants to go.

**Comments from upstream to downstream:**

- Quarry:
  - Consider using excess cut at quarry for fill as part of their reclamation area
  - Could take it from the area adjacent to the quarry and stream to lower floodplain
- Add sinuosity to reach downstream of quarry/upstream of bedrock bend?
- @ bedrock bend:
  - New road/embankment design includes benching on the inside (2-yr, 25-yr flow), does not include instream structures – proposed slope ~0.6%
  - Public suggestion to move road to improve conveyance
  - Move channel further west to take pressure off road
- Matthews and Holcombe combined diversion (across from John Hall’s property)
  - Include proposed location in our design
  - New location in stream – 2 ft. high (+/-)
  - Potentially move diversion upstream to bedrock bend
● Andesite bridge
  o 2x wider, need to coordinate design
  o Pipe for diversion tied into design
  o Addition of floodplain culvert(s) on left bank, may not be feasible given wider span
  o Need to stabilize area on right bank downstream of bridge (river was in this location, but the County moved it back)

● Plug area
  o Illegal levee built on the upstream side of the 2 houses in the floodplain, expand floodplain benching to include removal of the levee? Or keep?
  o Some folks want to keep plug so overflow does not occur
  o Concern with avulsion potential (re: overflow channel at plug)... can the overflow channel be moved further downstream?
  o Downstream of plug, improve channel/floodplain connection to provide “slow” crest over into floodplain
  o Concern expressed over overflow channels near road – worried about flow moving over the road again. Would like to see different options (away from road)
  o Maybe utilize “pilot channels” to encourage flow in floodplain without having a defined channel
  o Plug area is very important in terms of what the channel does downstream at the diversion

● South Ledge/Meadows Diversion:
  o Is anything planned in this area? Floodplain grading? Overflow channels?

● Longmont Diversion
  o Would like to see sediment removed downstream of diversion (concerned that Longmont filled in the channel alignments, instead of just leaving as overflow
  o Water is being sent to the east by raising the terrace

● Old South St. Vrain Bridge area
  o A lot of concern re: overflow channel that comes off of main channel upstream of bridge, crosses road and runs through private properties (house proposed on one of the parcels).
  o Interested in another option that sends flow around and back to the main channel without going very far into private property
  o Can the flow be optimized through bridge? What is the current capacity
  o Reroute channel to improve flow through bridge

**Channel Complexity:**

Channel complexity refers to channel features that contribute to geomorphically effective bedforms, as well as habitat quality and diversity. These features include:

● Low Flow Channel
● Pools, riffles, steps
● Bars (point, lateral, mid-channel)
● Large woody material (bank protection/habitat enhancement)
● Roughened channels/boulder clusters

Comments:

Folks were generally interested in the how the in-channel structures would help with sediment. Lots of interest in the wood structures but mostly curiosities.

Summary of comments, which mostly came from Boulder County:

● BCPOS is combining two points of diversion into one structure – looking for guidance on placement and structure type. Proposed location circled on map
● BCPOS wants our survey data as they need to get out and collect more data but don’t want to duplicate effort
● BCPOS can send bridge drawings if we still need them
● Received one random comment to re-visit the suggestions in the master plan for the Old SSV Bridge and Longmont diversion. I suspect this mostly refers to replacing the current structure with a fish passable structure.

Revegetation:

Revegetation will provide the framework for increased ecosystem function and aesthetic appeal along the corridor. Our team presented strategies that include:

● Protecting and preserving existing stands of vegetation.
● Incorporating bioengineering measures to increase habitat maturation and resiliency.
● Planting a diverse palette of native plant species.

Comments:

● A long conversation took place between Brandon Parsons (THK), Vince Zounek and Ron Gosnell. Mr. Parsons (THK) was asked to consider revegetation measures along the embankment of Old St. Vrain Road, across the street from Vince’s property. This area used to be heavily vegetated but pre-flood work eliminated both upland vegetation and willows in this area. Specific revegetation measures discussed include:
  o Installing coyote willows into the rip-rap.
  o Re-seeding the upland area currently used for parking.
  o Incorporating new bio-engineering measures along the embankment to establish more robust riparian zone.
● Brandon (THK) explained to Cecily Mui, from the St. Vrain Creek Coalition (SVCC), the methods behind the revegetation alternative.
● Ms. Mui (SVCC) inquired as to the exact location of the EPW project boundaries. Erst Strenge (BCPOS), drew the project limits on the map of the alternative and a brief discussion arose regarding their placement and connection to one another.
● Ms. Mui (SVCC) asked if a reference reach had been used to develop the revegetation plan and methods. Mr. Parsons (THK) explained that while a healthy reference reach had not been identified our experience in similar river systems helped guide the approach. David Hirt (BCPOS)
stepped in to share his expertise on the native plant species and the approach we will be taking to revegetate this corridor based on his experience in this area.

- Mr. Gosnell, asked the design team and BCPOS to consider a maintenance strategy and criteria to prevent woody debris from causing an issue. Ron, would like to develop a way to understand at what point mature vegetation could become a hazard during a flood. A discussion arose between Tim Shafer (BCPOS), Mr. Parsons (THK) and Mr. Gosnell regarding this issue.
- Mr. Gosnell, identified areas along the stretch where woody debris gathered during the floods. It was discussed that a way to decrease obstructions caused of woody debris would be to open up these “choke points” along the creek.

**Infrastructure Protection:**

Infrastructure Protection includes the protection of key infrastructure elements and onsite item that are considered “assets” to the corridor. Infrastructure elements include:

- Roads
- Bridges
- Houses
- Ditches

Strategies presented for infrastructure projection include:

- Bank Stabilization
  - Bioengineering
  - Buried Rootwads
- Offset Buried Natural/Structural Aspects
  - Buried Riprap Revetment
  - Buried Boulders
  - Structural Walls
- Channel Alignment: In-depth Analysis Required
  - Slope, Sinuosity, Wavelength, Belt Width
- Detention
- Cost

**Comments:**

- Moth Mullein: State priority list B along the roadside
- Approximate 2:1 Slope for Mine reclamation
- New combined ditch location for Matthews and Holcomb near Hall property
- will need to protect new diversion pipeline by Old South St Vrain Bridge
- Box culvert will be provided for Holcomb Matthews Ditch at Old South St Vrain Bridge
- Might need to protect diversion pipeline near Redmond’s
- Ok to move South Ledge and Meadows diversion as part of this project
- Vince Property: Parking along street, killing vegetation, need to plant willows
- Option to move Longmont diversion upstream
- Important to combine Longmont diversion into the EWP project limits.
- Sediment is starting to fill in downstream of Longmont Diversion.
- Option to straighten Highway 7 crossings should be evaluated
- Create Low Flow Channel Throughout Reach
- Do Not Harvest Boulders Or Break Boulders Greater Than 3' Diameter
- Place Large Instream Boulders In The Channel
- Provide Boat And Fish Passage
- Create Low Flow Channel Throughout Reach
- Do Not Harvest Boulders or Break Boulders Greater than 3’ diameter.
- Place Large Instream Boulders In The Channel
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<td><a href="mailto:wgriesl@gmail.com">wgriesl@gmail.com</a></td>
<td>Spring Mountain Ditch</td>
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<tr>
<td>Vince Zounek</td>
<td><a href="mailto:vzounek@msn.com">vzounek@msn.com</a></td>
<td>455 Old Saint Vrain Rd.</td>
</tr>
<tr>
<td>Dave Levy</td>
<td><a href="mailto:davelevy@qwestoffice.net">davelevy@qwestoffice.net</a></td>
<td>RESIDENT SVCC</td>
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<tr>
<td>Connie Davis</td>
<td><a href="mailto:connie.davis@aggregate-us.com">connie.davis@aggregate-us.com</a></td>
<td>Aggregate Inc</td>
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<tr>
<td>John Balletteer</td>
<td><a href="mailto:john.balletteer@hdrinc.com">john.balletteer@hdrinc.com</a></td>
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<td>Travis Snyder</td>
<td><a href="mailto:travis.snyder@hdrinc.com">travis.snyder@hdrinc.com</a></td>
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<td>Jim Kerr</td>
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<td>Lyons Resident</td>
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<tr>
<td>Michael Belleviecz</td>
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<tr>
<td>Ken Huso</td>
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<td><a href="mailto:tim.katers@state.co.us">tim.katers@state.co.us</a></td>
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<td>Cecily Mui</td>
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**Section 1A**

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| Limited Resource Area: | YES | NO |

**Section 1B Sponsor**

- **Sponsor Name:** Colorado Department of Natural Resources -CWCB
- **Address:** 1313 Sherman St. Room 721
- **City/State/Zip:** Denver/CO/80203
- **Phone Number:** (303) 866-3441
- **Fax:** (303) 866-4474
- **Email:** KEVIN.HOUCK@STATE.CO.US

**Section 1C Site Location Information**

- **County:** Boulder
- **State:** Colorado
- **Congressional District:** 2
- **Latitude:** 0
- **Longitude:** 0
- **UTM Coordinates Easting:** 475914
- **UTM Coordinates Northing:** 4451051
- **Drainage Name:** South St Vrain
- **Reach:** Reach 4b

**Damage Description:** Large amounts of sediment and debris deposits, from erosion caused by the 2013 flooding. There were changes in the river channel and flood plains.

**Section 1D Site Evaluation**

All answers in this section must be YES in order to be eligible for EWP assistance.

