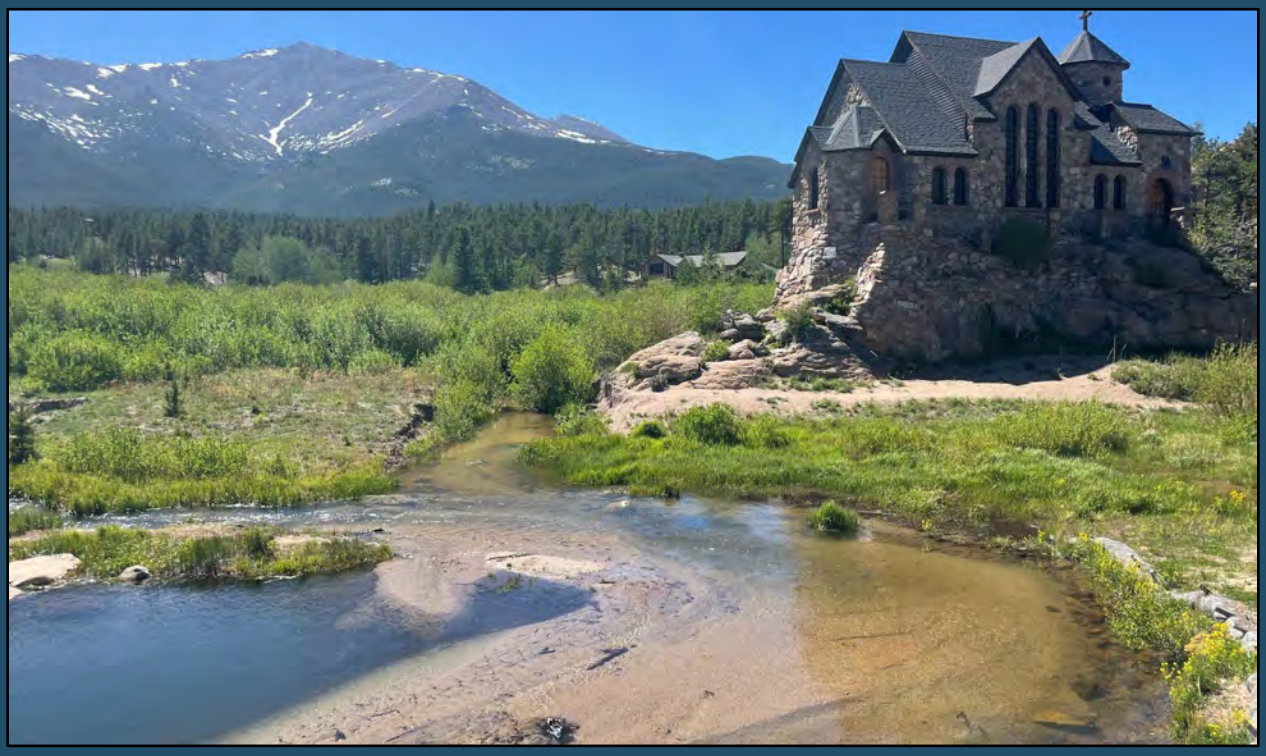
LEFT HAND watershed center

RESTORATION DESIGN CONCEPTS

CABIN CREEK

At Camp St. Malo,

Allenspark, Colorado



OCTOBER 28, 2022

WATERSHED SCIENCE + DESIGN

AlpineEco

ROUND RIVER DESIGN

CORDAY NATURAL RESOURCES CONSULTING, Montrose, CO

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This assessment was conducted with funding provided by the Colorado Water Conservation Board. The primary authors are Katie Jagt, Watershed Science and Design and Michael Blazewicz, Round River Design. Additional support provided by team members Molly Guiney, Cedar Geomorphic; Andy Herb, Alpine Eco; and Jackie Corday, Corday Natural Resources Consulting.

Executive Note

This document summarizes a rapid site assessment endeavor of Cabin Creek at the historic Camp St. Malo, Allenpark, CO. This assessment was conducted using remote sensing data and several field visits. The assessment was done at a high-level for planning purposes to support future management decisions for the site. Further study, data, observation, and analysis would provide a more detailed and in-depth understanding of the conditions, management recommendations, and design parameters for this reach; however, the authors have strong confidence in the broad approach and conceptual design alternatives detailed herein.

Our team concluded after the rapid site assessment that the restoration potential for the Cabin Creek corridor is excellent, though it may be costly. Our definition of restoration is to rehabilitate the stream corridor via the use of diverse natural actors and processes. This does not preclude the land use goals of providing space for nature access and education nor disturbances from natural actors such as floods, grazing ungulates, or wildfire from altering the corridor. It does, however, override an approach that is only targeted at providing an aesthetic experience for visitors or only protecting a single value or asset, such as a roadway, within the creek corridor to the detriment of others.

In addition, this document seeks to provide expert advice/opinion on how to proceed with restoration at a conceptual level. We provide information on decision-making, risk assessment, and techniques for Left Hand Watershed Center (LHWC) staff and stakeholders and provide a basis of design that can be utilized for project scoping and/or funding requests. This document and the associated conceptual design(s) do not constitute a final design or construction document and should not be used as such.

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1.0 Consultation Background

Left Hand Watershed Center (LHWC) is collaborating with Camp St. Malo property managers to consider restoration opportunities along Cabin Creek in Boulder County, Colorado. The creek corridor was highly impacted by a debris flow during the 2013 Colorado Flood. The primary goal of this project (as stated in the project RFP) is to develop a conceptual design(s) to restore this headwaters stream in order to build climate resilience into the North St. Vrain Watershed, and buffer downstream communities and water supplies from future flood impacts.

Watershed Science and Design was contracted in the summer of 2022 to evaluate the historic, existing, and anticipated trajectory of the reach and to assist in the determination of restoration approach(es) and techniques that would likely be most successful with respect to project goals and have the greatest benefit for the reach in the long-term.

The objectives of the project identified in the contract scoping were to:

- Provide 2-3 conceptual design alternatives for the project site.
- Provide a more detailed conceptual design for one selected alternative.

Additional project goals, themes, constraints, and requirements that were vocalized during the kick-off meeting with LHWC, Rocky Mountain National Park (RMNP) and Camp St. Malo included:

- Reduce flood/fire risk to existing infrastructure (LHWC)
- Increase site resiliency to future flood and fire (LHWC and Camp St. Malo). Practically this means:
    - Attenuate fluxes of water/sediment to buffer downstream communities and community assets during floods
    - Increase the ability of the camp and fire response units to suppress wildfire
- Reconnect the river with its floodplain (LHWC)
- Remediate 2013 flood impacts (LHWC and Camp St. Malo)
- Stabilize, protect, and keep sediment out of ponds (Camp St. Malo)
- Maintain the flow of water through the ponds (Camp St. Malo)
- Increase habitat for wildlife (All)
- Maintain emergency access/two points to entry/exit from highway (Camp St. Malo)
- The process of working within the RMNP boundaries is long and slow (RMNP). Actions proposed on federal lands will require consideration of NEPA (National Environmental Protection Act) timelines (RMNP)
- Enhance access and the natural space for learning and education (Camp St. Malo)
- To the extent possible, restore the reflecting pond near the St. Catherine's Chapel—this would mean enhancing Pond 6, and trapping mobile sediment in the wetland complex before it enters the reflecting pond (Camp St. Malo)
- If possible/feasible, stabilize the debris flow and/or reduce risk of future debris flow (LHWC)
- Foresters have suggested using prescribed fire in willow carr, is this recommended from an ecological standpoint? (Camp St. Malo)

- Forestry project included a search for historical artifacts, survey info may be useful in permitting (Camp St. Malo)
- Camp St. Malo currently has plans to build but would like to know what best options (lowest risk locations) are for building a learning center (Camp St. Malo)
- Consider constraints or recommendations regarding the Cabin Creek crossing at the Peak to Peak Highway (LHWC, Camp St. Malo)

2.0 Site Observations

2.1 Context, Characteristics, and Watershed

Cabin Creek is a small stream in the Colorado Front Range near Allenspark, CO. The creek begins in and runs through Rocky Mountain National Park (RMNP) until reaching Camp St. Malo, which constitutes this study's area of interest (Figure 1). The project reach has a watershed of 3.7 square miles and most of the watershed has a permanently protected status, however, this does not necessarily protect it from the ravages of fires, floods, or other fast or slow-moving natural disasters.

Cabin creek drains the eastern flank of Mount Meeker - a 13,916' mountain of the Twin Peaks Massif in the northern Front Range of the Rocky Mountains. Cabin Creek is located in the Southern Rocky Mountains physiographic region (as defined by the Colorado Geological Survey) and ecoregion 21b ("Crystalline subalpine forests")[1] as defined by the EPA. The Creek flows easterly gathering flow and sediment from a steep alpine slope with shallow soils. The valley margins are composed of bedrock outcrops and unsorted debris and surficial deposits. At its headwaters the watershed is generally above treeline becoming a pine-spruce dominated forest with increasing occurrence of willow (and some aspen) in the stream corridor as it makes its way downward in elevation and toward the study reach in the vicinity of Camp St. Malo. In the project area and upstream, the valley has a steep gradient and relatively high confinement. The adjacent hillslopes and stream corridor are well coupled (i.e., sediment and organic debris transported downslope can easily be deposited in the stream corridor (valley bottom).

With the exception of the alpine zone, the catchment is heavily forested, and though it is unclear if any recent fires occurred in the last 500 years, no recent fires have occurred in the last century, and it is likely that much of the forest in the region has remained relatively untouched since the early 1900s, particularly within RMNP. High flows typically occur in the late spring via snowmelt, but the region is also subject to monsoonal thunderstorms in the summertime, which can produce short bursts of precipitation (Sibold et al., 2006). The region was previously glaciated. Underlying bedrock consists primarily of Silver Plume granite (Braddock & Cole, 1990). Just upstream of the national park boundary, the creek flows over a fault zone, and is adjacent to an alluvial fan. The downstream end of the study site itself is located in an unconfined section of the valley with an open space lacking standing trees. Prior to the 2013 flood, multiple buildings, roads, and a parking lot were present in the area in addition to areas of forested lands.

Cabin Creek flows from west to east before eventually joining the North St. Vrain Creek. Historically channel location within the natural bounding features (hillslope margins) of the valley bottom was subject to change as a result of sediment and wood debris as well as the influence of beaver dams. Today the creek is pressed against the northern valley margin and held there by several road crossings. Between Pond 1 and 2, its channel is entrenched and lined with large rock and there is little to no floodplain nor riparian vegetation. The full flow of the creek currently runs through all the ponds on the Camp St. Malo property.

[1] https://gaftp.epa.gov/EPADataCommons/ORD/Ecoregions/co/co_eco_lg.pdf

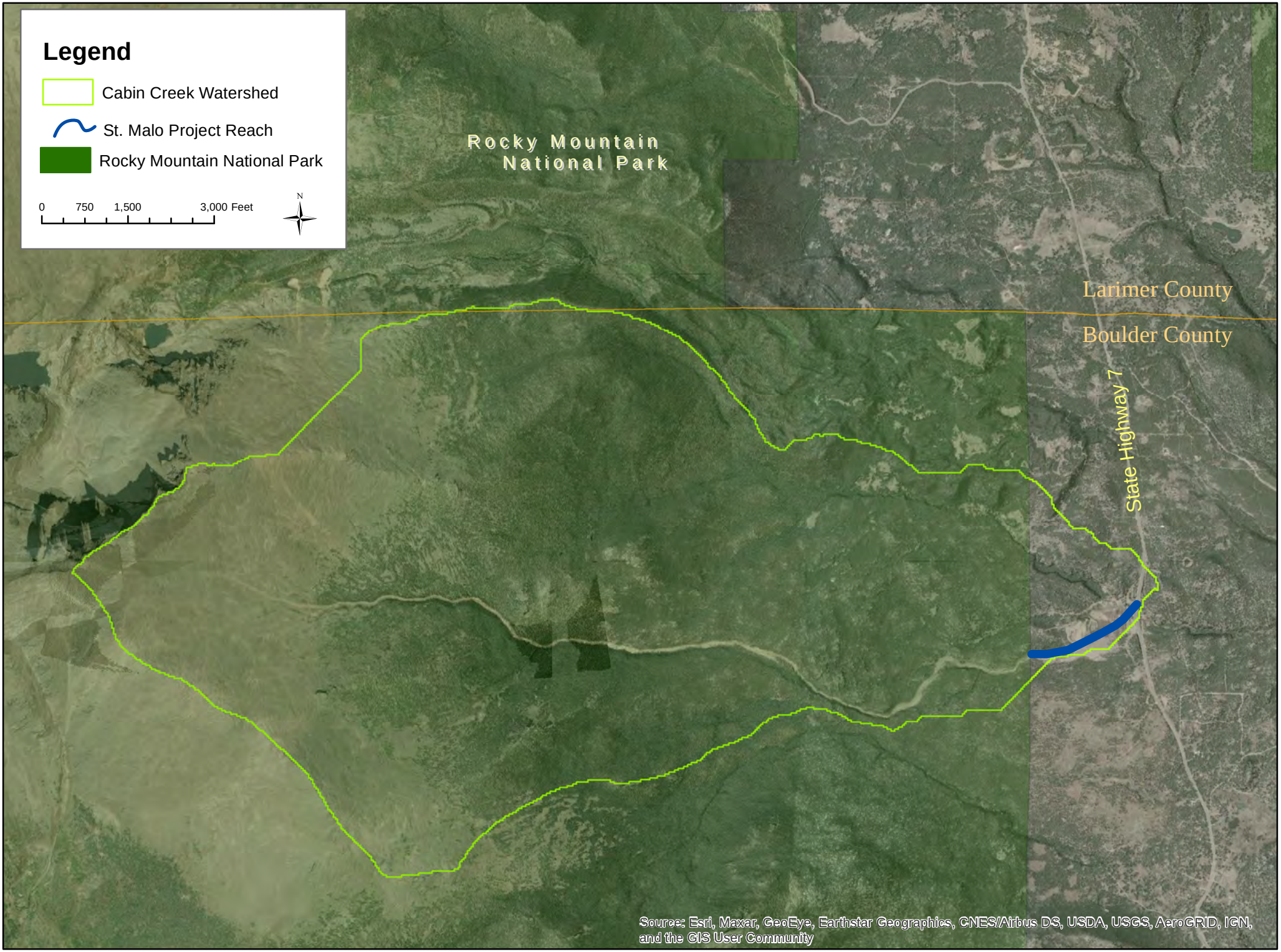


Figure 1. Cabin Creek watershed and project reach.

