U.S. FOREST SERVICE
NATIONAL STREAM AND AQUATIC ECOLOGY CENTER

September 15, 2016

FIRST CREEK: STREAM RESTORATION ASSESSMENT

Client: Routt National Forest
Location: Headwaters of Elkhead Creek in California Park, Colorado
Date of Visit: 7/27/2015
On-Site Participants: Rick Henderson, Fishery Biologist, Medicine Bow-Routt National Forest
Liz Schnackenberg, Hydrologist, Medicine Bow-Routt National Forest
Brian Hodge, Fish Biologist, Trout Unlimited
Pam Sponholtz, Biological Scientist, U.S. Fish and Wildlife Service
David Merritt, Riparian Ecologist, National Stream and Aquatic Ecology Center
Steven Yochum, Hydrologist, National Stream and Aquatic Ecology Center

The incision of First Creek, and the resulting perspective that restoration is needed, is due to a drop in the base level of Elkhead Creek and local meander cutoffs increasing slope, unit stream power and shear stress, and sediment transport capacity. This incision is likely due to historical and current grazing practices and browsing activities causing poor streambank vegetative condition. This is increasing the rate of bank erosion, with decreased root binding and lower hydraulic roughness. The lower roughness and flow resistance leads to higher velocities, higher momentum transfer to the channel banks, and larger forces acting on the weaker cut banks. This affect is exasperated by tight meander bends that reduce the area over which momentum transfer acts upon the bank within a channel bend. The resulting First Creek channel is Channel Evolution Model stages 3 and 4, with some reaches showing substantial floodplain width at the lower base level (stage 4) and other reaches showing overly-narrowed, channelized reaches (stage 3) that are actively eroding cutbanks.

If left to evolutionary processes, the incised First Creek channel is expected to continue to develop widened floodplains during high flow events until a floodplain width is developed to sufficiently reduce unit stream power. However, additional disturbances may result in new rounds of incision and continued impaired conditions.

The following alternatives are presented for consideration:

Alternative 1: No action
Alternative 2: Riparian management only
Alternative 3: Riparian management plus local streambank protection
Alternative 4: Riparian management plus channel reconstruction

Recommendation: We recommend alternative 3 for implementation due to its lower risk for impairing existing ecological resources (compared to alternative 4), specifically the oxbow-associated wetlands.

Prepared by: **Steven E. Yochum, PhD, PE**
NSAEC Hydrologist
970-295-5285, steveneyochum@fs.fed.us

David Merritt, PhD
NSAEC Riparian Ecologist
970-295-5987, dmmerritt@fs.fed.us

INTRODUCTION

Stream restoration projects are being planned or have been implemented in the headwaters of Elkhead Creek in California Park, on the Routt National Forest. California Park and its watershed ranges in elevation from 7800 to 10,879 feet (Meaden Peak). Average annual precipitation within the Park varies from 27 to 29 inches (PRISM, Daly et al., 2008), with the watershed receiving up to an estimated 49 inches. California Park has been designated as a special interest area, due to its geological, historical, scenic, and zoological values (USFS 2016). The Park's watershed has been classified as *Functioning at Risk* within the Forest Service Watershed Condition Framework (Potyondy et al. 2009).

California Park contains a population of Colorado River Cutthroat Trout, with potentially more than 40 miles of stream habitat. Impairments to the cutthroat trout population are thought to be primarily excessive peak summer temperatures (Bidelspach 2011). Historically, brook trout were stocked in the Park, but stocking was reportedly discontinued in about 1996 and brook trout are thought to be no longer present.

Other species reportedly of interest and present within California Park include sandhill cranes, sharp-tail grouse, leopard frog, and other native fish (dace, sculpin, and mountain sucker). Additionally, sage grouse habitat is present.

Stream restoration work is being planned for First Creek, an 18.2 square mile watershed to Elkhead Creek. The overall reach of concern is from County Road 150 to the confluence (Figure 1). This stream reach is on both National Forest and Colorado State Land Board lands. The goals of the project, as documented in USFS (2016), are to:

1. Improve stream and riparian health,
2. Improve habitat for and expand the range of sensitive species, and
3. Increase the resilience and resistance of native fishes and aquatic habitats to the effects of climate change.