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<td>Y</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Imminent threat was created by this event?**</td>
<td>Y</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>For structural repairs, not repaired twice within ten years?***</td>
<td>Y</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Access to property granted by landowner(s)?</td>
<td>Y</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**Site Defensibility**

- Economic, environmental, and social documentation adequate to warrant action? (Go to pages 3, 4, 5, and 6***): Y | 0 |
- Proposed action technically viable? (Go to Page 9***): Y | 0 |

Have all the appropriate steps been taken to ensure that all segments of the affected population have been informed of the EWP program and its possible effects? YES: Y NO: 0

* Statutory
** Regulation
*** DSR Pages 3 through 6 and 9 are required to support the decisions recorded on this summary page. If additional space is needed on this or any other pages in this form, add appropriate pages.
DSR NO: Boulder_South St Vrain_Reach 4b_2015_High

Section 1E Proposed Action

Describe the preferred alternative from Findings: Section 5 A:

| Restore river to pre flood measures to withhold a 100 year event contingent upon completion of CR investigation and in compliance with requirements of F&WS emergency consultation and all applicable categorical exclusions. |

Total installation cost identified in this DSR: Section 3: $2,409,099

Section 1F NRCS State Office Review and Approval

Reviewed By: ___________________________________________ Date Reviewed: ______________________
State EWP Program Manager

Approved By: ___________________________________________ Date Approved: ______________________
State Conservationist

PRIVACY ACT AND PUBLIC BURDEN STATEMENT

NOTE: The following statement is made in accordance with the Privacy Act of 1974, (5 U.S.C. 552a) and the Paperwork Reduction Act of 1995, as amended. The authority for requesting the following information is 7 CFR 624 (EWP) and Section 216 of the Flood Control Act of 1950, Public Law 81-516, 33 U.S.C. 701b-1; and Section 403 of the Agricultural Credit Act of 1978, Public Law 95334, as amended by Section 382, of the Federal Agriculture Improvement and Reform Act of 1996, Public Law 104-127, 16 U.S.C. 2203. EWP, through local sponsors, provides emergency measures for runoff retardation and erosion control to areas where a sudden impairment of a watershed threatens life or property. The Secretary of Agriculture has delegated the administration of EWP to the Chief or NRCS on state, tribal and private lands.

Signing this form indicates the sponsor concurs and agrees to provide the regional cost-share to implement the EWP recovery measure(s) determined eligible by NRCS under the terms and conditions of the program authority. Failure to provide a signature will result in the applicant being unable to apply for or receive the grant the applicable program authorities. Once signed by the sponsor, this information may not be provided to other agencies. IRS, Department of Justice, or other State or Federal Law Enforcement agencies, and in response to a court or administrative tribunal.

The provisions of criminal and civil fraud statutes, including 18 U.S.C. 286, 287, 371, 641, 651, 1001; 15 U.S.C. 714m; and 31 U.S.C. 3729 may also be applicable to the information provided. According to the Paperwork Reduction Act of 1995, an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0578-0030. The time required to complete this information collection is estimated to average 117/1.96 minutes/hours per response, including the time for reviewing instructions, searching existing data sources, field reviews, gathering, designing, and maintaining the data needed, and completing and reviewing the collection information.

USDA NONDISCRIMINATION STATEMENT

“The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202)720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, SW., Washington, DC 20250-9410, or call (800)795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Civil Rights Statement of Assurance

The program or activities conducted under this agreement will be in compliance with the nondiscrimination provisions contained in the Titles VI and VII of the Civil Rights Act of 1964, as amended; the Civil Rights Restoration Act of 1987 (Public Law 100-259); and other nondiscrimination statutes; namely, Section 504 of the Rehabilitation Act of 1973, Title IX of the Amendments of 1972, the Age Discrimination Act of 1975, and the Americans with Disabilities Act of 1990. They will also be in accordance with regulations of the Secretary of Agriculture (7 CFR 15, 15a, and 15b), which provide that no person in the United States shall on the grounds of race, color, national origin, gender, religion, age or disability, be excluded from participation in, be denied the benefits of, or otherwise subjected to discrimination under any program or activity receiving Federal financial assistance from the U.S. Department of Agriculture or any agency thereof.
## 2A Resource Concerns

### Soil

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>No Action</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive bank erosion from stream banks or conveyance channels</td>
<td>Reduce erosion to quality criteria. SVAP2=5 for bank condition/stability.</td>
<td>Continued degradation of stream bank and stream. SVAP2=1 for bank stability/condition.</td>
</tr>
<tr>
<td>Sheet and rill, wind and/or irrigation-induced erosion</td>
<td>Reduced erosion due to a stable system.</td>
<td>Continued loss of soil through sheet and rill erosion.</td>
</tr>
</tbody>
</table>

### Water

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>No Action</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank erosion has created excess dissolved sediment in surface waters.</td>
<td>Stabilize banks to reduce water quality degradation. SVAP2=5 for bank stability/condition.</td>
<td>Continued degradation of streambank and stream. SVAP2=1 for bank stability/condition.</td>
</tr>
<tr>
<td>Bank stabilization &amp; sediment/debris removal will open up areas and allow habitat to recover.</td>
<td>Bank treatments will improve habitat over current conditions.</td>
<td>Continued damage to potential habitat areas from erosion, sediment, and debris.</td>
</tr>
</tbody>
</table>

### Air

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>No Action</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of vegetation and new plantings</td>
<td>Continued subsidence in ecological processes</td>
<td></td>
</tr>
<tr>
<td>Removal / Increased Control of pest plant and planting, and reduced transport of seeds.</td>
<td>Continued overtake possibly and unbalanced in ecological processes, and continued transport of seeds.</td>
<td></td>
</tr>
</tbody>
</table>

### Plant

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>No Action</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early successional species cover landscape not helping hold ground.</td>
<td>Removal of vegetation and new plantings</td>
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<td></td>
</tr>
<tr>
<td>Potential habitat areas for Ute ladie's-tresses and CO butterfly plant was damaged by bank erosion, sedimentation, &amp; debris deposits.</td>
<td>Bank stabilization &amp; sediment/debris removal will open up areas and allow habitat to recover.</td>
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</tr>
</tbody>
</table>

### Animal

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>No Action</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage or destruction to habitat for T&amp;E species and other native species.</td>
<td>Bank stabilization and protection measures will safeguard/improve habitat over current conditions for T&amp;E and natives species. SVAP2=5.6 overall.</td>
<td>Suitable riparian conditions will continue to provide habitat areas, preventing vegetative recovery in the near future. SVAP2=2.7 overall.</td>
</tr>
<tr>
<td>Potential Preble’s meadow jumping mouse (PMJM) habitat has been damaged or destroyed</td>
<td>Bank treatments will improve habitat over current conditions.</td>
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</table>

### Other

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>No Action</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>No suitable habitat for other Phase II listed species: sage grouse, MSO, ferret, lynx, greenback cutthroat trout</td>
<td>No Effect</td>
<td>No Effect</td>
</tr>
<tr>
<td>No water depletions so no effect on South Platte species: sturgeon, p. phalar, l. tern, &amp; whooping crane</td>
<td>No Effect</td>
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</tr>
</tbody>
</table>

### DSR NO: Boulder_South St Vrain_Reach 4b_2015_High

### Section 2 Environmental Evaluation

<table>
<thead>
<tr>
<th>2A Resource Concerns</th>
<th>2B Existing Condition</th>
<th>2C Alternative Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Action</td>
<td>No Action</td>
<td>Alternative</td>
</tr>
<tr>
<td>Streambank Stabilization, Floodplain Establishment, and Debris Removal</td>
<td>Site continues to degrade and adversely affects environment and community.</td>
<td></td>
</tr>
</tbody>
</table>

### 2D Effects of Alternatives

<table>
<thead>
<tr>
<th>Proposed Action</th>
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### Water Quality Degradation -- Excessive sediment in surface waters

<table>
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### Other

<table>
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<tr>
<th>Proposed Action</th>
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<tbody>
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<td>No Effect</td>
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<tr>
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<td>No Effect</td>
<td>No Effect</td>
</tr>
</tbody>
</table>