2.2 Rapid Assessment and Analysis of Existing Conditions

A qualitative visual assessment was conducted during site walks (June 15 and August 4, 2022) along with review of readily available spatial data using ArcGIS and oral accounts of the site from project stakeholders. Data observed included historic aerial photographs, surficial geologic maps, and LiDAR. Below is a summary of this analysis by broad category.

Geology/Geomorphology

The focus reach is located at the transition zone where a steep, confined channel becomes an alluvial fan. Channel confinement transitions rapidly from semi-confined to unconfined and valley slope lessens a few hundred feet downstream of the RMNP boundary. Evidence of post-flood channel alteration (e.g., channelization and bank armoring) are evident on the lands owned by Camp St. Malo.

The channel bed and floodplain are underlain by an alluvial (deposited by moving water) layer of weathered boulders, cobbles and gravels of granitic origin which were deposited in this reach during past high flows. The greater Cabin Creek watershed is primarily underlain by Silver Plume Granite (Figure 2). Bank erosion, overbank erosion, and incision observed in RMNP indicate that stream power is high enough to exert forces that will cause sediments to be mobilized in the upstream reaches, especially where flows are concentrated. The deposition of this sediment is likely to occur in the Camp St. Malo reach, where stream power naturally declines as a result of the change in valley confinement and change in valley slope.

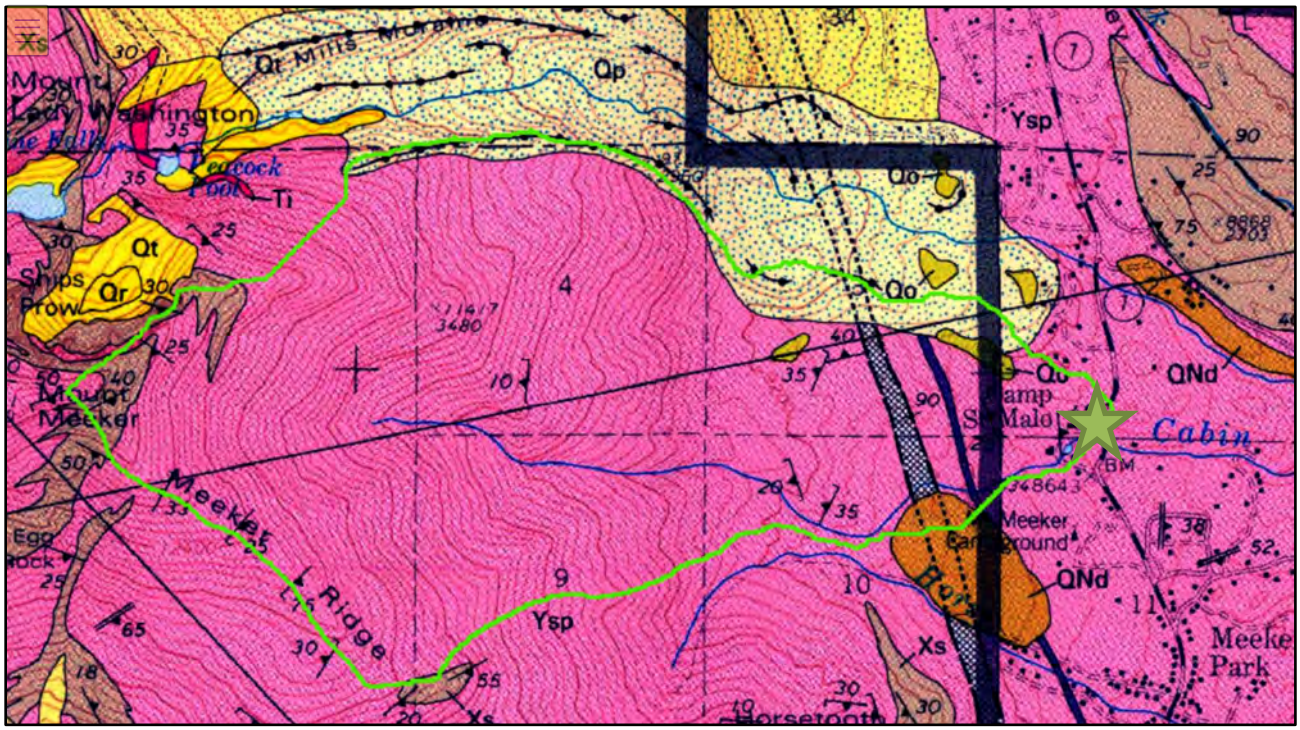


Figure 2: Generalized surficial geology of the area. Watershed is outlined in green, Camp St. Malo is denoted by the green star. Pink (Ysp) = silver plume granite of the Longs Peak - St. Vrain batholith. Orange (QNd) = diamicton (fan deposit in the Meeker Campground vicinity of boulders, cobbles, and pebbles in a silty sand matrix).

Post-Flood Changes

A major debris flow occurred between September 10 and 14th, 2013 when the Cabin Creek watershed received between 8-12 inches of rain over five days (Gochis et al., 2015). This debris flow initiated on the uppermost ridges of Mt. Meeker and accumulated water, sediment, and trees as it moved down the valley. This flow cleared a swath of land approximately 150 feet wide as it carved its way down the mountain (Figure 3).

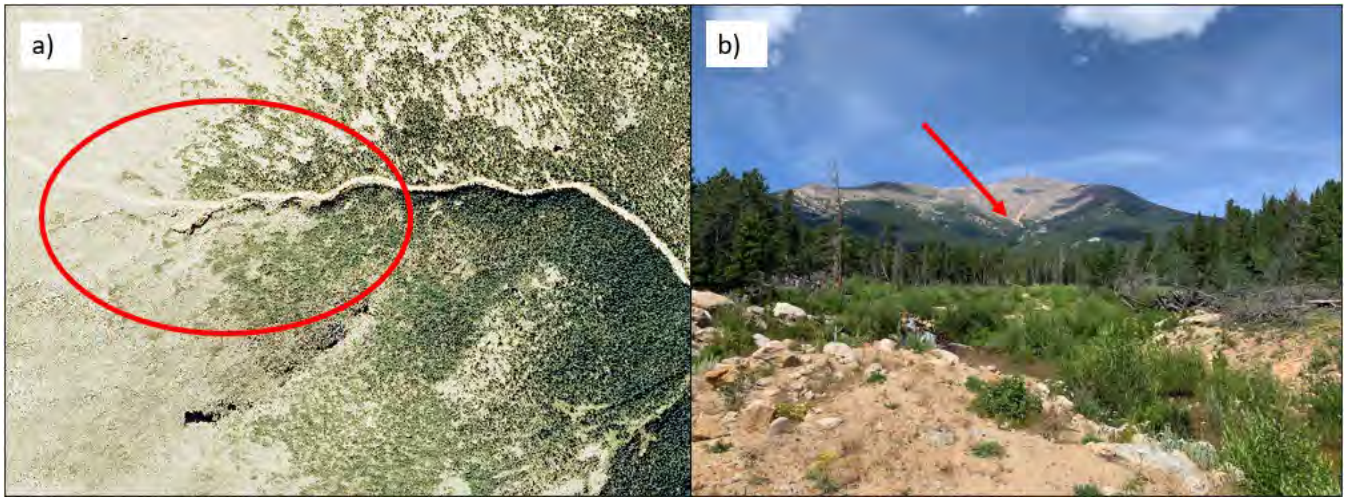


Figure 3. Images of the study region: a) the debris flow initiation point along Mt. Meeker, b) the initiation point viewable from the study site.

Just upstream of the Camp St. Malo property boundary widening of the valley and a lessening of the valley slope caused deposition of the debris flow gathered materials. The debris flow deposits—in some cases greater than 8 ft. in depth and ranging in size from gravel to large boulders—buried the old channel, as well as a road and parking lot on the site. Large wood deposited against the highway crossing forming a raft of wood on the property. Large wood also deposited far into the floodplain and against standing trees to form extensive large wood jams in the remaining trees on the corridor margin. We refer to these as “strandline jams”. Though the wood raft was removed, and work was done to move the channel back to its pre-flood location, the deposited sediment and strandline jams largely remain today. Above Camp St. Malo in Rocky Mountain National Park, the stream channel shows signs of substantial vertical incision and lateral erosion.

Using a high-resolution digital elevation model (DEM) of the area from 2011 (Boulder County, 2012) and another one from 2020 (DRCOG, 2022), we created a map that shows where sediment was eroded from and where it was deposited in this event (Figure 4).

This comparison of pre-flood and post-flood DEMs is also useful to illustrate the location in the stream corridor at which the transition from erosion to deposition took place, denoted by the red arrow in Figure 4. The “after” topography in this analysis is from 2020, as such, it shows the current deviation from pre-flood conditions (i.e., it captures the sediment removal done in the post-flood work activities), not the post-flood deviation from pre-flood conditions.

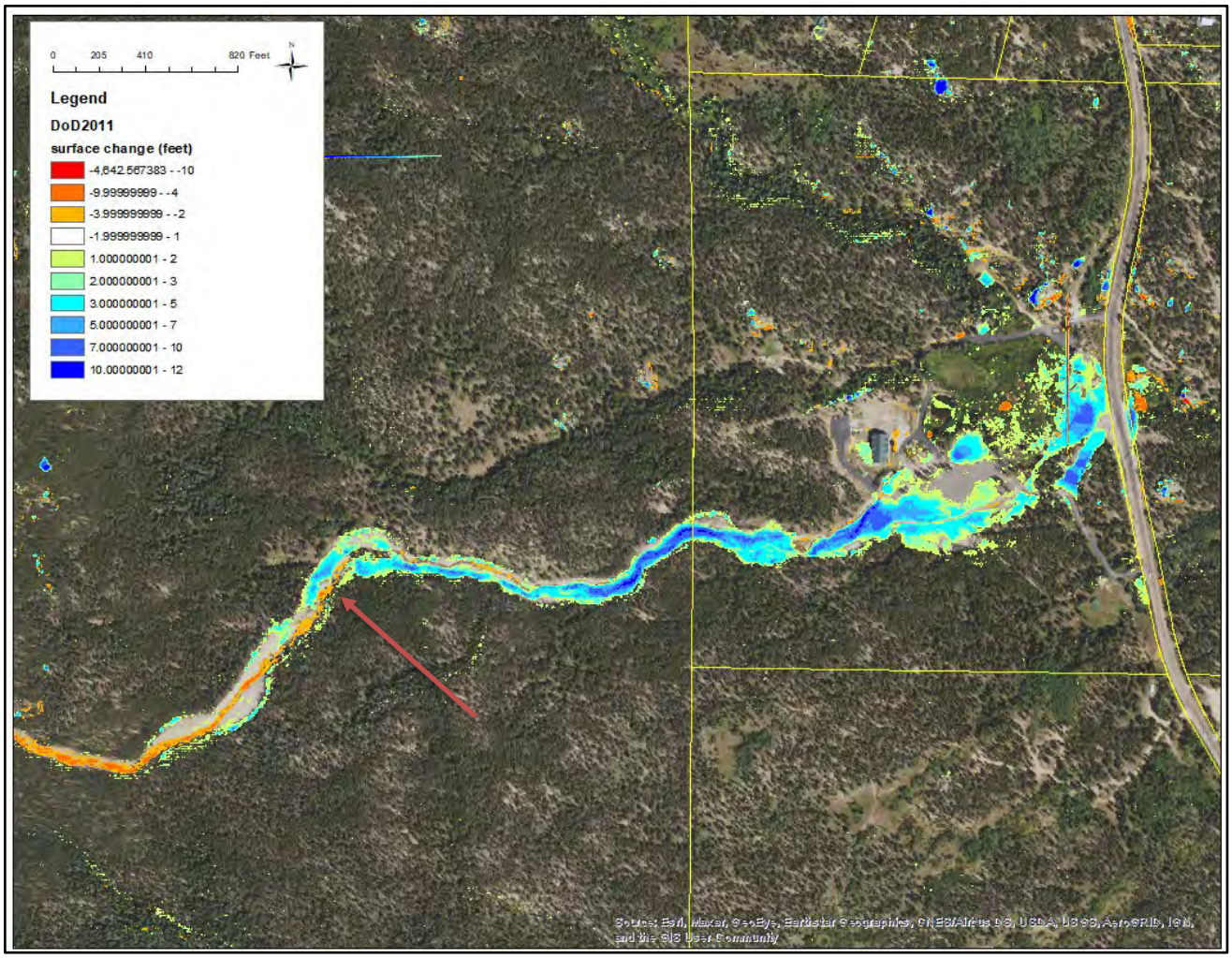


Figure 4. DEM of difference indicating the amount of change (in feet) of the surface of the land between 2011 and 2020. This is predominantly as a result of the 2013 flood and debris flow.