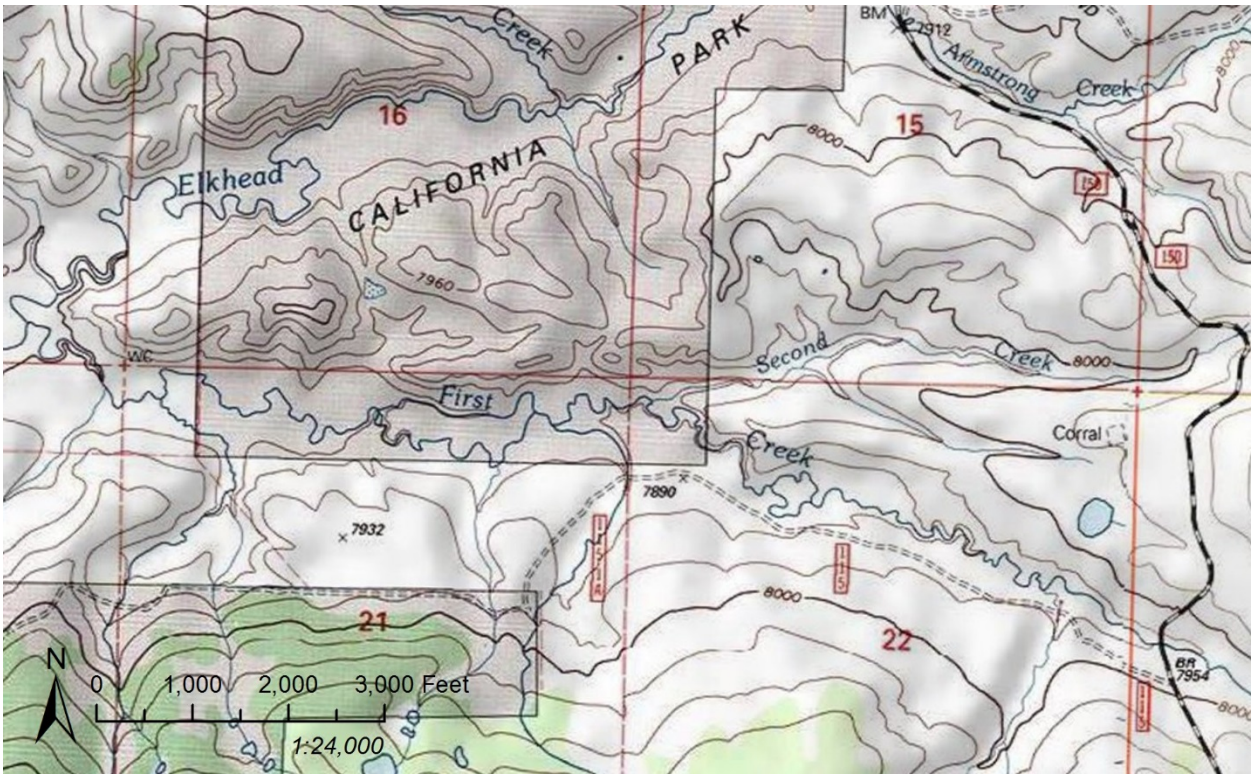

Figure 1: First Creek reach of concern, from County Road 150 to the confluence with Elkhead Creek.

Restoration activities being considered for First Creek, as detailed in USFS (2016), include:

- New channel construction at a raised bed elevation to address incised conditions
- Channel reconstruction at the existing grade
- Channel reconnection from existing into historic channels
- Wetland construction within the riparian zone
- Beaver dam enhancement to encourage more stable beaver dams
- Revegetation within the riparian zone
- Fencing to exclude ungulates

A site visit was performed to observe the conditions and potential for stream restoration within First Creek. Additionally, Elkhead Creek just downstream of its confluence with First Creek was also assessed. This report details observations collected during the site visits, and provides alternatives and recommended actions given current conditions.