### No Resource Concern Identified

| No Effect | No Effect | No Change |

---

3 of 11
### Section 2E Special Environmental Concerns

<table>
<thead>
<tr>
<th>Resource Consideration</th>
<th>Existing Condition</th>
<th>Alternatives and Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clean Water Act</strong></td>
<td>The stream and adjacent riparian area were damaged in the flood. Debris was deposited on the floodplain and in the river.</td>
<td>Proposed Action: Debris removal and bank stabilization will improve the stream and adjacent riparian areas. No Action: Damaged areas will recover slowly and with additional bank and riparian area losses. Downstream deposition will continue to occur in Waters of the U.S. Alternative:</td>
</tr>
<tr>
<td><strong>Coastal Zone Management Areas</strong></td>
<td>Not applicable to Colorado as determined by NOAA</td>
<td>Proposed Action: Not Applicable to Colorado No Action: Not Applicable to Colorado Alternative:</td>
</tr>
<tr>
<td><strong>Coral Reefs</strong></td>
<td>Not applicable to Colorado as determined by the US Coral Reef Task Force</td>
<td>Proposed Action: Reports on file in State Office for Cultural Resources Management, contact Marsha Sims or State Archeologist. No Action: No Effect Alternative:</td>
</tr>
<tr>
<td><strong>Cultural Resources</strong></td>
<td>No Effect</td>
<td>Proposed Action: No Effect No Action: No Effect Alternative:</td>
</tr>
<tr>
<td><strong>Endangered and Threatened Species</strong></td>
<td>Habitat for PMDM, Ute ladies-tresses, &amp; CO butterfly plant was damaged or destroyed. Bank stabilization and debris removal will prevent or slow further loss of habitat.</td>
<td>Proposed Action: Bank stabilization will help suitable migratory bird habitat to re-establish. No Action: Habitat will recover slowly with continued bank erosion. Alternative:</td>
</tr>
<tr>
<td><strong>Environmental Justice</strong></td>
<td>No Effect</td>
<td>Proposed Action: No Effect No Action: No Effect Alternative:</td>
</tr>
<tr>
<td><strong>Essential Fish Habitat</strong></td>
<td>Not applicable to Colorado as determined by NOAA</td>
<td>Proposed Action: Not applicable to Colorado No Action: Not applicable to Colorado Alternative:</td>
</tr>
<tr>
<td><strong>Fish and Wildlife Coordination</strong></td>
<td>Not Applicable</td>
<td>Proposed Action: NRCS is in consultation with USFWS and other federal and state agencies. No Action: Not Applicable Alternative:</td>
</tr>
<tr>
<td><strong>Floodplain Management</strong></td>
<td>Debris &amp; sediment deposition and bank erosion are negatively affecting the floodplain and adjacent and downstream areas.</td>
<td>Proposed Action: Debris removal and bank stabilization will improve floodplain condition in the immediate area and downstream. No Action: Continued deposition and erosion will negatively affect floodplain for the near future Alternative:</td>
</tr>
<tr>
<td><strong>Invasive Species</strong></td>
<td>Flooding created a seedbed and may have provided a seed source for common weed species. Practices will help trap some weed seed before it gets into the water course.</td>
<td>Proposed Action: Debris removal and bank work will help the area to revegetate to a more normal condition, improving scenic beauty. No Action: Debris will continue to harm the scenic beauty of the area. Alternative:</td>
</tr>
<tr>
<td><strong>Migratory Birds</strong></td>
<td>Habitat for many migratory bird species was harmed or destroyed. Bank stabilization will help suitable migratory bird habitat to re-establish.</td>
<td>Proposed Action: Habitat will recover slowly with continued bank erosion. No Action: Habitat will recover slowly with continued bank erosion. Alternative:</td>
</tr>
<tr>
<td><strong>Natural Areas</strong></td>
<td>None known</td>
<td>Proposed Action: None known No Action: None known Alternative:</td>
</tr>
<tr>
<td><strong>Prime and Unique Farmlands</strong></td>
<td>No conversions of prime/unique farmlands to non-ag uses expected.</td>
<td>Proposed Action: No conversions of prime/unique farmlands to non-ag uses expected. No Action: No conversions of prime/unique farmlands to non-ag uses expected. Alternative:</td>
</tr>
<tr>
<td><strong>Riparian Areas</strong></td>
<td>Riparian areas suffered extreme damage from the flood loss of vegetation, unstable banks, poor water quality. SVAP=2.7 overall.</td>
<td>Proposed Action: Riparian areas will be partly restored through debris removal, stabilizing streambanks and bank reconstruction. SVAP=5.6 overall. No Action: Riparian areas will continue to degrade into the near future. Stream will likely continue to move around the floodplain. SVAP=2.7 overall. Alternative:</td>
</tr>
<tr>
<td><strong>Scenic Beauty</strong></td>
<td>Flood removed woody vegetation and left behind debris which has made the area less scenic.</td>
<td>Proposed Action: Debris removal and bank stabilization will improve stream function and prevent further loss from erosion. No Action: Continued wetland losses from erosion and debris. Alternative:</td>
</tr>
<tr>
<td><strong>Wetlands</strong></td>
<td>Riparian wetland areas are covered with debris and are subject to loss through bank erosion. Debris removal and bank stabilization will restore some wetland function and prevent further loss from erosion.</td>
<td>Proposed Action: Debris removal and bank stabilization will restore some wetland function and prevent further loss from erosion. No Action: Continued wetland losses from erosion and debris. Alternative:</td>
</tr>
<tr>
<td><strong>Wild and Scenic Rivers</strong></td>
<td>Not Applicable to Site</td>
<td>Proposed Action: Not Applicable to Site No Action: Not Applicable to Site Alternative:</td>
</tr>
</tbody>
</table>

Completed By: J. Tashiro                         Date: 9/15/15
### Section 2F Economic

This section must be completed by each alternative considered

<table>
<thead>
<tr>
<th>Reach</th>
<th>UTM Easting</th>
<th>UTM Northing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach 4b</td>
<td>475914</td>
<td>4451051</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Properties Protected (Private)</th>
<th>Future Damages ($)</th>
<th>Damage Factor (%)</th>
<th>Near Term Damage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Houses: 10</td>
<td>$2,000,000</td>
<td>75%</td>
<td>$1,500,000</td>
</tr>
<tr>
<td>2. Town Of Lyons</td>
<td>$2,000,000</td>
<td>75%</td>
<td>$1,500,000</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td>$0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties Protected (Public)</th>
<th>Future Damages ($)</th>
<th>Damage Factor (%)</th>
<th>Near Term Damage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. County Bridge</td>
<td>$500,000</td>
<td>75%</td>
<td>$375,000</td>
</tr>
<tr>
<td>2. SH 7</td>
<td>$1,000,000</td>
<td>75%</td>
<td>$750,000</td>
</tr>
<tr>
<td>3. Meill Street Bridge</td>
<td>$500,000</td>
<td>75%</td>
<td>$375,000</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Business Losses</th>
<th>Future Damages ($)</th>
<th>Damage Factor (%)</th>
<th>Near Term Damage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Town of Lyons</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Other</th>
<th>Future Damages ($)</th>
<th>Damage Factor (%)</th>
<th>Near Term Damage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td>$0</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td>$0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Near Term Damage Reduction</th>
<th>$4,500,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Benefit (Total Near Term Damage Reduction minus Cost from Section 3)</td>
<td>$2,090,901</td>
</tr>
</tbody>
</table>
### Section 2G Social Considerations. This section must be completed by each alternative considered

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has there been a loss of life as a result of the watershed impairment?</td>
<td></td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>Is there the potential for loss of life due to damages from the watershed impairment?</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has access to a hospital or medical facility been impaired by watershed impairment?</td>
<td></td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>Has the community as a whole been adversely impacted by the watershed impairment (life and property ceases to operate in a normal capacity)</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a lack or has there been a reduction of public safety due to watershed impairment?</td>
<td>☑</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Completed By:  
J. Tashiro  
Date: 9/14/15
**Section 2H Group Representation and Disability Information**

This section is completed only for the preferred alternative selected

<table>
<thead>
<tr>
<th>Group Representation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Indian/Alaska Native Female Hispanic</td>
<td></td>
</tr>
<tr>
<td>American Indian/Alaska Native Female Non-Hispanic</td>
<td>5</td>
</tr>
<tr>
<td>American Indian/Alaska Native Male Hispanic</td>
<td></td>
</tr>
<tr>
<td>American Indian/Alaska Native Male Non-Hispanic</td>
<td>3</td>
</tr>
<tr>
<td>Asian Female Hispanic</td>
<td></td>
</tr>
<tr>
<td>Asian Female Non-Hispanic</td>
<td>14</td>
</tr>
<tr>
<td>Asian Male Hispanic</td>
<td></td>
</tr>
<tr>
<td>Asian Male Non-Hispanic</td>
<td>13</td>
</tr>
<tr>
<td>Black or African American Female Hispanic</td>
<td></td>
</tr>
<tr>
<td>Black or African American Female Non-Hispanic</td>
<td>5</td>
</tr>
<tr>
<td>Black or African American Male Hispanic</td>
<td></td>
</tr>
<tr>
<td>Black or African American Male Non-Hispanic</td>
<td>4</td>
</tr>
<tr>
<td>Hawaiian Native/Pacific Islander Female Hispanic</td>
<td></td>
</tr>
<tr>
<td>Hawaiian Native/Pacific Islander Female Non-Hispanic</td>
<td></td>
</tr>
<tr>
<td>Hawaiian Native/Pacific Islander Male Hispanic</td>
<td></td>
</tr>
<tr>
<td>Hawaiian Native/Pacific Islander Male Non-Hispanic</td>
<td></td>
</tr>
<tr>
<td>White Female Hispanic</td>
<td>449</td>
</tr>
<tr>
<td>White Female Non-Hispanic</td>
<td>817</td>
</tr>
<tr>
<td>White Male Hispanic</td>
<td>48</td>
</tr>
<tr>
<td>White Male Non-Hispanic</td>
<td>817</td>
</tr>
<tr>
<td>Total Group</td>
<td>2175</td>
</tr>
</tbody>
</table>

Census tract(s) 80130136.012

Completed By: Tboldt  Date: 10/31/15
Section 21. Required consultation or coordination between the lead agency and/or the RFO and another government unit including tribes:

Easements, permissions, or permits:
Need to work with the Army Corps of Engineers on appropriate 404 permit needed for the bank reconstruction and protection work. May be able to use Nationwide Permit #37 for this work. Boulder County permits.

Mitigation Description:

Agencies, persons, and references consulted, or to be consulted:
Army Corps of Engineers, SHPO, USFWS, CWCB, Boulder County, St Vrain Watershed Coalition.
## Section 3 Engineering cost Estimate

**Completed By:** J. Tashiro  
**Date:** 9/14/2015

This section must be completed by each alternative considered.

<table>
<thead>
<tr>
<th>Reach</th>
<th>Reach 4b</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTM Easting:</td>
<td>475914</td>
</tr>
<tr>
<td>UTM Northing:</td>
<td>4451051</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Proposed Recovery Measure (including mitigation)</th>
<th>Quantity</th>
<th>Units</th>
<th>Unit Cost ($)</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cross Vane</td>
<td>0</td>
<td>EA</td>
<td>$2,000</td>
<td>$0</td>
</tr>
<tr>
<td>2. J-Hook Vane</td>
<td>0</td>
<td>EA</td>
<td>$2,000</td>
<td>$0</td>
</tr>
<tr>
<td>3. Armored Resiliency</td>
<td>1362</td>
<td>LF</td>
<td>$300</td>
<td>$408,600</td>
</tr>
<tr>
<td>4. In-Stream Structures</td>
<td>0</td>
<td>LF</td>
<td>$200</td>
<td>$0</td>
</tr>
<tr>
<td>5. Bioengineering</td>
<td>0</td>
<td>LF</td>
<td>$35</td>
<td>$0</td>
</tr>
<tr>
<td>6. Streambank Shaping</td>
<td>4932</td>
<td>LF</td>
<td>$175</td>
<td>$863,100</td>
</tr>
<tr>
<td>7. Sediment Removal</td>
<td>11920</td>
<td>CY</td>
<td>$20</td>
<td>$238,400</td>
</tr>
<tr>
<td>8. Fill</td>
<td>0</td>
<td>CY</td>
<td>$25</td>
<td>$0</td>
</tr>
<tr>
<td>9. Debris Removal</td>
<td>267</td>
<td>CY</td>
<td>$20</td>
<td>$5,340</td>
</tr>
<tr>
<td>10. Seeding &amp; Mulching</td>
<td>1462980</td>
<td>FT2</td>
<td>$0</td>
<td>$146,298</td>
</tr>
<tr>
<td>11. Erosion Control Fabric</td>
<td>0</td>
<td>FT2</td>
<td>$7</td>
<td>$0</td>
</tr>
<tr>
<td>12. Trees &amp; Shrubs</td>
<td>0</td>
<td>FT2</td>
<td>$1</td>
<td>$0</td>
</tr>
<tr>
<td>13. Topsoil</td>
<td>747361</td>
<td>FT2</td>
<td>$1</td>
<td>$747,361</td>
</tr>
<tr>
<td>14. Wetland Restoration</td>
<td>0</td>
<td>FT2</td>
<td>$25</td>
<td>$0</td>
</tr>
</tbody>
</table>