Water Resources

The hydrology of the study reach is unaltered by human infrastructure or demands. In other words Cabin Creek has a natural hydrology.

Water Rights and Use in Cabin Creek

A review of water rights filed on Cabin Creek, as listed in the Colorado Decision Support System (CDSS) database managed by the Department of Water Resources (DWR), indicate that there are six ponds located on the Camp St. Malo property that all have water rights with a priority date of 12/31/1986. This water right allows the ponds to be "filled and refilled" according to the database notes.[2] The "structure type" for the water rights is listed as "Reservoir." The notes also indicate that another allowed use is an exchange for the Longmont Supply Ditch.[3] There is no other filed water right

[2] Net Amounts (state.co.us) – link to CDSS webpage for Cabin Creek water rights

[3] Exchanges are one of the more complicated facets of Colorado water law to explain. This is an excerpt from the Water Education Colorado Citizen's Guide to Colorado Water Law: "An exchange allows an upstream diverter to take water a downstream diverter would otherwise receive, if the water is replaced at the time, place, quantity and suitable quality the

above the Camp St. Malo property except for an Instream Flow right filed in 1979 for 2 cfs that begins in the headwaters, at an approximate elevation of 11,800 ft. There is also another Instream Flow right for 5 cfs located east of Highway 7 on Cabin Creek near the confluence with Tahosa Creek, also with a 1979 date.

As indicated in Figure 5, there are three locations on the Camp St. Malo property that are associated with water rights – the location to the west of the former retreat center has 8 rights (two water rights filed for each of Ponds 2, 3, 4, and 5), then the location directly east of the former retreat center (two rights filed for Pond 1), and then the location next to Highway 7 has one right for Pond 6. There is a 12th water right listed as the "Camp St. Malo Impact Reach" that is also associated with the Longmont Supply Ditch Exchange according to the CDSS notes. We note that the Pond 1 location on the map differs from the Pond 1 location on the property, but have made no attempt to look further into this discrepancy.

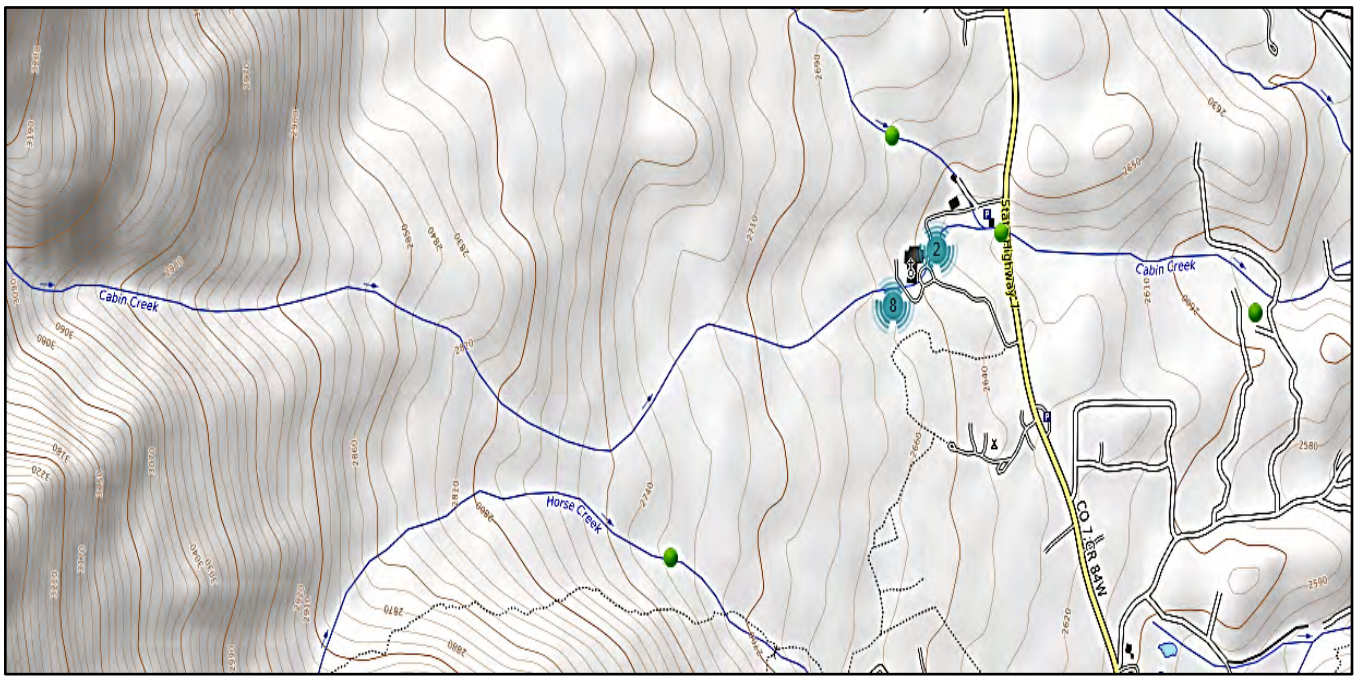


Figure 5. Screenshot from the CDSS platform showing the water rights on the Camp St. Malo property.

Biology

The influence of this woody perennial vegetation on stream form and stability is significant. Rooting of the shrubs and trees lends stability critical to the site. In addition, shade and organic inputs from streamside vegetation are beneficial to stream aquatic organisms. Recruitment of woody material (clumps and branches) during floods (or from future or past beaver activity) aids in creating channel form diversity and complexity and therefore habitat value.

downstream diverter enjoyed before the exchange. The four critical requirements for a water exchange are: (1) the source of substitute water supply must be upstream of the senior diversion calling the water; (2) the substitute water supply must be equivalent in amount and of suitable quality for the downstream senior; (3) substitute water must be from legally available flows; and (4) the water rights of others cannot be injured when implementing the exchange."

Under the modern prevailing conditions and in the absence of human intervention, this Cabin Creekstream corridor in the vicinity of Camp St. Malo from the NPS boundary downstream to the highway would most likely be willow-dominated and heavily influenced by beaver—we refer to this as a "beaver-meadow complex" (Polvi and Wohl, 2012). Today, the riparian community upstream of Pond 1 is dominated by willow (over 6 species observed), with limited aspen and alder. Lodgepole pine regeneration is occurring on higher terraces. Beaver activity, a critical driver of long-term channel form and stability, is currently absent in the lower part of the reach.

Figure 6. Willows reestablishing upstream of Pond 1.

Human Alterations and Stressors

Human alterations to the landscape, stream system, and riparian habitat, are prevalent and dominant from the Pond 1 diversion down to the beginning of the natural wetlands. The wetlands are influenced heavily by the Highway 7 embankment and the new culvert that has been placed through the embankment is working to destabilize and degrade the existing wetland system. Above Pond 1, the primary human impact comes in the form of climate change (which of course also impacts the other reaches as well).

2.3 Stream Form and Process Drivers in Cabin Creek

A "Stream Evolution Triangle" (Figure 7) may be useful to conceptualize how three drivers--*hydrology, geology, and biology*—interact to influence stream channel and floodplain form, stream function, and the evolutionary trajectory of this reach. The Stream Evolution Triangle summarized that streams may be dominated by a single driver, a pair of drivers, or (more commonly) some combination of all three drivers, depending on the watershed and land management contexts (Castro and Thorne, 2019).

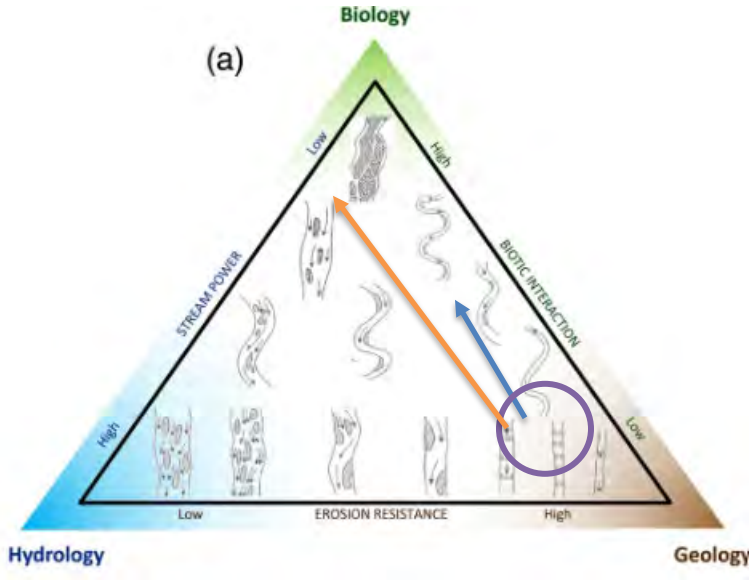


Figure 7: Stream Evolution Triangle as depicted in Castro and Thorne (2019). Cabin Creek upstream of Pond 1 is likely somewhere in the purple circle and traveling along the blue arrow as the plant community in the creek corridor reestablishes. Cabin Creek downstream of Pond 1 and upstream of the wetlands is most likely stuck in the purple circle unless space can be provided for the stream power to be reduced (this happens when the width of the corridor is increased) and biological drivers such as plants and wood are allowed to interact with the existing water (hydrology) and sediment (geology); if done, this could allow the creek to travel along the orange arrow toward a configuration that is safer, more robust and resilient, and with a more valuable riparian ecosystem.

We propose that this reach of Cabin Creek is influenced by all three drivers, as it should be; however, biology, and particularly the interaction of riparian shrubs and large wood (e.g., dead, fallen trees), is likely to become most responsible for the channel and floodplain form of this site in the long-term. Removal or reduction of this biotic driver from the system may result in excessive channel incision, bank erosion, channel widening, or habitat homogenization. Conversely, cultivation of the natural biotic drivers in the stream corridor is likely to enhance the resilience of the system to disturbances, improve habitat heterogeneity, and ensure maintenance of ecosystem services.

The Role of Large Wood

Large wood plays an integral role in geomorphic and biological processes influencing rivers across the world. Wood in stream channels can divert flow and influence both erosion and deposition. This can result in the formation of scour pools, sand bars, islands, and multi-thread channels (Abbe & Montgomery, 1996; Gurnell et al., 2005; Wohl, 2011) all of which are valuable habitat for aquatic and riparian species. Large wood may also act to stabilize channel banks and channel beds or forcing channel migration (Collins et al., 2012). When concentrated into accumulations, or jams, large wood can be even more influential and stable (Abbe & Montgomery, 1996). All these processes in turn increase biotic activity, providing nutrients to fish species in scour pools and allowing vegetation establishment on surfaces elevated above the water surface (Bilby & Ward, 1989; Collins et al., 2012; Gurnell et al., 2005).

On floodplains, large wood also influences flow and sedimentation patterns during higher flows (Sear et al., 2010). Large wood on the floodplain provides critical nutrients (C, N, P) to soils, enhancing abundance and diversity of vegetation (Pettit & Naiman, 2006), as well as improving seedling establishment rates after flood events (Pettit & Naiman, 2005). In addition to providing nutrients plants rely on, large wood adds significant amounts of organic carbon to the stream corridor, particularly on floodplains (Lininger et al., 2017; Sutfin et al, 2016).

All these processes ultimately increases the complexity and heterogeneity of stream corridors, which can lead to increased resilience to disturbance and climate change (Wohl, Lininger, et al., 2018; Wohl et al., 2022). Although in some cases, wood can become a hazard during flood events or in recreational activities (Cicco et al., 2018; Conley & Kramer, 2020), incorporating large wood has become an important feature of natural stream restoration and management due to the wide range of benefits large wood provides (Grabowski et al., 2019; Roni et al., 2015).

Viewed as a hazard and impediment, large wood was historically removed from streams (Wohl, 2014) and the combination of both wood removal and timber harvesting (removal of wood inputs) has likely resulted in major changes to streams across the United States. Though because throughout our life spans, both these actions have been the de faco “normal” the legacy of this influences how we view functioning streams and perform stream management actions today. Even as scientists began to realize the importance of the ‘wood regime’ (Wohl et al., 2019) in the 1970’s, it is difficult to wholly quantify historic wood loads in a stream and their importance on stream function and stability. Fortunately, much of the scientific literature regarding wood loads and wood dynamics has focused on Colorado Front Range rivers in relatively pristine areas untouched by major human impacts over the last 100 years, providing an opportunity to glimpse at what may have been. Studies of instream wood loads have been conducted throughout Colorado, with results roughly ranging between 50 and 400 m^3 ha^{-1} (Wohl et al., 2017). Cabin Creek was likely within this range as well.

Interactions between large wood and stream corridors, particularly the recruitment of wood to the corridor, can vary based on valley shape, size and location within a drainage basin. For example, in low gradient, unconfined streams, the primary mechanism for wood recruitment into the stream is lateral bank erosion. Over time, eroding banks will deposit large wood into the stream channel. On floodplains, individual tree mortality or wind can provide a steady source of wood that may eventually be recruited to the stream (Wohl, 2020). In higher gradient, more confined, and generally smaller drainages such as Cabin Creek, however, trees may die and drop into the channel. It is also possible in such catchments to recruit large amounts of wood at one time, as opposed to individual mortality of trees. This can be achieved by hillslope failures and debris flows. Mass recruitment events can initially cause an abundance of wood in a stream corridor, but over time will initiate a lack of wood inputs from that area as the forest regrows.