CURRENT CONDITIONS

Currently, First Creek between County Road 150 and the confluence is incised up to about 3 feet, with the amount of incision varying throughout the overall reach. No headcuts were observed, though aerial imagery indicates that multiple meander bends have been cut off and that lateral erosion in some locations is active and may likely be accelerated compared to pre-settlement conditions. Elkhead Creek at the confluence was also observed to be incised. Several terraces and hillslopes were actively eroding at their toe. These high eroding banks combined with active bank erosion at many locations are contributing to turbid conditions. Specific observations of conditions along First Creek, as well as a short section of Elkhead Creek downstream from the First Creek confluence, are presented below.

Elkhead Creek below First Creek Confluence

Elkhead Creek below the First Creek confluence (44.3 mi^2 catchment size; Figure 2) is incised, and appears to be in Channel Evolution Model (Schumm et al. 1984) stages 3 and 4 (Figure 3).

Figure 2: Elkhead Creek below the First Creek confluence. Aerial imagery dated 6/2010.

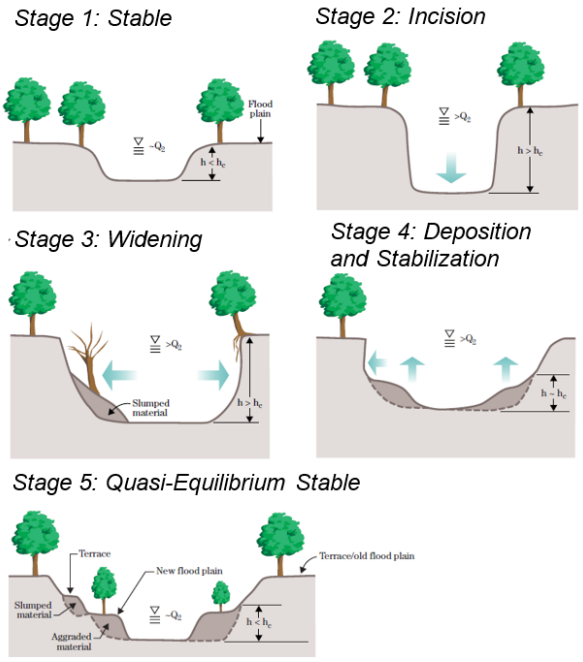

Figure 3: Channel evolution model, with channel cross sections illustrating the 5 channel stages (modified from NRCS 2007).

The Channel Evolution Model (CEM) is a valuable tool for understanding how channel form adjusts over space and time due to a disturbance that causes incision. At a specific location the channel evolves from an initial stable state (stage 1) through incision (stage 2), widening (stage 3), deposition and stabilization (stage 4), and once again stable (stage 5). Stages 2 and 3 are the most challenging stages of the evolution model for managers; this is the stage where sediment supply is highest and restoration options are limited. Over time, the incision moves upstream, forcing incision of the valley bottom on successive upstream reaches. With this reach of Elkhead Creek being in stage 3 within part of the observed reach, the stream appears to still be transitioning to a stable form (stages 4 and 5), with a sufficient floodplain width at the lower base level (oval, Figure 4).

Figure 4: Elkhead Creek, viewing upstream towards the First Creek confluence. The red arrows indicate cut banks eroding at a relatively-rapid rate as a new floodplain is established at the new base level. The blue oval indicates a reach that is transitioning from stage 3 to 4 in the channel evolution model.

First Creek

First Creek just above the confluence with Elkhead Creek (Figure 8) is incised about 2 feet, and has a substantial meander cutoffs present (compare 1970 to 2010 imagery in Figure 8), with sinuosity within the extent of this figure dropping from 1.74 (1970) to 1.61 (2010). The confluence has an upstream orientation (Figure 5), though erosion of the cutbank on First Creek just upstream of the confluence will soon correct this transient state. It was observed that additional potential cutoffs are possible in the near term, with apparently greater-than-average cutbank erosion rates. Like Elkhead Creek, First Creek throughout its lower extent appears to be in CEM stages 3 and 4 (Figure 6). Some meander bends are actively eroding to the point of threatening avulsions and, consequently, additional incision.