Total Installation Cost (Enter in Section 1F) **$2,409,099**
Section 4 NRCS EWP Funding Priority

Complete the following section to compute the funding priority for the recovery measures in this application (see instructions on page 14)

<table>
<thead>
<tr>
<th>Priority Ranking Criteria (if more than one number applies enter the highest ranking number, 1 is the highest ranking with 4 being the lowest)</th>
<th>Enter number selection (one number only) (1, 2, 3, or 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is this an exigency situation?</td>
<td>2</td>
</tr>
<tr>
<td>2. Is this a site where there is serious, but not immediate threat to human life?</td>
<td></td>
</tr>
<tr>
<td>3. Is this a site where buildings, utilities, or other important infrastructure components</td>
<td></td>
</tr>
<tr>
<td>4. Is this site a funding priority established by the NRCS Chief?</td>
<td></td>
</tr>
</tbody>
</table>

The following are modifiers for the above criteria

<table>
<thead>
<tr>
<th>Modifier (enter all alpha characters (no commas) that apply, i.e., abf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Will the proposed action or alternatives protect or conserve federally-listed threatened and endangered species or critical habitat? ae</td>
</tr>
<tr>
<td>b. Will the proposed action or alternatives protect or conserve cultural sites listed on the National Register of Historic Places?</td>
</tr>
<tr>
<td>c. Will the proposed action or alternatives protect or conserve prime or important farmland?</td>
</tr>
<tr>
<td>d. Will the proposed action or alternatives protect or conserve existing wetlands?</td>
</tr>
<tr>
<td>e. Will the proposed action or alternatives maintain or improve current water quality conditions?</td>
</tr>
<tr>
<td>f. Will the proposed action or alternatives protect or conserve unique habitat, including but not limited to, areas inhabited by State-listed species, fish and wildlife management area, or State identified sensitive habitats?</td>
</tr>
</tbody>
</table>

| Priority Ranking Value | 2ae |

Enter priority computation in Section 1A, NRCS Entry, Funding priority number.

Remarks:

See Pages 3 and 4
DSR NO: Boulder_South St Vrain_Reach 4b_2015_High

Section 5A Findings

Findings: Indicate the preferred alternative from Section 2 (Enter to Section 1E):

Restore river to pre flood measures to withhold a 100 year event contingent upon completion of CR investigation and in compliance with requirements of F&WS emergency consultation and all applicable categorical exclusions.

I have considered the effects of the action and the alternatives on the Environmental Economic, Social; the Special Environmental Concerns; and the extraordinary circumstances (40 CFR 1508.27). I find for the reasons stated below, that the preferred alternative:

- ✔️ Has been sufficiently analyzed in the EWP PEIS (reference all that apply)
  - Chapter 2.3.1
  - Chapter 2.3.2.1
  - Chapter 2.3.5.1
  - Chapter 5.2.2.1
  - Chapter 5.2.2.5

- □ May require the preparation of an environmental assessment or environmental impact statement.
  The action will be referred to the NRCS State Office on this date:  

NRCS representative of the DSR team

Title: Todd Boldt, EWP SPC Date: 11/2/15

Section 5B Comments:

Section 5C Sponsor Concurrence: __________________________

Sponsor Representative

Title: __________________________ Date: __________________________

Section 6 Attachments:
  A. Location Map
  B. Site Plan or Sketches
  C. Other (explain)
FIGURE XX
SOUTH ST. VRAIN
GEOMORPHIC REACHES AND
PEBBLE COUNT LOCATIONS

*This map contains data compiled from multiple sources and is for information purposes only. The data used to create the map are not guaranteed to be complete or accurate. The locations of all features are approximate.

Imagery Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Last Modified: 8/10/2016
Custom Soil Resource Report for Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties; and Boulder County Area, Colorado

August 7, 2016
Soil surveys contain information that affects land use planning in survey areas. They
highlight soil limitations that affect various land uses and provide information about
the properties of the soils in the survey areas. Soil surveys are designed for many
different users, including farmers, ranchers, foresters, agronomists, urban planners,
community officials, engineers, developers, builders, and home buyers. Also,
conservationists, teachers, students, and specialists in recreation, waste disposal,
and pollution control can use the surveys to help them understand, protect, or enhance
the environment.

Various land use regulations of Federal, State, and local governments may impose
special restrictions on land use or land treatment. Soil surveys identify soil properties
that are used in making various land use or land treatment decisions. The information
is intended to help the land users identify and reduce the effects of soil limitations on
various land uses. The landowner or user is responsible for identifying and complying
with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area
planning, onsite investigation is needed to supplement this information in some cases.
Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/
.nrsc/main/soils/health/) and certain conservation and engineering applications. For
more detailed information, contact your local USDA Service Center (http://
offices.sc.egov.usda.gov/locator/app?agency=nrsc) or your NRCS State Soil
Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?
cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are
seasonally wet or subject to flooding. Some are too unstable to be used as a
foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic
tank absorption fields. A high water table makes a soil poorly suited to basements or
underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department
of Agriculture and other Federal agencies, State agencies including the Agricultural
Experiment Stations, and local agencies. The Natural Resources Conservation
Service (NRCS) has leadership for the Federal part of the National Cooperative Soil
Survey.

Information about soils is updated periodically. Updated information is available
through the NRCS Web Soil Survey, the site for official soil survey information.

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and activities on the basis of race, color, national origin, age, disability, and where
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individual's income is derived from any public assistance program. (Not all prohibited
bases apply to all programs.) Persons with disabilities who require alternative means
for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.
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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the
individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.
Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.
The soil surveys that comprise your AOI were mapped at scales ranging from 1:20,000 to 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map:  Natural Resources Conservation Service
Coordinate System:  Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area:  Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties
Survey Area Data:  Version 4, Sep 22, 2014

Soil Survey Area:  Boulder County Area, Colorado
Survey Area Data:  Version 12, Sep 22, 2015

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed:  Apr 28, 2011—Apr 13, 2012

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.
## Map Unit Legend

### Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties (CO645)

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1701D</td>
<td>Ratake family-Rock outcrop complex, dry, 40 to 150 percent slopes</td>
<td>5.8</td>
<td>0.3%</td>
</tr>
<tr>
<td>2703B</td>
<td>Cypher-Ratake families complex, 5 to 40 percent slopes</td>
<td>190.0</td>
<td>8.5%</td>
</tr>
<tr>
<td>2705D</td>
<td>Ratake-Cathedral families-Rock outcrop complex, 40 to 150 percent slopes</td>
<td>20.1</td>
<td>0.9%</td>
</tr>
<tr>
<td>2706D</td>
<td>Cypher family-Rock outcrop complex, 40 to 150 percent slopes</td>
<td>10.2</td>
<td>0.5%</td>
</tr>
<tr>
<td>2717B</td>
<td>Cypher-Wetmore-Ratake families complex, 5 to 40 percent slopes</td>
<td>7.7</td>
<td>0.3%</td>
</tr>
<tr>
<td>5101A</td>
<td>Pachic Argiustolls-Aquic Argiudolls complex, 0 to 15 percent slopes</td>
<td>34.4</td>
<td>1.5%</td>
</tr>
<tr>
<td>ML</td>
<td>Dams and Mine dumps, 5 to 75 percent slopes</td>
<td>5.9</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

**Subtotals for Soil Survey Area**

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>274.0</td>
<td>12.3%</td>
</tr>
</tbody>
</table>

**Totals for Area of Interest**

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,224.5</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

### Boulder County Area, Colorado (CO643)

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>AcC</td>
<td>Ascalon sandy loam, 3 to 5 percent slopes</td>
<td>21.0</td>
<td>0.9%</td>
</tr>
<tr>
<td>Cu</td>
<td>Colluvial land</td>
<td>488.8</td>
<td>22.0%</td>
</tr>
<tr>
<td>JrF</td>
<td>Juget-Rock outcrop complex, 9 to 55 percent slopes</td>
<td>86.4</td>
<td>3.9%</td>
</tr>
<tr>
<td>MdB</td>
<td>Manter sandy loam, 1 to 3 percent slopes</td>
<td>7.0</td>
<td>0.3%</td>
</tr>
<tr>
<td>Nh</td>
<td>Niwot soils</td>
<td>158.8</td>
<td>7.1%</td>
</tr>
<tr>
<td>PgE</td>
<td>Peyton-Jugt very gravelly loamy sands, 5 to 20 percent slopes</td>
<td>11.9</td>
<td>0.5%</td>
</tr>
<tr>
<td>PrF</td>
<td>Pinata-Rock outcrop complex, 5 to 55 percent slopes</td>
<td>500.2</td>
<td>22.5%</td>
</tr>
<tr>
<td>Ro</td>
<td>Rock outcrop</td>
<td>676.5</td>
<td>30.4%</td>
</tr>
</tbody>
</table>

**Subtotals for Soil Survey Area**

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,950.5</td>
<td>87.7%</td>
</tr>
</tbody>
</table>