With Cabin Creek’s relatively confined, steep, and forested valley, wood was in no short supply prior to the 2013 Colorado Floods and was probably recruited to the corridor via individual mortality and erosion of the nearby hillslopes. Once recruited, the wood was likely retained for long periods in the reach of recruitment, due to its size relative to channel width (an indicator of transport capacity and wood frequency). Individual pieces, as well as large wood jams, spanning the partial or whole channel were likely common (Figure 8). Wood recruited via debris flows is possible, especially where historic fires, or beetle kill and mass mortality of trees, occurred. However, these events were probably not major influences in recent years. On the floodplains of Cabin Creek, it is unlikely that many fluvially-deposited jams existed prior to the 2013 event, except for perhaps just on the edge of bank margins, particularly in

more sinuous sections of the stream. However, wood recruited via individual mortality, as well as hillslope failure, would still be present and in abundance on the floodplain due to the low decay rate of the region.

Figure 8. Channel-spanning large wood jam on the North St. Vrain, CO.

Another consideration regarding wood is the presence of beaver. Historically, the occasional beaver dam likely would have been present in the stream, influencing processes similar to channel spanning jams. Camp St. Malo representatives have indicated that beaver were reintroduced in the years prior to the 2013 flood.

Cabin Creek: What is Expected?

As the 2013 debris flow traveled downstream, it ripped out the adjacent trees on either side of the channel. Some of the wood that was recruited during this event was deposited in the form of strandline jams on the higher terraces against still-standing trees. These strandline jams are generally vertically and laterally disconnected from the current channel and riparian zone, and almost act as a natural barrier to the river corridor.

The results of this event are that very few, if any, instream large wood pieces or jams exist in the channel or floodplain anymore; these were blown out by the high flows and redistributed onto the edges of the terraces or into the wood raft at the chapel. Today, this leaves the channel itself nearly barren of wood. Conversely, the terraces now have substantial amounts of wood in jams when it likely had only individual pieces and smaller jams previously.

This is not an uncommon response to debris flows and disturbance. Disturbances, including debris flows and post-fire flooding, can influence the spatial distribution of wood in semi-arid stream corridors. In the Southwestern US, semi-arid reaches that recently experienced a disturbance were found to have a greater ratio of floodplain large wood to instream large wood than semi-arid reaches with no recent disturbances (Wohl, Cadol, et al., 2018) (Figure 9).

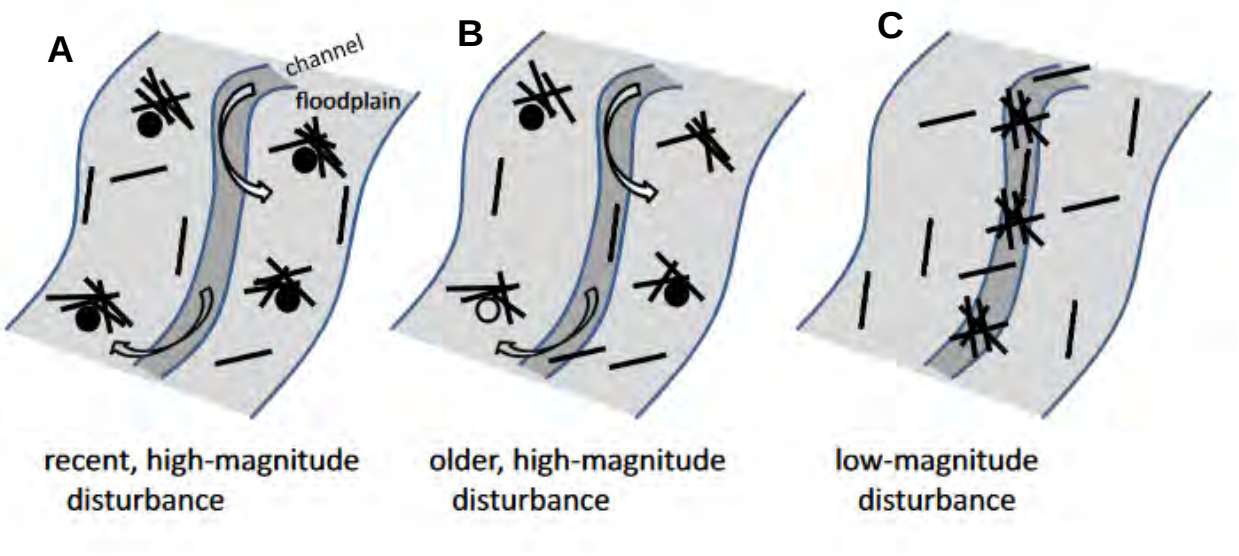


Figure 9. Figure adapted from Wohl, Cadol et al. (2018) relating disturbance to floodplain and instream wood loads.

During the 2013 flood, nearby drainage West Creek (Glen Haven, CO) experienced an upstream debris flow and massive estimated peak flood magnitude, resulting in similar strandline wood deposits on the floodplain with only a few instream jams (Guiney & Lininger, 2022; Lininger et al., 2021). This process seen in both West Creek and Cabin Creek is illustrated in part A of Figure 9. Conversely, the adjacent drainage (North Fork Big Thompson) experienced no debris flow, a smaller estimated peak flood magnitude, and ultimately had fewer floodplain jams and a greater proportion of instream to floodplain wood than West Creek (Guiney & Lininger, 2022); this is illustrated in part C of Figure 9. Similar results were found comparing Black Canyon Creek (debris flow, strandline jams and floodplain deposits) to the North Fork Big Thompson (DeWitt, 2016). Speeding up the natural restoration of Cabin Creek and promoting the effects of the biological drivers discussed in the stream restoration triangle above would involve transitioning the system from A to B as illustrated in Figure 9.

The amount of wood deposited outside of stream channels during the 2013 Colorado Floods may seem unusual, due to the extreme nature of the event. In fact, floodplain jam loads found on the previously-mentioned West Creek (~678.6 m3 ha-1), were higher than most studies documenting floodplain large wood volumes (Lininger et al., 2021). The only study with similar values of floodplain jam loads is from the Pacific Northwest (743 m3 ha-1), where large redwoods deposited by individual mortality (and not by fluvial means) contribute to wood loads (Busing & Fujimori, 2005). Cabin Creek is quite similar to West Creek, though we suspect more wood is located on Cabin Creek than even West Creek (Figure 10). Regardless, the deposition of wood onto floodplains and terraces after a major disturbance should be regarded as a natural occurrence and, over time, the ratio of floodplain to in-channel wood may decrease.

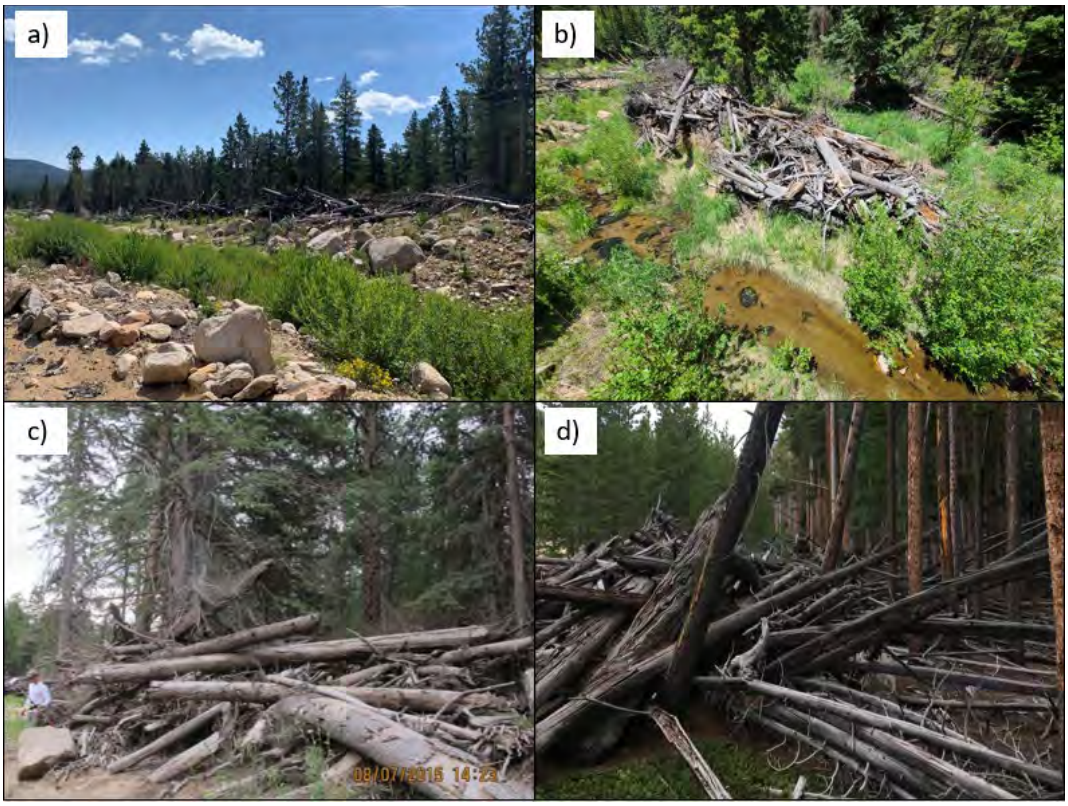


Figure 10. Examples of floodplain strandline jams in the Colorado Front Range: a) Cabin Creek @ project reach study site, b) West Creek near Glen Haven, c) Black Canyon Creek (DeWitt, 2016), and d) Roaring Fork

2.4 Recovery Potential

In brief, this site has excellent recovery potential. Neither upstream watershed inputs nor land use are expected to change dramatically. Unlike other more degraded sites in Colorado, this stream is not fully altered — ecological uplift through site- and scale-appropriate techniques is entirely attainable at a reasonable effort. Restoring natural biotic drivers (vegetation, wood, and setting the opportunity for beaver to re-occupy the site) should only help to speed the process of system recovery.

- For the areas within RMNP, the hydrology, existing sediment supply, and biota of a healthy functioning system are intact and already working towards recovery. The inset floodplain is also largely well connected (although reintroduction of large wood into the channel would benefit this recovery).
- In the area between Pond 1 and the wetlands, where the creek has been channelized, the potential uplift by restoration actions is the greatest, in large part because the flood and flood recovery actions have had such a detrimental impact to the stream corridor.
- For the existing wetlands at the lower end of the study area, the need for intervention is great as the area is actively downcutting (Figure 11) due to the installation of the new culvert under Highway 7; As such, work is needed to preserve the existing structure and function of the wetland complex.

Figure 11. One of the existing headcuts in the wetlands that is actively destabilizing the wetland and sourcing sediment into Pond 6.

3.0 Design Approach and Risk Evaluation

3.1 Process-Based Restoration

Process-based restoration is defined as: protecting, enhancing, and/or restoring the “rates and magnitudes of physical, chemical, and biological processes that sustain river and floodplain ecosystems” (Beechie et al., 2010). Process-based restoration seeks to restore the physical and ecological processes responsible for creating and maintaining those conditions. This approach to restoration focuses less on creating the ideal channel *form* and instead focuses restoration actions on providing elements that support natural stream *processes*, with the goal being a self-sustaining resilient stream corridor where floods and other normal channel change events can occur without consequence and with ecosystem service benefits. Documented use of a process-based approach to stream restoration goes back as far as the 1800’s, so it should not be considered new or novel. However, there is renewed advocacy and scientific support for this approach given the scale at which degraded watersheds need treatment.

Moving Streams
Streams need space. Stream adjustment is ever-present and an important process with important benefits; even “stable” stream channels may change from year to year. Healthy streams are dynamic, regularly shifting their position within a valley bottom, re-working and interacting with their floodplain and biota. Stream adjustment is essential for long-term maintenance of functional floodplains as well as maintaining healthy riparian and wetland systems and their underlying hyporheic and groundwater processes. Planning for channel adjustment through compatible land-use decisions is an important means of avoiding conflicts while providing long-term cost savings through reduced investment in failure-prone projects.

In many years of study in the field of fluvial geomorphology and stream restoration, particularly through the lens of increasing habitat value and reducing flood impacts, we have found that avoiding stream corridor encroachment, minimizing the placement of large channel form-controlling structures, when possible, and shifting the focus towards restoring the processes that allow streams to self-heal is the best long-term approach. This reach of Cabin Creek provides an excellent opportunity to implement a process-based approach as many of the foundational elements are in place and many processes are already at work or available to assist restoration practitioners. The work, however, will need to be kicked off though a relatively intensive construction process to reverse some of the past degradation. With this foundational perspective identified, design objectives, a framework for approach, and design concepts follow.

3.2 Opportunities

The following opportunities stand out as attributes of this project that may assist with project success:

- Land Ownership and Use - The single landowner, combined with adequate space for the stream corridor, can facilitate restoration work being done without significant constraints due to land use restrictions.
- Intact and protected upstream watershed - Aside from natural disruptions, the reach is unlikely to be stressed by upstream development or alterations. This makes planning for process-based restoration easier and investment into this area a lower risk.