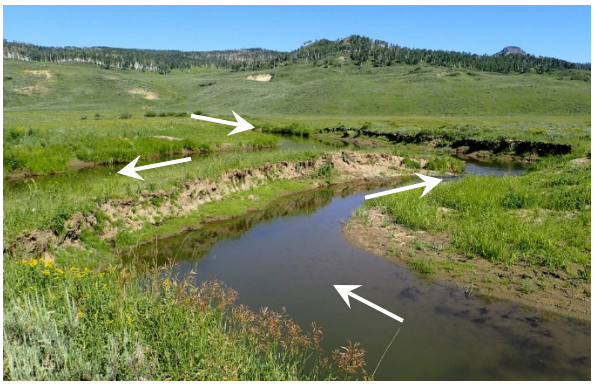

Figure 5: First Creek at the Elkhead Creek Confluence. The white arrows indicate the flow directions.

Figure 6: First Creek, incised about 2 feet in Channel Evolution Model stage 3.

Overall, the vegetation along the reach is dominated by native woody and herbaceous species such as *Salix lemmonii*, *S. boothii*, and *S. lutea*, *Carex aquatilis*, *C. utriculata*, and a rich flora of forbs. In the higher and drier portions of the valley bottom, non-native pasture grasses such as *Phleum pretense* and *Bromus inermis* were dominant. The willows, while visibly browsed, are in good shape along most of the reach, particularly in stem dense stands along middle reaches. However, along lower portions of First Creek, along the reach upstream from the confluence, the willows appear dwarfed, likely a result of browsing pressure. Willow recruitment was observed along open exposed bars, but signs of livestock and elk and deer grazing/browsing of these recruits was evident.

At the time of our field visit, cattle were dense and grazing in the channel and on its banks (Figure 9). Bank erosion resulting from livestock grazing was also evident. Defecation into the channel has likely contributed to the green algae, which was prominent in the channel.

A host of native plant species dominate First Creek, including those mentioned above. Particularly striking was the diversity and extent of willow-dominated riparian vegetation, indicating that whatever incision has occurred has not been sufficient to lower water tables to a depth that would adversely affect shallow-rooted willow communities. Contributions of groundwater from extra-stream sources also serve to support such valley-bottom willow communities. Note seeps along valley margins in Figure 7.

Figure 7: Note springs and seeps well above the active channel of First Creek. These indicate that groundwater is likely contributing to First Creek and supplying extra-stream sources of water for phreatophytic vegetation.

Grazing and browsing impacts upon vegetation are by elk, cows, and sheep. Together, this amounts to season-long impact and is a primary disturbance mechanism. Grazing and browsing intensity appeared to be highest near the confluence of First and Elkhead Creeks. Clear signs of grazing of seedlings of woody species, and browsing of willow and graminoids was evident along the entire reach. Along lower reaches, bare ground was common. Sloughing banks, hoof impacts, and cow and elk feces was evident along the entire reach surveyed.

Figure 8: Lower First Creek, with aerial imagery from 2010 (upper) and 1970 (lower).

Figure 9: Livestock grazing in and around the channel and on the floodplain of the lower reaches of First Creek. Note the turbidity in the foreground. Also note the patches of vegetation. These rhizomatous species would likely colonize and stabilize such channel margins if livestock and elk grazing were reduced or discontinued. This would likely occur without any manual seeding or planting.

Some of the eroding cutbanks have had small mass wasting failures that are vegetating at a lower level along outside banks, creating bankfull benches of riparian wetland. The portions of these benches that are stabilized by vegetation will likely result in reduced lateral migration rates and reduced fine sediment availability.

Along some reaches, high terraces and hillslopes were observed to be actively eroding by the stream (Figure 10). Along with the many existing rapidly-eroding cut banks, these hillslopes are primary sources of fine sediment to the channel.

Figure 10: High, unstable bank and hillslope eroding into the active steam channel.

Proceeding upstream, the incision depth appears to vary between 1 and 3 feet. This variable incision may be due to meander cutoffs and beaver dam failures, in addition to the general base level drop in First Creek from Elkhead Creek.