**Totals for Area of Interest**

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2,224.5</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a soil series. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly
indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A complex consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An undifferentiated group is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include miscellaneous areas. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.
Arapaho-Roosevelt National Forest Area, Colorado, Parts of Boulder, Clear Creek, Gilpin, Grand, Park and Larimer Counties

1701D—Ratake family-Rock outcrop complex, dry, 40 to 150 percent slopes

Map Unit Setting

- **National map unit symbol**: tlxd
- **Elevation**: 5,500 to 6,800 feet
- **Mean annual precipitation**: 12 to 25 inches
- **Mean annual air temperature**: 45 to 48 degrees F
- **Frost-free period**: 70 to 90 days
- **Farmland classification**: Not prime farmland

Map Unit Composition

- **Ratake family, dry, and similar soils**: 50 percent
- **Rock outcrop**: 35 percent

*Estimates are based on observations, descriptions, and transects of the map unit.*

Description of Ratake Family, Dry

**Setting**

- **Landform**: Mountain slopes
- **Parent material**: Colluvium and/or residuum derived from igneous and metamorphic rock

**Typical profile**

- **A - 0 to 8 inches**: very gravelly sandy loam
- **Bw - 8 to 18 inches**: very gravelly sandy loam
- **Cr - 18 to 28 inches**: bedrock

**Properties and qualities**

- **Slope**: 40 to 75 percent
- **Depth to restrictive feature**: 10 to 20 inches to paralithic bedrock
- **Natural drainage class**: Somewhat excessively drained
- **Runoff class**: Medium
- **Capacity of the most limiting layer to transmit water (Ksat)**: Very low to moderately low (0.00 to 0.06 in/hr)
- **Depth to water table**: More than 80 inches
- **Frequency of flooding**: None
- **Frequency of ponding**: None
- **Available water storage in profile**: Very low (about 1.2 inches)

**Interpretive groups**

- **Land capability classification (irrigated)**: None specified
- **Hydrologic Soil Group**: D
- **Other vegetative classification**: Mountain muhly - Arizona fescue (MUMO-FEAR2) (G2602), Rocky mountain juniper/true mountain mahogany (JUSC2/CEMO2) (W0304)

Description of Rock Outcrop

**Setting**

- **Landform**: Mountain slopes
- **Landform position (two-dimensional)**: Backslope, summit
Landform position (three-dimensional): Mountain flank

Typical profile
  \( R \) - 0 to 60 inches: bedrock

Properties and qualities
  Slope: 60 to 150 percent
  Depth to restrictive feature: 0 inches to lithic bedrock
  Runoff class: Very high
  Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)

Interpretive groups
  Land capability classification (irrigated): None specified
  Land capability classification (nonirrigated): 8
  Hydrologic Soil Group: D

2703B—Cypher-Ratake families complex, 5 to 40 percent slopes

Map Unit Setting
  National map unit symbol: tlxk
  Elevation: 6,500 to 8,500 feet
  Mean annual precipitation: 16 to 25 inches
  Mean annual air temperature: 45 to 48 degrees F
  Frost-free period: 70 to 90 days
  Farmland classification: Not prime farmland

Map Unit Composition
  Cypher family and similar soils: 40 percent
  Ratake family and similar soils: 40 percent
  Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ratake Family

Setting
  Landform: Mountain slopes
  Parent material: Colluvium and/or residuum derived from igneous and metamorphic rock

Typical profile
  A - 0 to 8 inches: very gravelly sandy loam
  Bw - 8 to 18 inches: very gravelly sandy loam
  Cr - 18 to 28 inches: bedrock

Properties and qualities
  Slope: 5 to 40 percent
  Depth to restrictive feature: 10 to 20 inches to paralithic bedrock
  Natural drainage class: Somewhat excessively drained
  Runoff class: Medium
  Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
  Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 1.2 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine-Rocky mountain juniper/true mountain mahogany (PIPO-JUSC2/CEMO2) (C1115), Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107)

Description of Cypher Family
Setting
Landform: Mountain slopes
Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock

Typical profile
A - 0 to 4 inches: very gravelly coarse sandy loam
Bw - 4 to 10 inches: very gravelly coarse sandy loam
R - 10 to 20 inches: bedrock

Properties and qualities
Slope: 5 to 40 percent
Depth to restrictive feature: 4 to 20 inches to lithic bedrock
Natural drainage class: Somewhat excessively drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 0.6 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/antelope bitterbrush (PIPO/PUTR2) (C1120)

2705D—Ratake-Cathedral families-Rock outcrop complex, 40 to 150 percent slopes

Map Unit Setting
National map unit symbol: tlxn
Elevation: 6,500 to 9,000 feet
Mean annual precipitation: 16 to 25 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 70 to 90 days
Farmland classification: Not prime farmland
Map Unit Composition

*Ratake family and similar soils*: 50 percent  
*Cathedral family and similar soils*: 20 percent  
*Rock outcrop*: 15 percent  
*Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Ratake Family

**Setting**
- **Landform**: Mountain slopes  
- **Parent material**: Colluvium and/or residuum derived from igneous and metamorphic rock

**Typical profile**
- **A - 0 to 8 inches**: very gravelly sandy loam  
- **Bw - 8 to 18 inches**: very gravelly sandy loam  
- **Cr - 18 to 28 inches**: bedrock

**Properties and qualities**
- **Slope**: 40 to 75 percent  
- **Depth to restrictive feature**: 10 to 20 inches to paralithic bedrock  
- **Natural drainage class**: Somewhat excessively drained  
- **Runoff class**: Medium  
- **Capacity of the most limiting layer to transmit water (Ksat)**: Very low to moderately low (0.00 to 0.06 in/hr)  
- **Depth to water table**: More than 80 inches  
- **Frequency of flooding**: None  
- **Frequency of ponding**: None  
- **Available water storage in profile**: Very low (about 1.2 inches)

**Interpretive groups**
- **Land capability classification (irrigated)**: None specified  
- **Hydrologic Soil Group**: D  
- **Other vegetative classification**: Ponderosa pine/Arizona fescue (PIPO/FEAR2) (C1109), Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107)

Description of Cathedral Family

**Setting**
- **Landform**: Mountain slopes  
- **Parent material**: Residuum weathered from igneous and metamorphic rock

**Typical profile**
- **Oi - 0 to 0 inches**: slightly decomposed plant material  
- **A - 0 to 6 inches**: very stony sandy loam  
- **Bw - 6 to 11 inches**: extremely stony sandy loam  
- **C - 11 to 17 inches**: extremely stony sandy loam  
- **R - 17 to 26 inches**: bedrock

**Properties and qualities**
- **Slope**: 40 to 75 percent  
- **Depth to restrictive feature**: 10 to 20 inches to lithic bedrock  
- **Natural drainage class**: Somewhat excessively drained  
- **Runoff class**: Medium  
- **Capacity of the most limiting layer to transmit water (Ksat)**: Very low to moderately low (0.00 to 0.01 in/hr)  
- **Depth to water table**: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 0.9 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107), Ponderosa pine/antelope bitterbrush (PIPO/PUTR2) (C1120)

Description of Rock Outcrop

Setting
Landform: Mountain slopes
Landform position (two-dimensional): Backslope, summit
Landform position (three-dimensional): Mountainflank

Typical profile
R - 0 to 60 inches: bedrock

Properties and qualities
Slope: 60 to 150 percent
Depth to restrictive feature: 0 inches to lithic bedrock
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D

2706D—Cypher family-Rock outcrop complex, 40 to 150 percent slopes

Map Unit Setting
National map unit symbol: tlxp
Elevation: 6,500 to 9,000 feet
Mean annual precipitation: 16 to 25 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 70 to 90 days
Farmland classification: Not prime farmland

Map Unit Composition
Cypher family and similar soils: 50 percent
Rock outcrop: 35 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Cypher Family
Setting
Landform: Mountain slopes
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock

Typical profile
A - 0 to 4 inches: very gravelly coarse sandy loam
Bw - 4 to 10 inches: very gravelly coarse sandy loam
R - 10 to 20 inches: bedrock

Properties and qualities
Slope: 40 to 75 percent
Percent of area covered with surface fragments: 0.0 percent
Depth to restrictive feature: 4 to 20 inches to lithic bedrock
Natural drainage class: Somewhat excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 0.6 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107), Ponderosa pine/antelope bitterbrush (PIPO/PUTR2) (C1120)

Description of Rock Outcrop

Setting
Landform: Mountain slopes
Landform position (two-dimensional): Backslope, summit
Landform position (three-dimensional): Mountainflank

Typical profile
R - 0 to 60 inches: bedrock

Properties and qualities
Slope: 60 to 150 percent
Depth to restrictive feature: 0 inches to lithic bedrock
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D
2717B—Cypher-Wetmore-Ratake families complex, 5 to 40 percent slopes

Map Unit Setting
- National map unit symbol: tlxs
- Elevation: 6,500 to 8,500 feet
- Mean annual precipitation: 16 to 25 inches
- Mean annual air temperature: 45 to 48 degrees F
- Frost-free period: 70 to 90 days
- Farmland classification: Not prime farmland

Map Unit Composition
- Cypher family and similar soils: 30 percent
- Wetmore family and similar soils: 30 percent
- Ratake family and similar soils: 20 percent
- Estimates are based on observations, descriptions, and transects of the map unit.