- Material Balance - Cut (material excavation) should be able to be balanced on site thereby keeping costs lower (hauling of material can be very expensive). Boulders and cobbles can be screened from on-site material if necessary.
- Proximity to Materials Needed for Construction - The site itself is abundant with plant materials that can be harvested for utilization in the project, thereby saving costs and keeping endemic species on site. Live cuttings, clumps that can be transplanted, brush/slash, and large wood are available in the project area.
- Lift Required - At the upstream and downstream ends of the project site, the creek and its supporting ecosystem have the potential to self-heal (with some support). The middle reach between Pond 1 and the wetlands is quite degraded, but it sits between and within a fairly natural system and thus has great potential to be supported by the functional processes upstream and downstream.
- The system has a natural flow regime and seems to have ample perennial water, which is a huge benefit for natural revegetation and maintenance of the corridor.
- The senior 2 cfs instream flow right provides an opportunity to do work for the purpose of maintaining this right.
- Native plant diversity and natural regeneration upstream and in the wetlands portion of the site is excellent. This existing vegetation can potentially provide live plant material for restoration (permissions likely required) as well as a future seed source.
- There did not appear to be any substantial eroding gullies coming into Cabin Creek ("just" the huge main source of Mount Meeker at the headwaters), which indicates restoring the creek itself can be the main focus (i.e. many other restoration projects must deal with addressing multiple eroding gullies that could otherwise undo the work in the main channel). However, we did not go further than about 3/4 mile upstream when in the field looking for tributary inputs.

3.3 Recommended Restoration Approach

Site-specific recommendations are provided in Section 4. Generalized recommendations for this site (many of which are adapted from the low-tech restoration principles found in Wheaton et. al., 2019) are:

1. **Match the scale of restoration to the scale of the problem.** Because foundational stream process drivers exist in the upstream reach (primarily vegetation, flow, and sediment supply) radical intervention is not recommended for the upper or lower segments. Below Pond 1, the ability of the stream to self-heal in its current configuration is extremely limited. A low-tech, process-based restoration approach may have been hoped for, but in the middle reach, it is not recommended. We can create the space for natural processes to eventually take over, but limiting risk to the landowners while also promoting ecologic uplift and areas for sediment and debris deposition cannot be accomplished without the use of heavy equipment.

2. **Dissipate stream energy.** Inefficient conveyance of water and sediment is very often healthy for stream and riparian ecosystems. Resistance in the channel and floodplain can help to attenuate potentially damaging floods and provide slow release of that water helping to elevate baseflow and producing critical ecosystem services to downstream reaches. Structures introduced into a

stream corridor that would naturally occur, such as large wood, act to check the erosive power of a stream while promoting floodplain flows that produce physically diverse habitats for riparian plants and native aquatic species. As a restoration technique, structures are fed to the system like a meal. These structures do not have to be perfectly engineered to yield desirable outcomes such as the development of scour pools and meanders, shading, vegetation succession, etc.

3. **Build strength in numbers.** Use many smaller structures to provide redundancy and reduce the importance of any one structure. A large number of smaller structures working in concert with each other can achieve more than a few isolated, over-built structures. Many smaller structures will work together to promote the processes of floodplain reconnection, meander induction, and riparian regeneration that lead to desired outcomes.

4. **Use natural materials.** Natural materials (large wood and existing on-site boulders and cobbles) should be used because structures are simply intended to initiate process recovery and be "eaten" by the system over time. Locally-sourced materials are preferable because they simplify logistics and keep costs down.

5. **Defer decision-making to the system.** Let the stream system make critical design decisions by providing the tools and space it needs to adjust. Deferring decision-making to the system downplays the significance of uncertainty due to limited knowledge. For example, choosing a specific bankfull elevation, channel width, or meander wavelength based on limited information can be a complex, expensive, and uncertain endeavor, but deferring to the hydrology and sediment inputs of that system to build its own dimensions reduces the importance of uncertainty due to limited knowledge.

6. **Focus on enhancing riparian vegetation** throughout the corridor in a way that provides structure and supports (and even triggers) the desired geomorphic responses within the stream corridor. Natural regeneration has already proven to be an effective "partner" in this system when floodplains are connected to the channel. Further enhancement can be achieved by installing willow stakes, wetland plugs, and/or woody plants in containers in a way that provides floodplain roughness with the above ground plants and structural stability via the establishment of their intertwined root masses. The totality of these actions will achieve many goals including increasing the likelihood that in time beaver populations will move back into the area.

7. **Maintain expectation of adjustment and adopt adaptive management practices** for the restoration process as the creek will continue to adjust in the future and maintenance activities may be needed based on Adaptive Management feedback.

8. **Large wood.** Historically, it is likely that large wood has been a driver of physical and biotic complexity in Cabin Creek. However, because of the force involved with the debris flow on Cabin Creek, it seems unlikely that the large amounts of wood deposited so distantly from the current inset channel could be fully recruited into the channel. One example of persisting floodplain strandline jams exists on the Roaring Fork in the Rocky Mountain National Park, which experienced a natural dam breach in the second half of the 20th century. Large floodplain

strandline jams still exist on the margins of the incised region today. Though Roaring Fork is an extreme example, it may be a similar situation on Cabin Creek in a few places, especially where the channel and corridor have incised substantially. Coupled with the loss of nearby material for recruitment, the channel will continue to starve of wood for decades unless the stream can reach and mobilize some of the strandline jams, or until adjacent areas are able to redevelop forest patches. As seen in recent field visits, this process has already begun, with lodgepole pines sprouting up in droves. Even then, it will take time for these forests to influence fluvial processes to a degree similar to pre-flood scenarios, primarily because the previous forest was much older (i.e., larger and more resistant to transport, thus more influential). The recommendation is to restore wood to the channel and inset floodplain to mimic a low-magnitude disturbance regime since otherwise the timeline to get back to that type of natural wood loaded setting is far too long.

3.4 Design Constraints and Risk

Evaluation of project risk can be critical to design recommendations. The following risks were identified. While any number or combination of these risks may occur, significant risks to this reach that would change the recommended design were not identified.

3.4.1 Land Ownership, Boundaries, Access and Existing Infrastructure

The major constraint to implementing a restoration project on this reach is that the RMNP boundary effectively creates an unnatural, upstream stopping point. Not doing work in the Park leaves some minor vulnerability to the project, but the corridor has been naturally stabilizing without intervention and should continue to do so barring another major flood event. Other lesser constraints are access due to existing wetlands, the highway crossing and Camp St. Malo roadway infrastructure.

3.4.2 Future Floods and Geomorphic Change

Risk exists that a large flood may cause failure of constructed structures or cause the channel to avulse (see also section 3.5.1). Alluvial fans are, by their very nature, locations where channel avulsions (a relocation of the entirety of the channel) are the predominant form of geomorphic change. A single channel is not a sustainable solution for the area between Pond 1 and the wetlands and multiple channels complicate the location and crossings in the access road. These stream-infrastructure conflicts can be resolved, but they do require a willingness for compromise.

3.4.3 Revegetation and Invasive/Noxious Plants

Revegetation efforts will be at risk due to browse from wild animals and possibly wildfire. The upland portions of the alluvial fan (and associated disturbed areas) are relatively weedy with several noxious weeds present that may require some treatment before, during, and after construction. It is recommended that the design/construction team have a botanist/ecologist available to consult on revegetation and noxious weed control during and following construction.

3.4.4 The Uncertainty of Beaver

It sounds like both LHWC and the landowner are interested in supporting the return of beaver, especially if that can happen with natural recolonization post-restoration work. Unfortunately, at this time there is not enough food and dam-building material for beaver outside of the existing wetland complex. However, we observed several places where the grade would allow early recolonization of beaver within a few years of restoration work assuming further recovery of the riparian corridor. Even so, beaver are subject to predation, disease, and death by accident, especially in proximity to a highway. Beaver may always be an intermittent component of the landscape in this reach.

3.5.3 Site/Setting Related Challenges

Human activities after the 2013 flood severely channelized Cabin Creek from the asphalt circle to Pond #1 with large boulders, which essentially precludes the use of a low-tech approach to restore this stretch—heavy equipment will be needed.

- The asphalt circle and two undersized culverts create a substantial pinch point for Cabin Creek—so much so that the creek cannot really be "restored" upstream of the circle and will continue to fill in the ponds they created with sediment. If willing, removal of the circle and undersized culverts, would allow that area to be redesigned to be more natural and connect and flow better to the downstream large wetland. There still could be car access/some parking set back from the north side of the creek and a walking path to the creek.
- The 2013 flood relocated the previous stream channels and deposited huge amounts of fine- to medium-sized gravel in about a 10-acre area that the landowner finds unattractive. It seems that no matter what design we conceptualize, this area will continue to experience overflow/large depositions during any large flooding event. Camp St. Malo representatives and LHWC will need to understand that it can be "restored" and made to look and function better, but that may not last beyond a decade or two and it could be blown out again at any large flood event.

4.0 Restoration Alternatives

4.1 Restoration Alternatives

Conceptual restoration alternatives are offered to help meet the project goals, objectives, and design criteria outlined above. These alternatives consider the constraints and opportunities of the site. There will be a preferred concept for Work Area 1, Work Area 2, and Work Area 3 (Figure 12). The preferred concepts for Work Area 2 and 3 will need to work together, but for the concept phase, we can evaluate them independently. Note Figures 12 through 17 are all after the Section 4.1 text.

Work Area 1: NPS boundary downstream to Pond 1 (Figure 13)

Existing Condition:

The upper corridor is stabilizing and seems to be on a good recovering trajectory. The existing channel is not incised, or only slightly in places and thus there is a great opportunity to reconnect the channel to its post-flood floodplain. Revegetation with native species through natural regeneration is excellent. Channel stability is high for low flow events but may be low for high flow events.

Design Challenges:

Headcut at top of Pond 1

Concept 1a.

Speed up natural recovery and increase floodplain roughness to minimize sediment inputs from future high water events by strategically pulling large wood displaced to corridor margins back into the channel corridor. Wedge large wood pieces against large boulders and willow clumps and intertwine with each other. Partially bury some into existing alluvium. Realign channel above existing Pond 1 headcut (steep waterfall at entrance to Pond 1) to take the existing lower path to the north.

The large wood placement work would be a super low risk of any water rights issues - in my opinion, this work could proceed without DWR consultation (but we can talk again about that when appropriate). This type of work could extend up into RMNP in another phase of work if the park was interested in collaborating on this project.

Construction will likely need to be with hand crews and/or stock animals. This could also be done with a helicopter.

Concept 1a Park.

Same as above, but also into Rocky Mountain National Park

Concept 1b.

Repair the damage done by the excavation of Pond 1 after the flood. Realign the main channel above Pond 1 to the north side of the valley to eliminate the 6’ drop and subsequent fish passage barrier into the pond. Stabilization of this drop is imperative for

keeping this reach from sourcing a significant amount of sediment to the lower areas during higher energy flows.

Concept 1c.
Do nothing.

Work Area 2: Pond 1 Diversion d/s to wetlands

Existing Condition:
This area was heavily altered following the 2013 flood. Current configuration is a split channel with most of the flow being diverted to the north and only high flows/seepage in the southern channel. Both channels are incised with only very narrow riparian areas. Geomorphic instability during a flood is all but guaranteed due to the concentration of energy in these channels. The large land area between these two channels is arid and weedy and has had poor regeneration of native perennial woody plants.

Design Challenges:
There is an avulsion zone to the south. Existing wood and accumulation of sediment on the right side may help block a large flood from accessing (avulse) low lands to the south.

Concept 2a (Figure 14).
Enhance the existing south channel and create an inset floodplain(s). Improve the existing southern channel road crossing and replace with an adequately sized crossing with fish passage capabilities. Facilitate flows into the wetland on the south side. Use the existing north channel as diversion ditch (or pipe and cover it) to run diverted water into the lower ponds.

Concept 2b (Figure 15).
Remove armoring boulders and widen the existing north channel to increase it's length and inset floodplain capacity. This option would also include excavating the FEMA spoils downstream of Pond 1 to allow that area more space to be restored into a riverine wetland as it appears it was prior to the 2013 flood - keeping the size of the area in line with any historic photos we can find from the 1980s when they filled their water rights. This option would also create an overflow channel into the floodplain in the center of the fan at a strategic location that maximizes protection to the existing infrastructure and minimizes construction costs. Enhance the existing south channel as a high flow bypass.

Concept 2b+ (Figure 15).
Same as 2b with additional work: Take out asphalt circle and reestablish floodplain in order to restore the area to a more natural functioning stream that continues to deliver water to the downstream ponds and wetlands, but with reduced sedimentation and velocity that is currently happening. Parking can be reconfigured to be on the north side of the creek that would also continue to allow for car access to the area. Foot trail could be designed to access from the new parking area to the creek. Eventually a few years after restoration, this area would become a much better representation of a natural stream environment for the people who visit - maybe even

beaver could return to this reach. Maintain Pond 2/3 as either online or offline and Pond 4 as offline.

Concept 2c (Figure 16).
Realigning the main creek through the wedge of upland by mass grading a new inset corridor to match existing channel elevations. Create a messy design with subtle earthen berms on the edges to direct high flows, large wood for roughness and habitat. Utilize the existing south channel as a potential relief valve. This creates the possibility of building a wet fire break down the valley.

Concept 2d.
Do nothing.

Work Area 3: Wetlands to Highway 7 culvert (Figure 17)

Existing Condition:
At take this reach is healthy with abundant wetlands and willows. Closer investigation of the stream channel just upstream of the new highway culvert reveals a series of headcuts that threaten to undermine the existing wetland and dry large portions of it.

Design Challenges:
CDOT culvert
Road crossing(s)

Concept 3a.
Preserving the wetland is top priority. This can be achieved by fixing the headcuts (Figure 17) and trying to set a new outlet elevation. Enhancement of the wetland outlet could also restore the reflection abilities of the pond in front of the chapel (an iconic photographic) and this could possibly be done in conjunction with a boardwalk to allow access to and from that area. Stabilizing the headcuts should reduce sediment loads into Pond 6. Stabilization of the headcuts and Pond 6 will likely need to be done with sculpted boulder drops/cascades. This work could also include removing the sediment deposited in Pond 5.