An abandoned channel has been proposed to be reconnected with the primary stream channel (Figure 11). Sinuosity of this reach has decreased

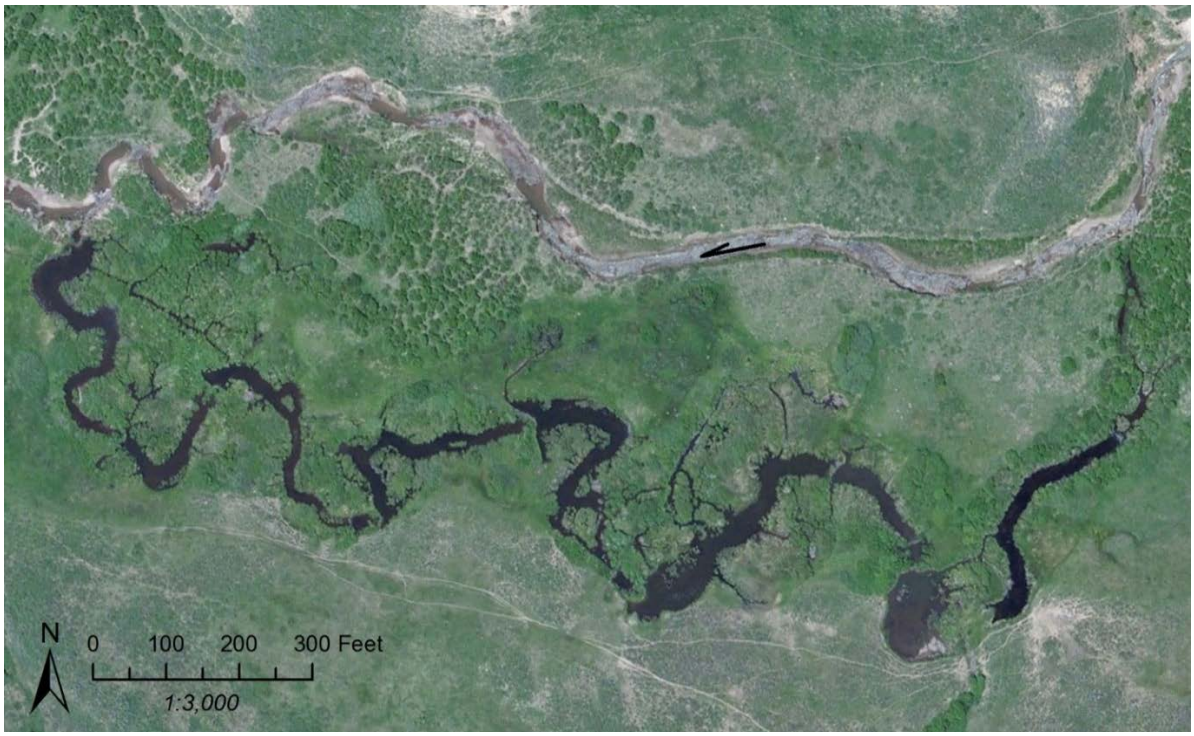

Figure 11: Proposed channel reconnection reach.

from 2.2 to 1.2; the once substantially-meandering channel on the south side of the valley has been replaced by a relatively-strait and incised channel on the north side of the valley (Figure 12). This new channel and associated floodplain has recruited a substantial amount of riparian vegetation, though has a fairly channelized and homogenous cross sectional and longitudinal form. This cutoff occurred sometime prior to 1970, according to historical aerial imagery.

Incision both upstream and downstream (Figure 13) of the proposed channel reconnection is evident. Linking the bed grade of the new channel, at its lower base level, and the old channel and floodplain may be problematic in any restoration effort within this reach.

The abandoned channel is functioning well as a wetland (Figure 14), with a surface source for water from a small tributary (southeast corner of Figure 11) and potentially additional sources of water from a spring along the adjacent hillslope. The tributary has introduced sediment as a small fan, which has filled a portion of the abandoned channel. This wetland is considered a valuable resource and should be highlighted for protection. Threats to the long-term stability of this feature include breaching of the natural levees that retain the water by a large flood in the primary, incised conveyance channel, as well as failure of grade control for any restoration efforts that seeks to reconnect this abandoned channel to the primary channel.