Description of Wetmore Family

Setting
- Landform: Mountain slopes, benches
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Residuum weathered from igneous and metamorphic rock

Typical profile
- Oi - 0 to 1 inches: slightly decomposed plant material
- A - 1 to 3 inches: gravelly sandy loam
- E - 3 to 11 inches: very gravelly sandy loam
- Bt - 11 to 17 inches: very gravelly sandy clay loam
- Cr - 17 to 19 inches: bedrock
- R - 19 to 29 inches: bedrock

Properties and qualities
- Slope: 5 to 40 percent
- Percent of area covered with surface fragments: 0.0 percent
- Depth to restrictive feature: 10 to 18 inches to paralithic bedrock; 12 to 20 inches to lithic bedrock
- Natural drainage class: Somewhat excessively drained
- Runoff class: Medium
- Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Available water storage in profile: Very low (about 1.5 inches)

Interpretive groups
- Land capability classification (irrigated): None specified
- Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine-Rocky mountain juniper/true mountain mahogany (PIPO-JUSC2/CEMO2) (C1115), Ponderosa pine/antelope bitterbrush (PIPO/PUTR2) (C1120)

Description of Cypher Family

Setting
Landform: Mountain slopes
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Residuum and/or slope alluvium derived from igneous and metamorphic rock

Typical profile
A - 0 to 4 inches: very gravelly coarse sandy loam
Bw - 4 to 10 inches: very gravelly coarse sandy loam
R - 10 to 20 inches: bedrock

Properties and qualities
Slope: 5 to 40 percent
Percent of area covered with surface fragments: 0.0 percent
Depth to restrictive feature: 4 to 20 inches to lithic bedrock
Natural drainage class: Somewhat excessively drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.01 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 0.6 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/elk sedge (PIPO/CAGE2) (C1105), Ponderosa pine/antelope bitterbrush (PIPO/PUTR2) (C1120)

Description of Ratake Family

Setting
Landform: Mountain slopes
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Colluvium and/or residuum derived from igneous and metamorphic rock

Typical profile
A - 0 to 8 inches: very gravelly sandy loam
Bw - 8 to 18 inches: very gravelly sandy loam
Cr - 18 to 28 inches: bedrock

Properties and qualities
Slope: 5 to 40 percent
Percent of area covered with surface fragments: 2.0 percent
Depth to restrictive feature: 10 to 20 inches to paralithic bedrock
Natural drainage class: Somewhat excessively drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water storage in profile: Very low (about 1.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Hydrologic Soil Group: D

Other vegetative classification: Ponderosa pine/Arizona fescue (PIPO/FEAR2) (C1109), Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107)

5101A—Pachic Argiustolls-Aquic Argiudolls complex, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: tqlg

Elevation: 5,800 to 8,530 feet

Mean annual precipitation: 16 to 30 inches

Mean annual air temperature: 39 to 46 degrees F

Frost-free period: 50 to 80 days

Farmland classification: Not prime farmland

Map Unit Composition

Pachic argiustolls and similar soils: 55 percent

Aquic argiudolls and similar soils: 30 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pachic Argiustolls

Setting

Landform: Stream terraces

Parent material: Alluvium derived from igneous, metamorphic and sedimentary rock

Typical profile

A1 - 0 to 10 inches: gravelly loam

A2 - 10 to 21 inches: gravelly loam

Bt1 - 21 to 31 inches: gravelly sandy clay loam

Bt2 - 31 to 42 inches: gravelly sandy clay loam

BCt - 42 to 60 inches: very gravelly sandy clay loam

Properties and qualities

Slope: 0 to 15 percent

Depth to restrictive feature: More than 80 inches

Natural drainage class: Well drained

Runoff class: Medium

Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
**Depth to water table:** More than 80 inches  
**Frequency of flooding:** None  
**Frequency of ponding:** None  
**Available water storage in profile:** Moderate (about 6.8 inches)

**Interpretive groups**  
*Land capability classification (irrigated):* None specified  
*Hydrologic Soil Group:* C  
*Other vegetative classification:* Arizona fescue - mountain muhly (FEAR2-MUMO) (G1902), Needleandthread - mountain muhly (HESPE11-MUMO) (G3106)

**Description of Aquic Argiudolls**

**Setting**  
*Landform:* Drainageways, alluvial flats  
*Parent material:* Alluvium derived from igneous, metamorphic and sedimentary rock

**Typical profile**  
*A - 0 to 8 inches:* gravelly loam  
*Btg1 - 8 to 15 inches:* gravelly sandy clay loam  
*Btg2 - 15 to 23 inches:* very gravelly sandy clay loam  
*Cg - 23 to 28 inches:* very gravelly sandy loam  
*Cr - 28 to 38 inches:* bedrock

**Properties and qualities**  
*Slope:* 0 to 10 percent  
*Percent of area covered with surface fragments:* 0.0 percent  
*Depth to restrictive feature:* 20 to 60 inches to paralithic bedrock  
*Natural drainage class:* Very poorly drained  
*Runoff class:* Low  
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately high (0.20 to 0.60 in/hr)  
*Depth to water table:* About 6 to 12 inches  
*Frequency of flooding:* Occasional  
*Frequency of ponding:* None  
*Available water storage in profile:* Low (about 3.0 inches)

**Interpretive groups**  
*Land capability classification (irrigated):* None specified  
*Hydrologic Soil Group:* C/D  
*Other vegetative classification:* Willow/Thurber's fescue (SALIX/FETH) (S1499), Arctic rush - sedge (JUAR2-CAREX) (G2302)

**ML—Dams and Mine dumps, 5 to 75 percent slopes**

**Map Unit Setting**  
*National map unit symbol:* tlzf  
*Elevation:* 6,000 to 11,000 feet  
*Mean annual precipitation:* 20 to 40 inches  
*Mean annual air temperature:* 36 to 45 degrees F  
*Frost-free period:* 30 to 70 days
*Farmland classification:* Not prime farmland

**Map Unit Composition**
- **Dumps, mine:** 45 percent
- **Dams:** 45 percent

*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Dams**

**Setting**
- **Parent material:** Mine spoil and/or earthy fill derived from igneous, metamorphic and sedimentary rock

**Interpretive groups**
- **Land capability classification (irrigated):** None specified
- **Land capability classification (nonirrigated):** 8

**Description of Dumps, Mine**

**Interpretive groups**
- **Land capability classification (irrigated):** None specified
- **Land capability classification (nonirrigated):** 8
Boulder County Area, Colorado

AcC—Ascalon sandy loam, 3 to 5 percent slopes

Map Unit Setting

- National map unit symbol: 2tln
- Elevation: 3,550 to 5,970 feet
- Mean annual precipitation: 12 to 16 inches
- Mean annual air temperature: 46 to 57 degrees F
- Frost-free period: 135 to 160 days
- Farmland classification: Prime farmland if irrigated

Map Unit Composition

- Ascalon and similar soils: 80 percent
- Minor components: 20 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ascalon

Setting

- Landform: Interfluves
- Landform position (two-dimensional): Shoulder, summit
- Landform position (three-dimensional): Interfluve
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Wind-reworked alluvium and/or calcareous sandy eolian deposits

Typical profile

- Ap - 0 to 6 inches: sandy loam
- B11 - 6 to 12 inches: sandy clay loam
- B12 - 12 to 19 inches: sandy clay loam
- Bk - 19 to 35 inches: sandy clay loam
- C - 35 to 80 inches: sandy loam

Properties and qualities

- Slope: 3 to 5 percent
- Depth to restrictive feature: More than 80 inches
- Natural drainage class: Well drained
- Runoff class: Low
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum in profile: 10 percent
- Salinity, maximum in profile: Nonsaline (0.1 to 1.9 mmhos/cm)
- Sodium adsorption ratio, maximum in profile: 1.0
- Available water storage in profile: Moderate (about 6.9 inches)

Interpretive groups

- Land capability classification (irrigated): 3e
- Land capability classification (nonirrigated): 4c
- Hydrologic Soil Group: B
- Ecological site: Sandy Plains (R067BY024CO), Sandy (North) Draft (April 2010) (PE 16-20) (R072XA022KS)
Minor Components

Stoneham

Percent of map unit: 10 percent
Landform: Interfluves
Landform position (two-dimensional): Shoulder, summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Plains (R067BY002CO), Loamy Upland (North) (PE 16-20) (R072XA015KS)

Vona

Percent of map unit: 8 percent
Landform: Interfluves
Landform position (two-dimensional): Backslope, footslope, shoulder
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Sandy Plains (R067BY024CO), Sandy (North) Draft (April 2010) (PE 16-20) (R072XA022KS)

Platner

Percent of map unit: 2 percent
Landform: Interfluves
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Plains (R067BY002CO), Loamy Upland (North) (PE 16-20) (R072XA015KS)

Cu—Colluvial land

Map Unit Setting
National map unit symbol: jprk
Elevation: 7,500 to 9,000 feet
Mean annual precipitation: 6 to 10 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 80 to 100 days
Farmland classification: Not prime farmland

Map Unit Composition
Colluvial land: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the map unit.
Description of Colluvial Land

Setting
- **Landform:** Valleys
- **Landform position (three-dimensional):** Side slope, base slope
- **Down-slope shape:** Concave
- **Across-slope shape:** Linear
- **Parent material:** Colluvium

Typical profile
- **H1 - 0 to 3 inches:** gravelly sandy loam
- **H2 - 3 to 60 inches:** gravelly sand, very gravelly sand, gravelly loamy sand
- **H2 - 3 to 60 inches:**
- **H2 - 3 to 60 inches:**

Properties and qualities
- **Slope:** 9 to 25 percent
- **Depth to restrictive feature:** 2 to 60 inches to lithic bedrock
- **Natural drainage class:** Excessively drained
- **Runoff class:** Low
- **Capacity of the most limiting layer to transmit water (Ksat):** Moderately high to high (0.60 to 6.00 in/hr)
- **Calcium carbonate, maximum in profile:** 10 percent
- **Available water storage in profile:** Very low (about 0.3 inches)

Interpretive groups
- **Land capability classification (irrigated):** None specified
- **Land capability classification (nonirrigated):** 7s
- **Hydrologic Soil Group:** A

Minor Components
- **Haverson**
  - Percent of map unit: 10 percent
- **Kim**
  - Percent of map unit: 7 percent
- **Otero**
  - Percent of map unit: 3 percent

JrF—Juget-Rock outcrop complex, 9 to 55 percent slopes

Map Unit Setting
- **National map unit symbol:** jprw
- **Elevation:** 6,300 to 8,200 feet
- **Mean annual precipitation:** 18 to 24 inches
- **Mean annual air temperature:** 43 to 46 degrees F
- **Frost-free period:** 80 to 120 days
- **Farmland classification:** Not prime farmland
Map Unit Composition