Concept 3b.
Remove the deposited sediment and material from the south side of the wetland/alternate flow path. Restore the wetland to a functional status. Facilitate the overflows into and through this area to reduce damage to the infrastructure to the north.

Concept 3c.
Do nothing.

Work Area 4: East of Highway 7

Existing Condition:

A healthy riparian area exists in the unconfined valley on the downstream side of the highway before the channel enters into a confined valley. Culvert replacement work created a large stone-lined catch basin at the culvert outlet. The channel downstream of this basin was straightened and a berm built on the south side of the channel that now appears to be cutting off the channel from its former floodplain.

Design Challenges:
Work in this area will be in the Boulder County Regulatory Floodplain.

Concept 4a.
Remove the berm that they put in with the rockwork below the road.

Concept 4b.
Do nothing.

Figure 12. The approximate extents of the work areas referred to in this report.

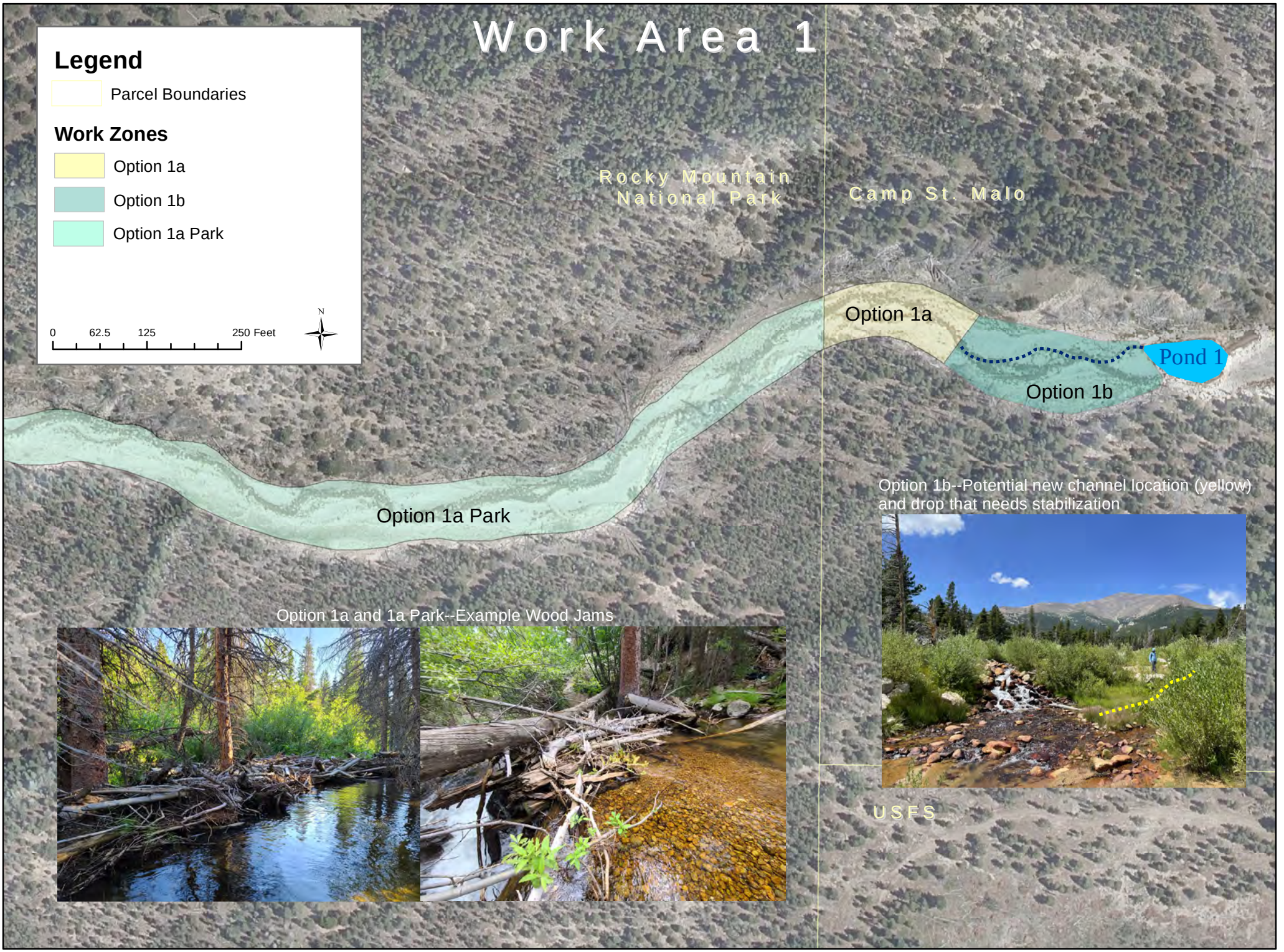


Figure 13. Project concepts for Work Area 1. These concepts are additive (i.e., one or all of them can be chosen).

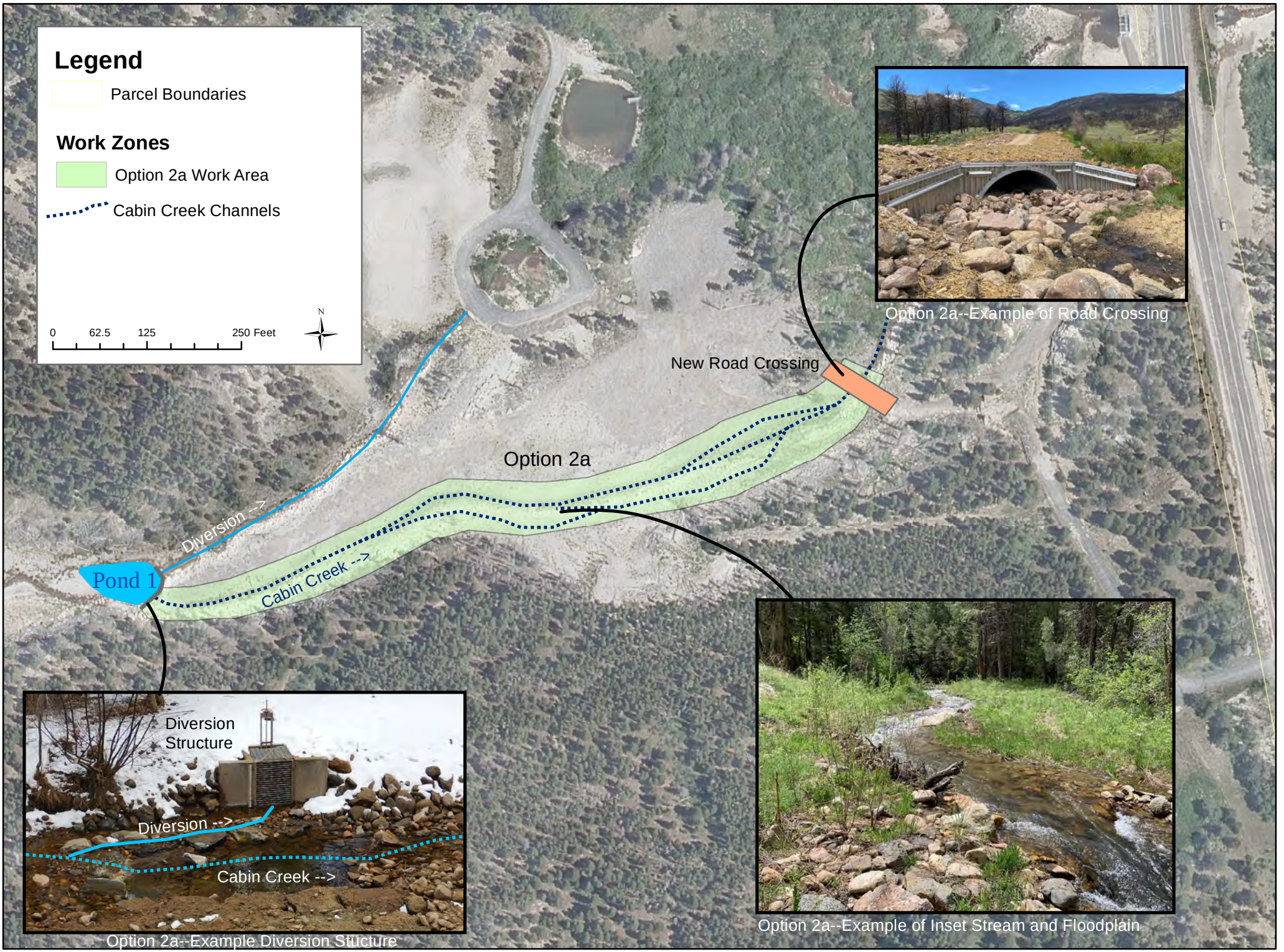


Figure 14. Option 2a is one concept for Work Area 2. The Work Area 2 concepts are exclusive (i.e., only one can be chosen).

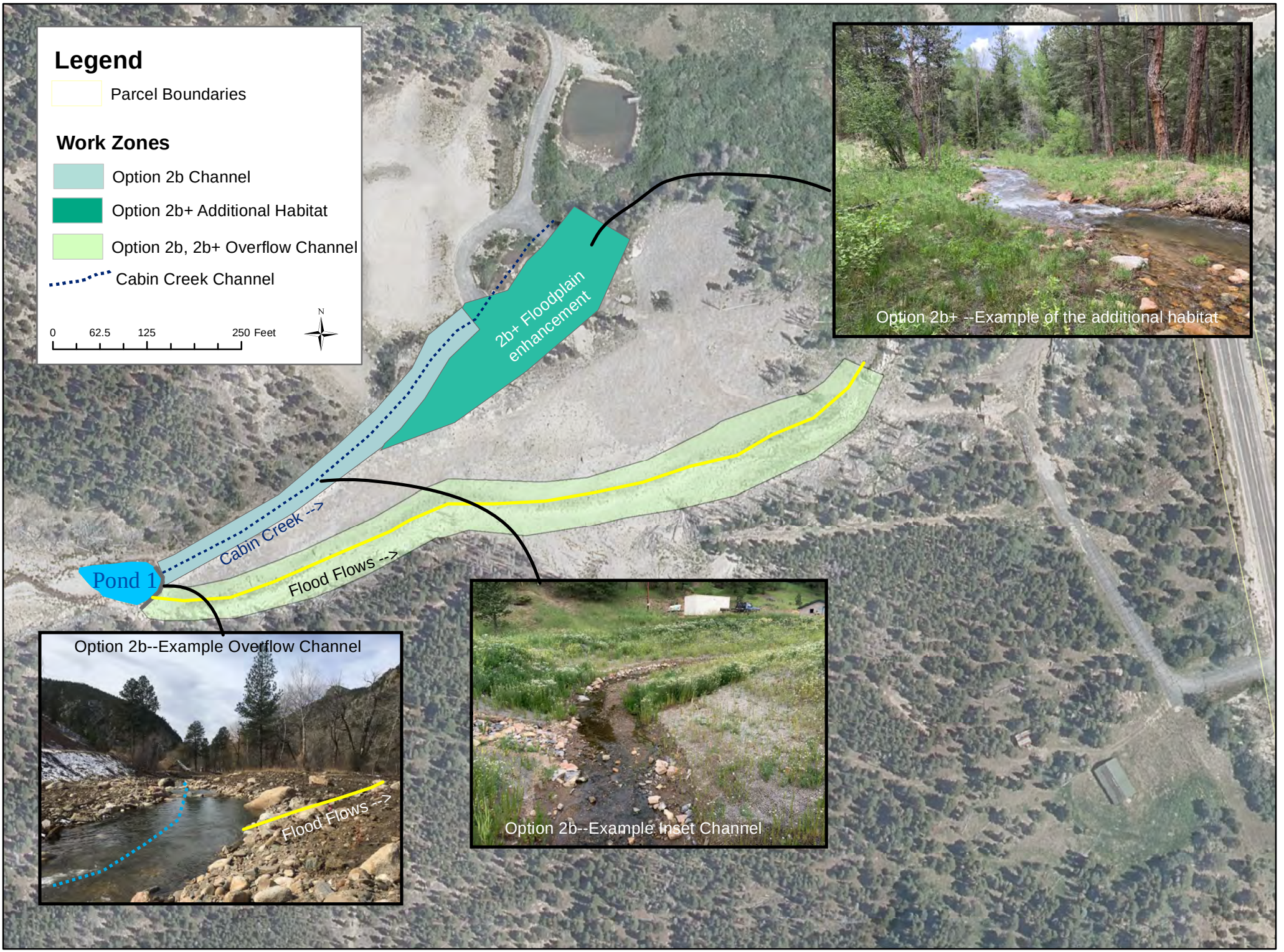


Figure 15. Option 2b is one concept for Work Area 2. The Work Area 2 concepts are exclusive (i.e., only one can be chosen).