Figure 12: Relatively-strait cutoff channel on north side of the First Creek valley.

Figure 13: Just downstream from the proposed channel reconnection, with 2 to 3 feet of incision.

The stream condition was also inspected in the reach just downstream of county road 150. Generally, this reach was relatively stable, without rapidly-eroding cut banks. Willows and sedges are present along the outside of the meander bends and throughout the extensive floodplain width. Beaver dams were present, and appeared to be holding better. This reach may be steeper; more coarse bed material sizes was observed (cobbles and boulders present) than what was seen in the downstream reaches. The flow was still turbid. Compared to downstream, the channel appeared to be generally narrower (at bankfull), had more variable widths, and was faster flowing during the low flow conditions that existed during inspection. This reach may be incised to a minor degree (and obscured by vegetation). The collected LiDAR data should be able to detect this incision if present, though these data were not provided to us for our assessment.

Figure 14: Current wetland within abandoned channel proposed for reconnection.

CONDITION AND RESTORATION POTENTIAL SUMMARY

The fundamental processes causing the channel instability are hypothesized to be the loss of flow resistance and bank stability from vegetation impairments due to livestock grazing and game browsing, and meander cutoffs induced by the resulting accelerated streambank erosion rates. The mechanisms underlying these processes are presented in the following paragraphs.

Using Natural Channel Design terminology, restoration at the current (incised) grade is defined as a priority 2 restoration, while raising the grade of the channel to the abandoned floodplain level is defined as a priority 1 restoration. The Stantec conceptual restoration report (Bidelspach 2011) refers to priority 1 restorations as a "low risk option." We take exception to this assertion. While this approach can often better satisfy goals and objectives, they are inherently higher risk due to increased potential for failure.

Elkhead Creek

With CEM stages of 3 and 4 being present on Elkhead Creek just below the First Creek confluence (Figure 5), and the majority of this channel in stage 3, conditions within Elkhead Creek are inherently unstable. The incised and laterally-constrained channel during annual high flows has, in consequence, higher shear stress ($\omega = \gamma hS$, due to deeper flow depths [h] and, potentially, meander cutoffs that increase the slope [S]), higher unit stream power ($\omega = \gamma QS/w$, due to substantially narrowed floodplain widths [w] and, potentially, meander cutoffs), and increased sediment conveyance capacity. During high flows continued relatively-high erosion rates will occur, resulting in additional floodplain widening, a reduction in unit stream power and shear stress, and the CEM stage 4 (and eventually 5) evolution states. With this channel evolution, the stream should stabilize at the lower base level, though additional disturbances that induce further incision is also a possibility.

Additionally, the oftentimes poor vegetative condition of the banks, due to grazing and browsing impacts, is likely influencing bank erosion rates, with decreased root binding (resulting in weaker bank condition) and lower roughness. Lower roughness and, consequent flow resistance (Manning's n) leads to higher velocities ($V = \frac{R^{2/3}S^{1/2}}{n}$), higher momentum transfer to the channel banks ($F = \rho Q \Delta V$), and larger forces acting on the weaker cut banks. This mechanism can be compounded by tight meander bends resulting from bank instability, accelerated downstream meander migration, and a reduction of the area over which the momentum transfer acts upon the bank. The result is substantially accelerated bank erosion rates.

At this point in the channel evolution, Elkhead Creek is in an inconvenient state for restoration. At the current lower grade, a floodplain has yet to consistently form to sufficiently reduce unit stream power during high flows. The stream will be unstable until a new dynamic equilibrium is reached. Alternatively, a more aggressive approach could be used to create a new channel within the former floodplain (which is now a terrace), a priority 1 restoration, but this would require large amount of earth movement and redundant grade control that are maintained in perpetuity. While reestablishing the channel on the former floodplain surface may best satisfy the declared objectives (USFS 2016), it is higher in risk due to the relatively large scale of this channel resulting in high stream power and erosive potential, potential loss of grade control (through direct structural failure or bypass) that will need to be maintained in perpetuity, and the risk of reversion to incised conditions through channel capture by floodplain ponds that often remain after such projects, as borrow pits. This restoration approach may also be cost prohibitive due to earth movement quantities, and may substantially disturb existing vegetative conditions that are essential for channel stability.