Juget and similar soils: 50 percent
Rock outcrop: 30 percent
Minor components: 20 percent

*Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Juget

Setting

*Landform:* Ridges, mountain slopes
*Landform position (three-dimensional):* Mountainflank
*Down-slope shape:* Convex
*Across-slope shape:* Convex
*Parent material:* Sandy residuum weathered from granite

Typical profile

- H1 - 0 to 6 inches: very gravelly sandy loam
- H2 - 6 to 11 inches: very gravelly loamy sand, very gravelly sand, extremely gravelly sand
- H2 - 6 to 11 inches: weathered bedrock
- H2 - 6 to 11 inches:
- H3 - 11 to 15 inches:

Properties and qualities

*Slope:* 9 to 55 percent
*Depth to restrictive feature:* 8 to 20 inches to lithic bedrock
*Natural drainage class:* Somewhat excessively drained
*Runoff class:* High
*Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to high (0.06 to 2.00 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Very low (about 0.8 inches)

Interpretive groups

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 7s
*Hydrologic Soil Group:* D
*Other vegetative classification:* Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107)

Description of Rock Outcrop

Setting

*Landform:* Ridges
*Landform position (three-dimensional):* Mountaintop, free face
*Parent material:* Granite

Typical profile

- H1 - 0 to 60 inches: unweathered bedrock

Properties and qualities

*Slope:* 20 to 55 percent
*Depth to restrictive feature:* 0 inches to lithic bedrock
*Runoff class:* Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)

Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s

Hydrologic Soil Group: D

Minor Components

Allens park
Percent of map unit: 10 percent

Peyton
Percent of map unit: 7 percent

Pinata
Percent of map unit: 3 percent

MdB—Manter sandy loam, 1 to 3 percent slopes

Map Unit Setting
National map unit symbol: jps3
Elevation: 4,900 to 5,500 feet
Mean annual precipitation: 12 to 18 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 140 to 155 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition
Manter and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the map unit.

Description of Manter

Setting
Landform: Terraces
Landform position (three-dimensional): Side slope, tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy eolian deposits and/or outwash

Typical profile
H1 - 0 to 6 inches: sandy loam
H2 - 6 to 16 inches: fine sandy loam, sandy loam
H2 - 6 to 16 inches: sandy loam, loamy sand, loamy fine sand
H3 - 16 to 60 inches:
H3 - 16 to 60 inches:
H3 - 16 to 60 inches:
Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 10 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very high (about 17.9 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: A
Ecological site: Sandy (R067XB026CO)

Minor Components

Calkins
Percent of map unit: 8 percent

Ascalon
Percent of map unit: 7 percent

Nh—Niwot soils

Map Unit Setting
National map unit symbol: jps8
Elevation: 4,900 to 5,500 feet
Mean annual precipitation: 12 to 18 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 140 to 155 days
Farmland classification: Not prime farmland

Map Unit Composition
Niwot and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Niwot

Setting
Landform: Flood plains, terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy over sandy and gravelly alluvium
Typical profile

H1 - 0 to 14 inches: loam
H2 - 14 to 60 inches: gravelly sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high
(0.60 to 6.00 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Available water storage in profile: Low (about 4.4 inches)

Interpretive groups

Land capability classification (irrigated): 4w
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B
Ecological site: Wet Meadow (R067XB038CO)

Minor Components

Loveland
Percent of map unit: 10 percent

Nunn
Percent of map unit: 4 percent

Aquolls
Percent of map unit: 1 percent
Landform: Flood plains

PgE—Peyton-Juget very gravelly loamy sands, 5 to 20 percent slopes

Map Unit Setting
National map unit symbol: jpsj
Elevation: 5,800 to 7,500 feet
Mean annual precipitation: 18 to 24 inches
Mean annual air temperature: 44 to 48 degrees F
Frost-free period: 80 to 120 days
Farmland classification: Not prime farmland

Map Unit Composition
Peyton and similar soils: 65 percent
Juget and similar soils: 20 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.
Description of Peyton

Setting
- **Landform:** Mountain slopes, valleys
- **Landform position (two-dimensional):** Backslope
- **Landform position (three-dimensional):** Mountainflank
- **Down-slope shape:** Linear
- **Across-slope shape:** Linear
- **Parent material:** Locally transported loamy and/or sandy slope alluvium

**Typical profile**
- **H1 - 0 to 11 inches:** very gravelly loamy sand
- **H2 - 11 to 30 inches:** gravelly sandy clay loam
- **H3 - 30 to 43 inches:** gravelly coarse sandy loam
- **H4 - 43 to 60 inches:** gravelly sandy loam

**Properties and qualities**
- **Slope:** 5 to 20 percent
- **Depth to restrictive feature:** More than 80 inches
- **Natural drainage class:** Well drained
- **Runoff class:** Medium
- **Capacity of the most limiting layer to transmit water (Ksat):** Moderately high to high (0.20 to 2.00 in/hr)
- **Depth to water table:** More than 80 inches
- **Frequency of flooding:** None
- **Frequency of ponding:** None
- **Available water storage in profile:** Low (about 5.3 inches)

**Interpretive groups**
- **Land capability classification (irrigated):** None specified
- **Land capability classification (nonirrigated):** 6s
- **Hydrologic Soil Group:** B
- **Ecological site:** Loamy Park (R048AY222CO)

Description of Juget

Setting
- **Landform:** Ridges, mountain slopes
- **Landform position (three-dimensional):** Mountaintop, mountainflank
- **Down-slope shape:** Linear
- **Across-slope shape:** Linear
- **Parent material:** Sandy residuum weathered from granite

**Typical profile**
- **H1 - 0 to 6 inches:** very gravelly loamy coarse sand
- **H2 - 6 to 11 inches:** very gravelly loamy sand, very gravelly sand, extremely gravelly sand
- **H2 - 6 to 11 inches:** weathered bedrock
- **H2 - 6 to 11 inches:**
- **H3 - 11 to 15 inches:**

**Properties and qualities**
- **Slope:** 6 to 20 percent
- **Depth to restrictive feature:** 8 to 20 inches to lithic bedrock
- **Natural drainage class:** Somewhat excessively drained
- **Runoff class:** Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to high (0.06 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 0.7 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107)

Minor Components
Allens park
Percent of map unit: 9 percent
Breece
Percent of map unit: 6 percent

PrF—Pinata-Rock outcrop complex, 5 to 55 percent slopes

Map Unit Setting
National map unit symbol: jpsk
Elevation: 6,000 to 7,000 feet
Mean annual precipitation: 14 to 18 inches
Mean annual air temperature: 47 to 51 degrees F
Frost-free period: 100 to 130 days
Farmland classification: Not prime farmland

Map Unit Composition
Pinata and similar soils: 45 percent
Rock outcrop: 35 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pinata
Setting
Landform: Ridges, mountain slopes
Landform position (three-dimensional): Mountaintop, mountainflank
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Stony sandy clayey colluvium over residuum weathered from sandstone and shale

Typical profile
H1 - 0 to 12 inches: very stony loamy fine sand
H2 - 12 to 32 inches: very stony clay
H3 - 32 to 36 inches: unweathered bedrock

Properties and qualities
Slope: 5 to 55 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 2.2 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7s
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/true mountain mahogany (PIPO/CEMO2) (C1107)

Description of Rock Outcrop
Setting
Landform: Mountain slopes
Landform position (three-dimensional): Free face
Parent material: Sandstone and shale

Typical profile
H1 - 0 to 60 inches: unweathered bedrock

Properties and qualities
Slope: 30 to 55 percent
Depth to restrictive feature: 0 inches to lithic bedrock
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s
Hydrologic Soil Group: D

Minor Components
Hargreave
Percent of map unit: 8 percent

Terry
Percent of map unit: 7 percent

Baller
Percent of map unit: 3 percent

Peyton
Percent of map unit: 2 percent
Ro—Rock outcrop

Map Unit Composition
Rock outcrop: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rock Outcrop

Setting
Landform: Cliffs, mountain slopes
Landform position (three-dimensional): Free face, mountaintop
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Mixed

Typical profile
H1 - 0 to 60 inches: unweathered bedrock

Properties and qualities
Slope: 20 to 95 percent
Depth to restrictive feature: 0 inches to lithic bedrock
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8s
Hydrologic Soil Group: D
References


The following preliminary information was prepared to assist with completion of the Damage Survey Report. Information may be revised as more project information is obtained.

<table>
<thead>
<tr>
<th>Project</th>
<th>Fall River</th>
<th>Estes Valley Coalition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conditions</td>
<td>Flooding, stream bank erosion and sedimentation along South St Vrain affect residences, roads, and bridges. There are 3 project areas within this South St Vrain DSR: South St Vrain 1, South St Vrain 2, and South St Vrain 3 (Upstream to downstream).</td>
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<tr>
<td>Watershed</td>
<td>South St Vrain</td>
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</tr>
<tr>
<td>Elevation Range (ft.)</td>
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<td></td>
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</table>
| Lat-Long | South St Vrain 1 Lat: 40.209522 Long: 105.283037 (from ArcGIS online)  
South St Vrain 2 Lat: 40.216767 Long: -105.275005  
South St Vrain 3 Lat: 40.218529 Long: -105.272615 |
| Stream Flow | Perennial |
| Aquatic Habitat | Average |
| Potential Habitat Uplift | Greatly |
| Proposed Work | All project areas have one or more of the following treatments: Sediment removal to establish a flood plain, bioengineering to stabilize stream banks, armored resiliency to stabilize stream banks, critical area treatment (CAT) including willow planting, seeding, mulching and topsoiling. Refer to the attached maps and corresponding engineering cost estimate for details. |
| Project Boundary (Acres) | South St Vrain 1: 60 acres  
South St Vrain 2: 4 acres  
South St Vrain 3: 9.2 acres  
Total: 73.2 acres (sf) |
<p>| Construction Equipment | Excavator and/or front end loader to place large rock toe boulders and logs and to remove sediment. Small bobcat to spread and incorporate topsoil. Hand labor to broadcast seed, spread mulch and plant willows. |
| Total Project Length (ft.) | 6500 |</p>
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<tr>
<th><strong>Drainage Area (mi²)</strong></th>
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<td><strong>Q₂ (cfs)</strong></td>
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<tr>
<td><strong>Q₁₀₀ (cfs)</strong></td>
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<tr>
<td><strong>Cost Estimate</strong></td>
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</table>