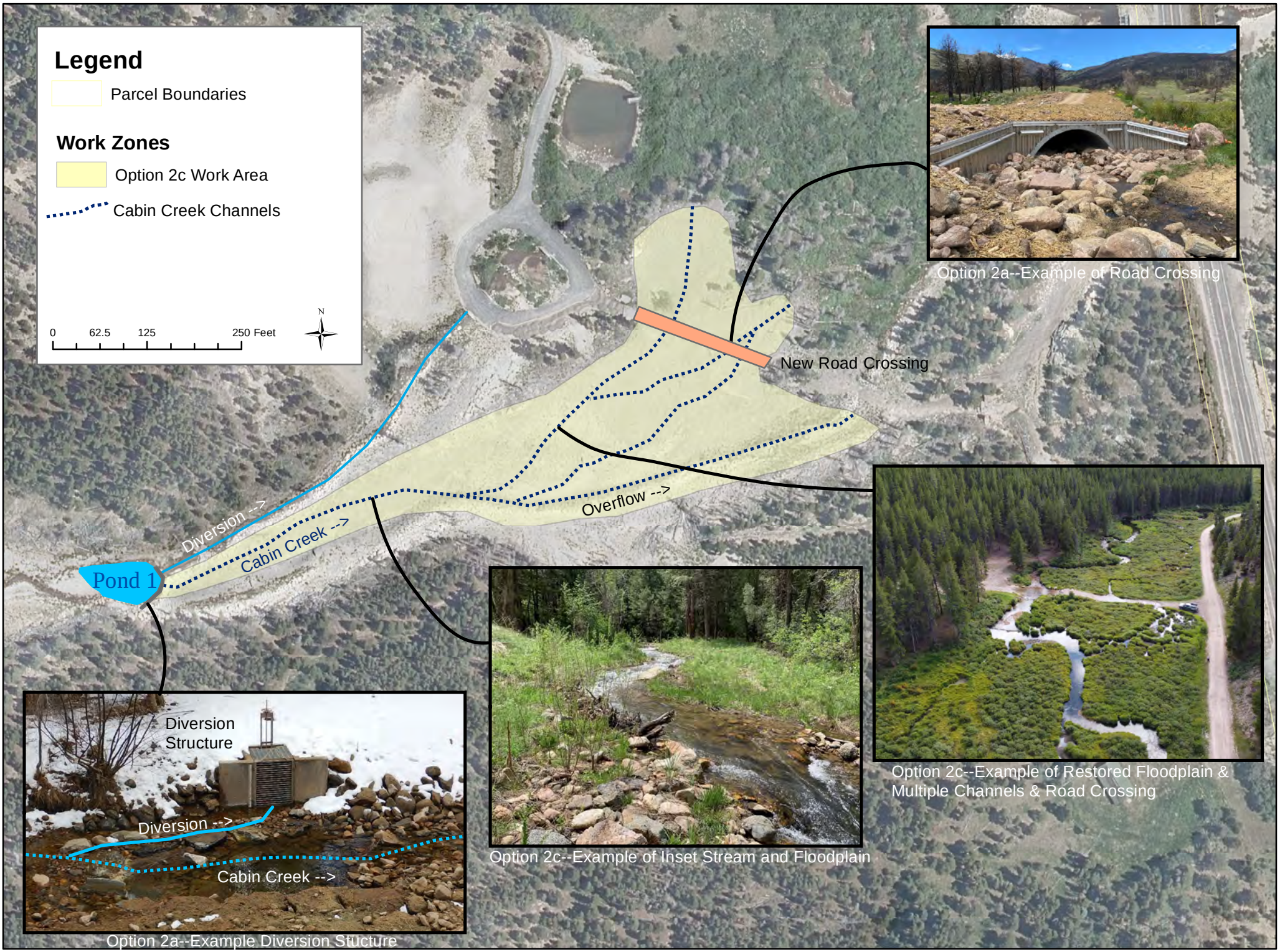


Figure 16. Option 2c is one concept for Work Area 2. The Work Area 2 concepts are exclusive (i.e., only one can be chosen).

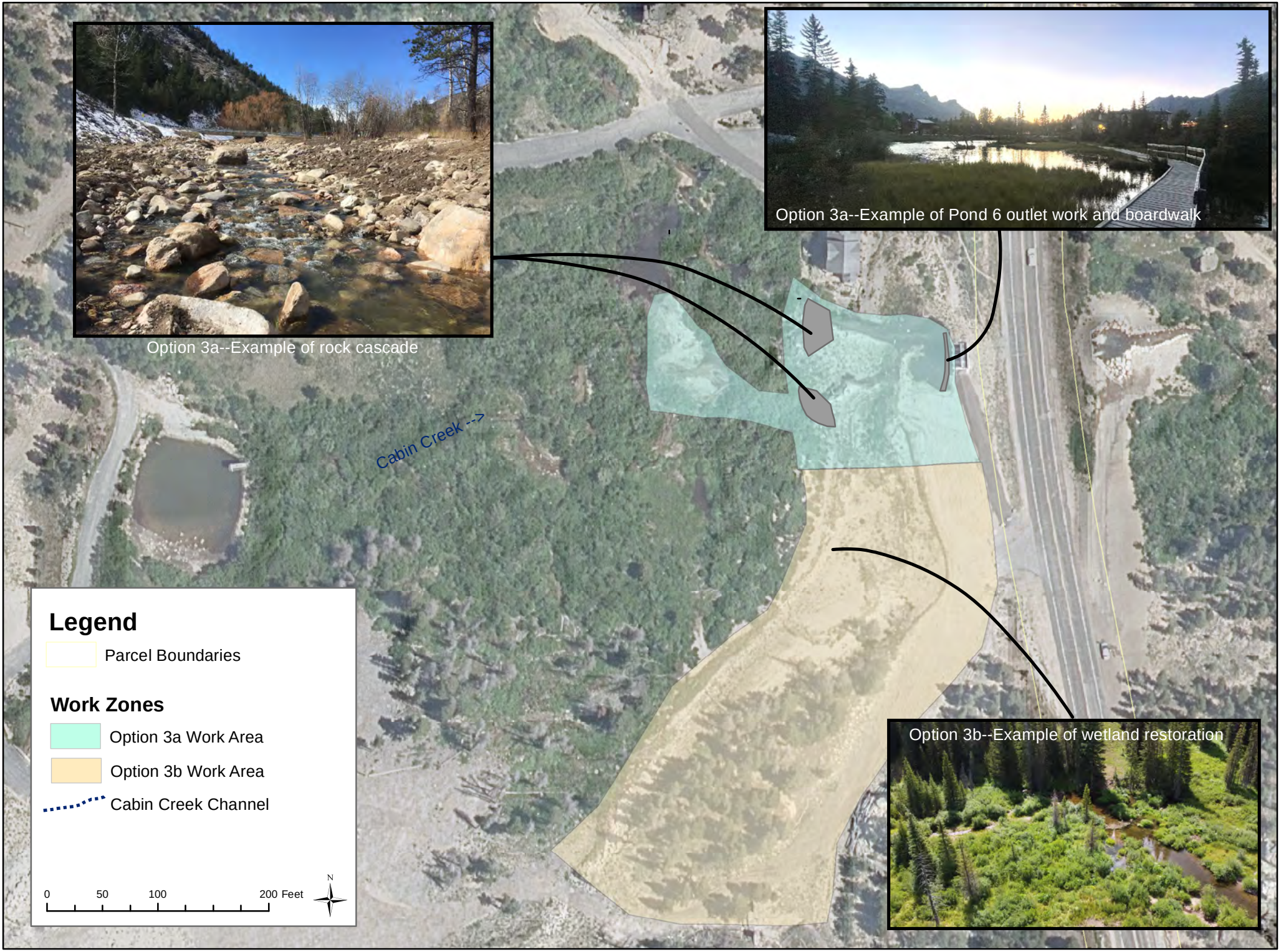


Figure 17. Project concepts for Work Area 3. These concepts are additive (i.e., one or all of them can be chosen).

4.2 Restoration Alternatives Benefit-Cost Analysis

Each conceptual restoration alternative, including the no action alternatives, outlined in Section 4.1 have both benefits and costs associated with the work. Table 2, offered below, gives a qualitative assessment of the impact of each alternative on major project goals identified by the stakeholders and discussed in Section 1.0. We note that many of the goals, such as recreational or educational access, can be addressed in the specific design of the final project and are effectively achievable with any of these concept alternatives—as such we did not include them in this table.

Table 2. Benefit-Cost Analysis for Cabin Creek Concepts. Text is color coded to denote the relative benefit of each concept (dark green is the highest, grey is low or neutral, red denotes a loss of an existing benefit).

Project Concept	Relative Benefits	Relative Cost
1a	Restore a headwaters stream in order to build climate resilience: Low Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Medium Increase habitat for wildlife: Medium	$-$$
1a Park	Restore a headwaters stream in order to build climate resilience: Medium Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Medium Increase habitat for wildlife: Medium	$-$$
1b	Restore a headwaters stream in order to build climate resilience: Low Reduce flood/fire risk to existing infrastructure: High Attenuate fluxes of water/sediment: Medium Reconnect the river and the floodplain: High Increase habitat for wildlife: High	$$$
1c	Restore a headwaters stream in order to build climate resilience: n/a Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Low Increase habitat for wildlife: Low	n/a
2a	Restore a headwaters stream in order to build climate resilience: Low Reduce flood/fire risk to existing infrastructure: Medium Attenuate fluxes of water/sediment: Medium Reconnect the river and the floodplain: Low Increase habitat for wildlife: Low	$$$
2b	Restore a headwaters stream in order to build climate resilience: Low Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Medium Reconnect the river and the floodplain: Low Increase habitat for wildlife: Low	$$$
2b+	Restore a headwaters stream in order to build climate resilience: Medium Reduce flood/fire risk to existing infrastructure: Low	$$$$

	Attenuate fluxes of water/sediment: Medium Reconnect the river and the floodplain: Medium Increase habitat for wildlife: Medium	
2c	Restore a headwaters stream in order to build climate resilience: High Reduce flood/fire risk to existing infrastructure: Medium Attenuate fluxes of water/sediment: High Reconnect the river and the floodplain: High Increase habitat for wildlife: Medium	$$$$
2d	Restore a headwaters stream in order to build climate resilience: n/a Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Low Increase habitat for wildlife: Low	n/a
3a	Restore a headwaters stream in order to build climate resilience: Medium Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Medium Reconnect the river and the floodplain: Low Increase habitat for wildlife: Low	$$
3b	Restore a headwaters stream in order to build climate resilience: Medium Reduce flood/fire risk to existing infrastructure: Medium Attenuate fluxes of water/sediment: High Reconnect the river and the floodplain: High Increase habitat for wildlife: Medium	$$$
3c	Restore a headwaters stream in order to build climate resilience: n/a Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Expect a decrease with no work Increase habitat for wildlife: Expect a decrease with no work	n/a
4a	Restore a headwaters stream in order to build climate resilience: Low Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Medium Increase habitat for wildlife: Medium	$$
4b	Restore a headwaters stream in order to build climate resilience: n/a Reduce flood/fire risk to existing infrastructure: Low Attenuate fluxes of water/sediment: Low Reconnect the river and the floodplain: Low Increase habitat for wildlife: Low	n/a

5.0 Preferred Alternative

5.1 Preferred Alternative Description

After discussion with the land management team at Camp St. Malo, the following was advanced as the preferred alternative, as shown in Figure 18:

Work Area 1: Concept 1a
Speed up natural recovery and increase floodplain roughness to minimize sediment inputs from future high-water events by strategically pulling large wood displaced to corridor margins back into the channel corridor. Wedge large wood pieces against large boulders and willow clumps and intertwine with each other. Partially bury some large wood into existing alluvium.

Work Area 2: Concept 2c
Realigning the main creek through the wedge of upland by mass grading a new inset corridor to match existing channel elevations. Create a messy design with subtle earthen berms on the edges to direct high flows, large wood for roughness and habitat. Utilize the existing south channel as a potential relief valve. This creates the possibility of building a wet fire break down the valley.

Work Area 3: Concept 3a and 3b
Preserve the wetland by stabilizing the headcuts and setting a new outlet elevation for Pond 6. Enhancement of the wetland outlet could also restore the reflection abilities of the pond in front of the chapel and this could possibly be done in conjunction with a boardwalk to allow access to and from that area. Additionally, remove the deposited sediment and material from the south side of the wetland. Facilitate the overflows into and through this area to reduce damage to the infrastructure to the north.

The preferred options in Work Areas 1, 2, and 3 will work in tandem to stabilize and restore the site. A reduction of sediment out of Work Area 1 will transition the stream into Work Area 2 where the constructed inset floodplain will then work to distribute sediments and floodwaters through a much wider and much-improved riparian corridor. The multiple flow paths in Work Area 2 will shunt flood flows into the restored southern wetlands which will reduce the erosive power of the water in the channels directly upstream of Pond 6.

Legend

Parcel Boundaries

Work Zones

Proposed Cabin Creek Channels

Option 1a Work Area

Option 1b Work Area

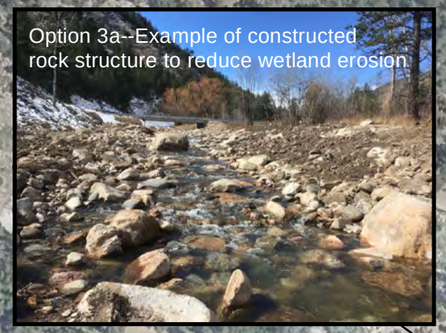
Option 2c Work Area

Option 3a Work Area

Option 3b Work Area

0 60 120 240 Feet

N



Option 3a--Example of constructed rock structure to reduce wetland erosion

Option 3a--Example of Pond 6 outlet work and boardwalk

Option 3a

Option 3b

Option 3c

Option 3b--Example of wetland restoration

Flood Overflow -->

Diversion -->

Cabin Creek -->

cascade

Rocky Mountain National Park

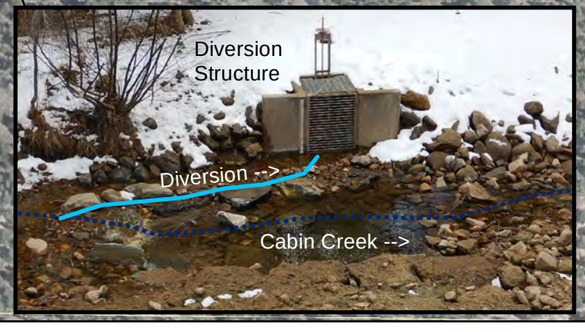
Camp St. Malo

Option 1a

Option 1b

Option 1a--Example of wood in channel and floodplain

Option 2a--Example Diversion Stucture



Option 2c--Example of Restored Floodplain & Multiple Channels & Road Crossing

Option 2a--Example of Road Crossing

Figure 18. Camp St. Malo Preferred Alternative conceptual layout

5.2 Preferred Alternative Benefits

The following table discusses the benefits of the preferred alternative in relation to the goals set forth by LHWC, Camp St. Malo, and Rocky Mountain National Park.