First Creek

Incision of First Creek near the confluence (Figure 6) is due to a drop in the base level of Elkhead Creek. The resulting First Creek channel is CEM stages 3 and 4, with some reaches showing substantial floodplain width at the lower base level (CEM 4) and many other reaches showing overly-narrowed, channelized reaches (CEM 3) that are actively eroding cutbanks (Figure 15). Like Elkhead Creek below the confluence, the

restoration potential of First Creek is complicated by the channel evolutionary state. However, First Creek has less than half the drainage area of Elkhead Creek below the First Creek confluence. Because of this, the stream has substantially less flow, smaller channel dimensions, and likely less total stream power ($\Omega = \gamma QS$, depending upon slope). Similar to unit stream power, total stream power is directly proportional to sediment transport capacity and erosion potential.

Figure 15: Typical cutbank with high erosion rates.

The influence of the Elkhead Creek incision upon First Creek likely decreases in influence as one proceeds further upstream. Instead, observed incision upstream may be instead dominated by local meander cutoffs increasing slope, unit stream power and shear stress, and sediment transport capacity. For example, a large meander cutoff near the confluence is evident in the aerial photo comparison between 2010 and 1970 (Figure 8).

Like Elkhead Creek, historical and current grazing practices and browsing activities has left poor streambank vegetative condition. This is likely increasing bank erosion rates, with decreased root binding and lower roughness. The lower roughness and flow resistance leads to higher velocities, higher momentum transfer to the channel banks, and larger forces acting on the weaker cut banks. This affect is exasperated by tight meander bends that reduce the area over which momentum transfer acts upon the bank within a channel bend.

If left to evolutionary processes, the incised First Creek channel is expected to continue to develop widened floodplains during high flow events until a floodplain width is developed to sufficiently reduce unit stream power during high flows to obtain CEM stages 4 and 5 at the lower base level. However, additional disturbances may result in new rounds of incision. Additional meander cutoffs from the accelerated bank erosion rates would be an example of such a disturbance.

It was observed that the wood material available for beaver dam construction is limited to relatively-short lengths of willow, which is less effective for constructing stable beaver dams. This may be a key reason for frequent dam failures. If the dams failed less frequently, these dams can, in time, counteract incision through deposition and gradual return of the stream channel to a higher base level. Grade control is maintained by the beaver, reducing human maintenance needs required with priority 1 restoration approaches. However, cattle browsing appears to be keeping the willows low to the ground in many location. In this sense, the cattle are directly competing with the beaver, with the result being less resilient dams.

The local restoration team (Rick, Liz, Brian) expressed concern regarding sediment loading from erosion of high (Mancos shale) banks and unstable hillslopes immediately adjacent to the stream channel (Figure 10). This makes sense considering the detrimental impacts of fine sediment on spawning gravels for cutthroat trout. However, it has been hypothesized that the apparent brook trout extirpation from California Park is in large part due to this turbidity and suspended sediment load. From this perspective, this fine sediment may not necessarily be a detriment to the restoration goals. Further, suspension and transport of these Mancos shale banks is likely an historic phenomenon to which the local cutthroat populations are adapted.

Like Elkhead Creek below the confluence, First Creek has yet to develop a consistent floodplain at the lower grade that sufficiently reduces unit stream power during high flows. The stream will be unstable until enough widening occurs at the lower base level and a new dynamic equilibrium is reached. However, restoration consisting of bank stabilization at locations that threaten additional meander cutoffs and incision may likely be prudent. In any case, riparian management is needed to reduce the impacts of grazing and

browsing. Otherwise, impaired conditions will likely continue.