**South St. Vrain: Overview Map**

![Map of South St. Vrain with Project Areas]
## South St Vrain: ALL PROJECTS SUMMARY

**DSR NO:** Boulder_South St Vrain_Reach 4b_2015_High

### Section 3 Engineering cost Estimate

**Completed By:** J. Tashiro  
**Date:** 9/14/2015

This section must be completed by each alternative considered

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<th>UTM Easting</th>
<th>UTM Northing</th>
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<th>Amount ($)</th>
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Total Installation Cost (Enter in Section 1F) **$2,409,099**
**Project: South St Vrain 1**

DSR NO: Boulder_South St Vrain_Reach 4b_2015_High

Section 3 Engineering cost Estimate

Completed By: J. Tashiro                      Date: 9/14/2015

This section must be completed by each alternative considered

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Total Installation Cost (Enter in Section 1F): **$1,573,189**
## Project: South St Vrain 2

DSR NO: Boulder_South St Vrain_Reach 4b_2015_High

### Section 3 Engineering cost Estimate

Completed By: J. Tashiro  
Date: 9/14/2015

This section must be completed by each alternative considered

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Total Installation Cost (Enter in Section 1F) $161,630
## Project: South St Vrain 3

**DSR NO:** Boulder_South St Vrain_Reach 4b_2015_High

### Section 3 Engineering Cost Estimate

**Completed By:** J. Tashiro  
**Date:** 9/14/2015

This section must be completed by each alternative considered.

### Project 3 Name: South St Vrain 3

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<td>CY</td>
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<td>11. Trees &amp; Shrubs</td>
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<td>$0</td>
</tr>
<tr>
<td>12. Topsoil</td>
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<td>FT2</td>
<td>$1</td>
<td>$82,100</td>
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<td>13. Wetland Restoration</td>
<td>0</td>
<td>FT2</td>
<td>$25</td>
<td>$0</td>
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Total Installation Cost (Enter in Section 1F): $674,280
Summary of Sediment and Discharge Measurements: South St. Vrain Creek
By Blue Mountain Consultants, LLC

Sampling

On June 14, 2016 sediment transport and discharge measurements were made on South St. Vrain Creek near the Old St Vrain Road Bridge to estimate the bedload and suspended sediment transport rates near bankfull flow conditions. Two bedload measurements were taken; one from 6 to 7 am and the other from 8 to 9 am, by using a six-inch Helly-Smith sampler suspended from a truck mounted crane off the bridge. Each sample consisted of 10 equally spaced verticals across the bridge span, sampling at two minutes per vertical. Samples from the ten verticals were aggregated in a heavy-duty plastic bag, labeled, and taken back to the laboratory for analysis. A suspended sediment sample was taken after each bedload sample using a depth-integrating DH-59 sampler to collect approximately 300 ml of water from 3 verticals (100 ml/vertical). Standard laboratory methods were used to analyze both the bedload (organics removal, oven drying and sieving) and suspended sediment (filtration, oven drying and sand/wash load fraction determination). A summary of the laboratory analysis is presented in Appendix A.

A single discharge measurement was taken between 10 am and 10:50 am on June 14, 2016 just upstream from the bridge at a location that was conducive to wading. Stretching a tape perpendicular to the flow from the left to right bank, measurements were made at 24 verticals using a top-setting wading rod, a Price AA current meter and Model 3000 Swoffer data logger. Using the standard USGS incremental width methodology to calculate flow, the measured discharge was 355 ft³/s. A summary of the discharge measurement is presented in Appendix B.

Analysis

Figure 1 shows the June 2016 hydrographs for 3 stream gages in the St Vrain system, as well as the timing for the measured sediment and discharge samples on June 14th. Bankfull discharge is estimated to be 450 ft³/s and based on our discharge measurement, the lag to the St Vrain stream gage in Lyons (SVCLYOCO) and the North St Vrain gage below Button Rock Reservoir (NSVBBRCO), the discharges at the bridge during the sediment samples are estimated to be 437 ft³/s and 411 ft³/s, respectively. We will assume, with the natural variability in sediment transport rates, these measurements were taken close enough to bankfull discharge to average the two samples. The estimated bankfull bedload transport rate is 0.5813 kg/s and the estimated bankfull suspended sediment concentration is 122.28 mg/l (sand fraction, only).

To get an estimate of average annual sediment yield, we can use the dimensionless sediment transport rating curves developed by Rosgen (2006) and the bankfull sediment transport estimates and apply them to a hydrograph or flow duration curve. While there is no current stream gage on South St. Vrain Creek in the vicinity of our study, the USGS did operate a stream gage for four water years (1977-1980: USGS Gage No. 06723400) that was located within a few hundred feet of where we took our June 14th discharge measurement (Figure 2). Though the gage was operated for only a short period of the time, the flows it measured represent a reasonable range of discharges from wet and dry years (Figure 3) and I would rather use flows measured at that location than scale flows from other nearby gages that perhaps would not reflect the operational hydrology and flow regulation that influences the South St. Vrain Creek hydrograph.
Figure 1. Hydrographs for three St. Vrain stream gages for early June 2016 with sediment and discharge measurements located on the St. Vrain River at Lyons gage.
Figure 2. Location of USGS stream gage.
To estimate sediment yield using the four years of South St Vrain Gage data, I divided seasonal daily mean flow (Q) values (April 1 to September 30) by the bankfull value 450 ft³/s (Qb). Seasonal flow values were used because very little if any sediment is being transported by the low flows from October 1 to March 31 (Figure 2). Using four dimensionless sediment transport equations (Rosgen 2006), I calculated dimensionless sediment transport value for each seasonal daily mean flow in the period of record based on sediment type and stream channel stability. Multiplying each dimensionless sediment transport value by the bankfull estimate, converting units from kg/s or mg/l to tons/day, summing all dates and dividing 4 (4 years in the period of record) provides an estimate of average annual sediment in South St. Vrain Creek (Table1).

\[ \text{Equation 1. Dimensionless Bedload (Good/Fair)} = -0.0113 + 1.0139 \left( \frac{Q}{Qb} \right)^{2.1929} \]
\[ \text{Equation 2. Dimensionless Bedload (Poor)} = 0.0718 + 1.0218 \left( \frac{Q}{Qb} \right)^{2.3772} \]
\[ \text{Equation 3. Dimensionless Suspended (Good/Fair)} = 0.0636 + 0.9326 \left( \frac{Q}{Qb} \right)^{2.4085} \]
\[ \text{Equation 4. Dimensionless Suspended (Poor)} = 0.0989 + 0.9213 \left( \frac{Q}{Qb} \right)^{3.659} \]

The Good/Fair and Poor designations refer to stream channel stability ratings, which pre-flood would have been Good/Fair for the majority of the reach while post-flood is dominated by Poor sections. Comparing sediment transport by channel stability is both an indication how much more sediment is being transported post-disturbance but also of the potential to reduce downstream sediment delivery by properly stabilizing and restoring sections of the river generating the excess sediment from bed and banks. Because the dimensionless sediment transport equations are based on measured data, as are the South St. Vrain Creek bankfull sediment values, the resulting estimates of sediment yield should be reasonable values.

Table 1. Summary of average annual sediment yield for South St. Vrain Creek.

<table>
<thead>
<tr>
<th></th>
<th>Average Annual Sediment Yield (Tons)</th>
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<tr>
<td></td>
<td>Bedload</td>
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<tr>
<td>Good/Fair</td>
<td>1185</td>
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<tr>
<td>Poor</td>
<td>1935</td>
</tr>
<tr>
<td>Difference</td>
<td>750</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>63.3%</td>
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Literature Cited

USGS 06723400 SOUTH ST. VRAIN CREEK ABOVE LYONS

Annual Hydrographs: 1977 - 1980

- **Annual Yield (Acre Feet)**
  - 1977 = 19,650
  - 1978 = 45,456
  - 1979 = 59,952
  - 1980 = 54,982

- **Bankfull = 450 cfs**
Appendix A

Summary of Sediment Samples made on South St. Vrain Creek June 14th 2016
### Summary of Sediment Samples: South St. Vrain Creek 2016

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Estimated Discharge (cfs)</th>
<th>Particle Size (mm)</th>
<th>Bedload Captured on Sieve (g)</th>
<th>Susp. Sediment (mg/l)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32 mm</td>
<td>16 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Largest</td>
<td>2nd Largest</td>
<td>Width (ft)</td>
</tr>
<tr>
<td>6/14/2016</td>
<td>6:00 AM</td>
<td>437</td>
<td>48.4</td>
<td>85.7</td>
<td>100</td>
</tr>
<tr>
<td>6/14/2016</td>
<td>8:00 AM</td>
<td>411</td>
<td>0</td>
<td>128.9</td>
<td>131.6</td>
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Appendix B

Discharge Measurement made on South St. Vrain Creek June 14th 2016
**STREAM NAME:** South St Vrain Creek abv Lyons  
**DATE:** 6/14/2016  
**TIME:** START: 10 MDT  END: 10:50 MDT  
**COMMENTS:** Wading measurement just downstream of "plug" where channel width was conducive to wading swift current. Stage taken at Longmont weir right bank side.  
**Meter:** AA  
**SPIN TEST:** BEFORE: ok  AFTER: ok

<table>
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<th>Distance (ft)</th>
<th>Increment of Width (ft)</th>
<th>Depth (ft)</th>
<th>Increment of Area (Sq. ft)</th>
<th>Revolutions Seconds</th>
<th>Velocity (ft/sec)</th>
<th>Increment of Discharge (cfs)</th>
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<tr>
<td>4.6</td>
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<td>5.5</td>
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