Table 3. Preferred alternative benefits

Reduce flood/fire risk to existing on-site infrastructure	By shifting the high energy flows and primary sediment delivery pathways to the south and away from the existing ponds, roadways, bridges, and buildings, the preferred alternative reduces the overall flood risk to Camp St. Malo. Additionally, by ceding nearly the full extent of the alluvial fan to the stream corridor, the opportunities for building additional facilities or infrastructure in a high hazard zone are reduced. Transitioning the dry flood deposits to a wetted riparian corridor and away from high density lodgepole may reduce the burn intensity and break up high severity burn continuity on the property.
Attenuate fluxes of water/sediment to buffer downstream communities and community assets during floods	Practically speaking, the Highway 7 road embankment and undersized culvert acts as a de facto dam which facilitates water and sediment attenuation on the Camp St. Malo property during high flows—until the highway embankment or culvert fails or otherwise breaks. The preferred alternative can and will provide sediment storage by rehabilitating the natural processes on the alluvial fan but this coarse sediment may not have ever reached downstream communities due to the discontinuity caused by the highway embankment. The existing, and hopefully future, wetland complex(es) will attenuate and store water, however, this will be more pronounced during low or moderate flow events and during droughts.
Increase the ability of the Camp and fire response units to suppress wildfire	Transitioning the dry flood deposits to a wetted riparian corridor and away from high density lodgepole may reduce the burn intensity and break up high severity burn continuity on the property.
Reconnect the river with its floodplain	The preferred alternative will reconnect the stream with its floodplain throughout Work Areas 1 and 2 and preserve the existing connection in Work Area 3.
Remediate 2013 flood impacts	This goal is more accurately stated as “remediating the 2013 Flood emergency response impacts”. The preferred alternative will, especially in Work Area 2, rehabilitate the area nearly 10 years after the flood response. Similarly, the cause of the current wetland degradation above Pond 6 is directly tied to the new Highway 7 culvert which was replaced due to damage from the 2013 flood.
Stabilize, protect, and keep sediment out of ponds	The use of a diversion structure to fill and refill the existing ponds will reduce the amount of sediment moving into Ponds 2, 3, and 4 from the upstream reaches of Cabin Creek. Similarly, roughening the channel and inset floodplain with large wood and woody vegetation in Work Area 1 will trap sediment above Pond 1. The sediment in Pond 6 is primarily due to the ongoing degradation of the existing wetland complex. The preferred alternative will address this by stabilizing the head cuts and incision in Work Area 3.
Maintain the flow of water through the ponds	The use of a diversion structure on Cabin Creek will allow for more active regulation of the flow that is used to fill and refill the ponds.
Increase habitat for wildlife	The preferred alternative will increase riparian habitat substantially throughout Work Area 2 and maintain and enhance riparian habitat for Work Areas 1 and 3. Riparian habitat is critical, either directly or indirectly, for most species that call Camp St. Malo home.
Maintain emergency access/two points to entry/exit from highway	The preferred alternative will maintain both access points to the property and enhance the utility of the road by upgrading the Cabin Creek crossings.
Enhance access and the natural space for learning and education	The preferred alternative will encourage engagement with the natural space by providing multiple access points to the different types of habitat and different physical reaches of Cabin Creek. The existing analysis and future work throughout the corridor can be easily translated into an interpretive trail that winds through the property. By using natural materials to the greatest extent possible, the space can also serve to educate the guests of the Camp about naturally healthy rivers, watersheds, and wetlands.
To the extent possible, restore the reflecting pond near the St. Catherine’s Chapel	The preferred alternative proposes to restore the water storage capacity of Pond 6 (which was lost during the 2013 flood and response actions). By stabilizing the head cuts above Pond 6, the sediment load into the pond will be reduced, hopefully resulting in restoration of the pre-flood pond depths and surface areas.
If possible/feasible, stabilize the debris flow and/or	Based on our rapid examination of the site, the past debris deposits above Camp St. Malo are relatively stable and are continuing to stabilize as the riparian vegetation continues to

reduce risk of future debris flow	establish. Within Work Area 2, the existing debris flow deposits will be reconfigured and stabilized with the work proposed in the preferred alternative. It is not feasible to reduce the future debris flow hazards, however, by reestablishing the primary flow path down the center of the alluvial fan and away from the existing and proposed infrastructure, the risk from future debris flows will decrease as there may be fewer negative consequences and asset damage should a debris flow occur.
Camp St. Malo currently has plans to build but would like to know what best options (lowest risk locations) are for building a learning center	We have advised Camp St. Malo to not build anywhere on the face of the fan or near the stables to the south of the site. The safest location to build a learning center (from a flood and debris flow hazard perspective) is site where the residential facility stood prior to 2011. There are also safer areas immediately off of Highway 7 near the rock outcrops.
Complete the project in an efficient, logical, and timely manner	With the stakeholder team, including RMNP, opting to forego work within the boundaries of the National Park, the project can proceed without NEPA review, and the prolonged timelines associated with that process. A recommended construction approach is included in the following section which can maximize flexibility and effectiveness given the uncertainties on the site.

5.3 Recommended Construction Approach

We recommend that this project go to bid for construction as an RFQ with hourly rates. We also recommend that this project proceed with a dedicated construction contract that is executed on a time and materials basis. Given the natural supply of materials on site, contracting labor and machinery to sort and stockpile the rock and wood that will be used appears to be a cost-effective and lower-risk means to utilize the resources already at Camp St. Malo. Additionally, because it is unknown what lies beneath the surface of the alluvial fan, a time and materials contract allows for more flexibility both for the contractor and design team to adjust to unforeseen or variable conditions found in the new stream corridor.

Natural environments are complex and ever changing. These complexities make construction plans difficult to translate and implement exactly as they are shown. Because of this uncertain environment, stream work often involves a field-fit component and it is highly valuable—necessary even—for the design engineer (or a representative) to be significantly involved in the pre-construction and construction oversight process. In this context, we are not referring to construction management (i.e. someone in the field simply observing and measuring daily progress) but instead the oversight of an actual river engineer, geomorphologist, or ecologist (depending on the work being completed). As such, we recommend substantial construction oversight support from the design team to facilitate making direct and immediate decisions about design and implementation in the field as complexities arise (especially since there is no cell phone service at the project location). We have found that contractors appreciate the efficiency of having a “decision-maker” on site to answer questions and ultimately this approach results in an end product that closely resembles a stream corridor in its most natural form.

5.4 Preferred Alternative Treatment Types

With the exception of the crossing, diversion structure, and pond outlets, the preferred alternative is proposed to be built using predominantly natural materials. Practically, this means that the stream channel and floodplains will be stabilized by using the existing rock that is on-site, the large wood that is racked on the margins of the corridor, and live cuttings from the existing willow stands. Arrangements of this material can take many forms and ultimately, the treatments to be used are to be determined in the final phases of design. Based on the preliminary analysis and the discussions of the preferred

alternative, we could see the following treatments being installed on the site. Please refer to the CWCB construction manual found at
https://drive.google.com/drive/folders/1GrCphSzz9K4EM6EUtcGgYL94_juk1ofh
for descriptions of and information on what these treatments entail.

For channel shaping, bedforms, and habitat
Habitat boulders
Large wood and other wood structures
Pools
BDAs (only in the existing wetland)

For channel bed stability:
Boulder cascade or boulder step
Constructed riffle
Log vanes

For channel bank stability:
Large wood complex
Boulder-cobble toes with willows
Soil lifts
Willow toe

For floodplain roughness and sediment deposition in overbank areas:
Floodplain wood
Brush trench
Microtopography-mountain streams
Overflow channel

For revegetation:
Live cuttings
Vertical bundles and live clumps
Containers
Sod mats
Seed
Mulch

5.5 Permitting

5.5.1 Section 404 and SHPO

Based on what we currently know about the project and its potential funding sources, it is likely that this project will fall under a Nationwide 27 permit with the ACOE for compliance with Section 404 of the Clean Water Act so long as it retains its primary objective of stream restoration.

It's possible that the cultural resources review that was already completed for the forestry work could cover any SHPO requirements, but another review could also be necessary.

5.5.2 Boulder County Land Use

Due to its size, this project would be subject to a Boulder County Limited Impact/Special Use review. The requirements for this are not extensive and do not require undue additional analysis—typically just a grading plan and construction plan as well as an application. The processing time for this with Boulder County, however, may be lengthy.

5.5.3 Regulatory Floodplain

The Boulder County Regulatory Floodplain on Cabin Creek begins east of Highway 7 (Figure 19) and the FEMA Regulatory floodplain begins at Button Rock Reservoir, meaning the proposed work zones on the Camp St. Malo property are not subject to Boulder County or FEMA Floodplain Regulations.

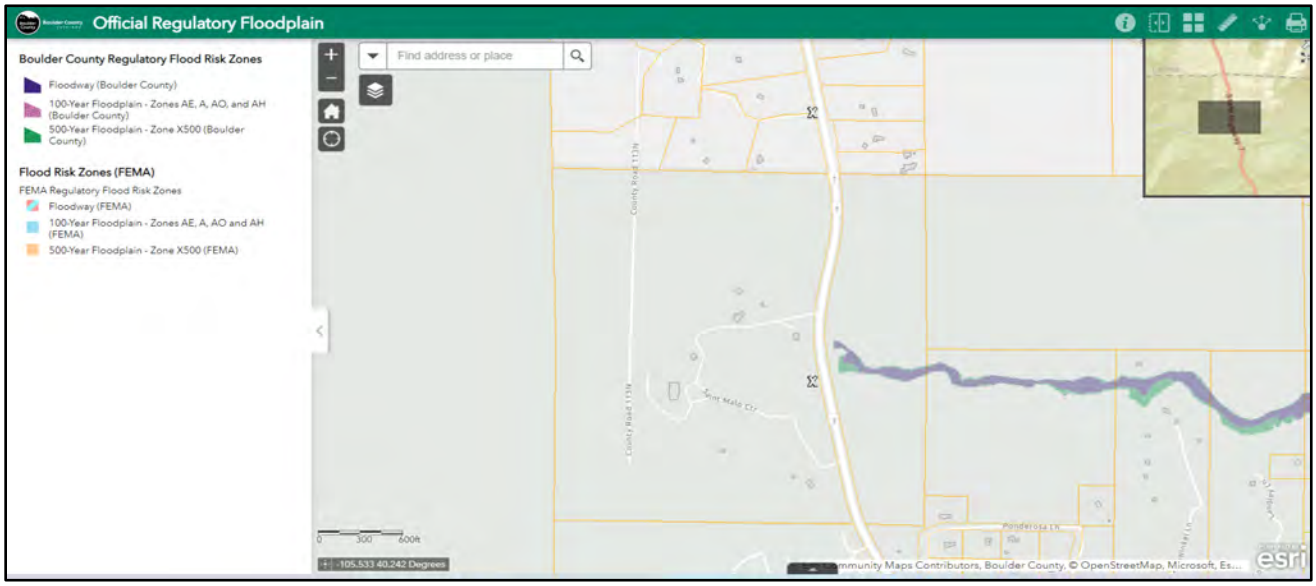


Figure 19. Screenshot from the Boulder County floodplain viewer showing no regulatory floodplain east of Highway 7. Screenshot from August 15, 2022. https://bouldercounty.maps.arcgis.com/apps/webappviewer/index.html?id=1e2e9b4171014c99b9bed023bbb65947

5.6 Preferred Alternative Cost Estimate

Task	Estimate	Assumptions
Finalize Design	$40,000	Assumes construction can begin with a ~80% design for the stream corridor components and proceed with intensive field fitting. The intention of this 80% design is to allow for the project to go to bid for construction for permitting to be completed, and to finalize expectations between the land managers and LHWC.
Permitting	$ 15,000	Assumes no floodplain modeling and only basic permitting including a wetland delineation and Nationwide 27 permit. Project will require Boulder County LISU review. Assumes NEPA is not required.
Construction Oversight	$ 75,000	Assumes intensive and consistent construction oversight for a 3-month construction window.
Construction	$ 650,000	Assumes a time and materials contract with a large field fit component with a skilled operator. Assumes most materials for construction (aside from those for the crossing(s) and diversion structure) are collected from on-site and all excavated material is wasted on-site. Use of trees/slash for structures and rock could be a match opportunity. This does not include trail building, signs, benches, etc.
Revegetation	$ 35,000	Assumes that revegetation is predominately live staking, transplants, and containerized stock with limited seeding and mulch. Assumes live stakes can be harvested onsite.
Monitoring/Reporting/Permit Close Out	$ 20,000	As-built construction report to document completed work. Monitoring for grant and permitting reporting and to inform adaptive management.
Contingency	$ 125,000	~15% of project budget
Total Estimate	$960,000	

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