Alternatively, a priority 1 restoration could be performed along all or a portion of the incised stream reaches, which through lateral reconnection of the floodplain across the entire valley bottom will better satisfy project goals (USFS 2016). Due to the smaller stream scale and power, First Creek has less chance for failure than Elkhead Creek, but failure is still a substantial concern from bypass of grade control structures or the eventual loss of function of grade control structures due to rot (if wood is used). This is especially a concern for the proposed channel reconnection reach (Figure 11), where loss of grade control could lead to the loss of an existing high-quality wetland (Figure 14). This restoration approach may also be cost prohibitive due to earth-movement quantities, and may substantially disturb existing vegetative conditions that are essential for channel stability.

RESTORATION ALTERNATIVES

Restoration recommendations for First Creek based upon counteracting fundamental processes inducing instability and the restoration goals are presented below.

Alternative 1: No action

This alternative will likely result in continued impaired conditions, with relatively-rapid bank erosion and hillslope failures at some locations, and potentially additional localized incision and floodplain disconnectivity.

Alternative 2: Riparian management only

This alternative would only consist of constructed exclosures to protect riparian vegetation from over grazing by both livestock and elk. The channel would be allowed to stabilize at the current lower grade through vegetation recovery, though additional localized incision is possible in some locations as cutbanks cut off additional meander bends. Beaver dam construction may eventually raise the channel grade, though this process would years or decades.

Alternative 3: Riparian management plus local streambank protection

This alternative would consist of the constructed exclosures of alternative 2 plus protection of strategic cutbanks that threaten to cut off meander bends, reducing the possibility for additional localized incision. This protection could consist of only planted vegetation (sedge plugs, willow poles and bundles, willow clumps), or vegetated plantings in combination with flow deflection structures (such as bank vanes), toe armoring (such as toe wood), or wood jams. However, a drawback of this approach is that existing oxbow-associated wetlands may be lost with channel migration. Once the vegetation has recovered beaver dam construction may eventually raise the channel grade, though this process would take years or decades. The beaver dams could be reinforced through poles installed in existing dams, to provide better resistance to floods. Beaver dam analogs could also be constructed.

Alternative 4: Riparian management plus channel reconstruction

This alternative would consist of reestablishment of the stream channel within its former floodplain, as a priority 1 restoration, as well as the riparian management of alternative 2. Such work could occur for all of the incised portions of First Creek or only selected portions, with alternative 3 approaches used elsewhere (if the longitudinal profile indicates this is possible). In the 5 or 6 locations where recently-abandoned channels exist, the stream could be reestablished within these channels. Substantial earth movement and expense would be incurred with this alternative, and cut/fill balances could be difficult to achieve. However local hillslopes could provide needed borrow material for filling channels. This approach has higher risk for failure, due to threats from failed or bypassed grade control structures, but has higher ecological rewards if successful due to reconnection of the channel with the currently-abandoned floodplain surface, providing lateral connectivity. If the raised grade is maintained, this approach does reduce the chance of meander migration eventually eliminating the existing oxbow-associated wetlands. The grade control structures would need to be monitored and maintained in perpetuity.

RECOMMENDED STRATEGY

We recommend alternative 3 for implementation due to its lower risk for impairing existing ecological resources, specifically the oxbow-associated wetlands.

The risks associated with a priority 1 restoration (alternative 4), with reestablishing the channel at a higher grade through abandoned meander channels that are now functioning as wetlands, are substantial due to potential for loss of these ecologically-valuable wetlands. These oxbow channels currently have standing water with rich, structurally diverse emergent and wetland vegetation. This provides high quality habitat for water fowl, mammals, and amphibians, including leopard frogs and salamanders. If these channels were reconnected and underwent incision to the current base level, these wetlands would be degraded or destroyed. Grade control structures would be at risk of being undercut or laterally bypassed, as was observed at upper Armstrong Creek.

Additionally, considering the inherent threat that brook trout present to cutthroat communities, we recommend eDNA sampling of streams across California Park to verify that brook trout have been extirpated. Action to exterminate is suggested if presence is detected.

Regardless of which alternative is selected, the scientists at the National Stream and Aquatic Ecology Center are available for additional consultation and collaboration on this project.

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