Big Cottonwood Creek Recovery Plan: (5+ Yrs.) Opportunities & Recommendations

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Figure 1. Image of Big Cottonwood Creek (taken April 2021) depicting the prevalent channel incision, highly mobile fine sediment, and a lack of habitat (i.e., no pools).

Summary

This report is the final chapter of the Hayden Peak Fire Recovery efforts, and it looks towards the future and explores current needs, opportunities, and recommendations for a full recovery. As shown in this report, the fire and post-flood damages have significantly degraded Big Cottonwood Creek, a significant tributary to the Arkansas River. The degraded creek conditions have limited concerns toward life and property (as discussed in this report). However, the more significant problems are the remaining long-term impacts to hydrological impairment, exacerbated hydraulic conditions, poor water quality, and the drastic reduction in viable habitat. While this report highlights this specific creek's issues and several opportunities, it also provides a looking-glass toward other post-fire degraded streams that exist and will likely exist in the future. In 2020, 1% of our State's land burned in wildfires, which translates to over 1,000 miles of creeks in burned watersheds. As fire and flooding are tied together, we must consider the long-term impacts that are less obvious. Specifically, post-fire effects on our hydrology, water quality, and habitat go well beyond the 5 to 10-year fire recovery often discussed.

Contents

1. Introduction

The Hayden Peak Fire of July 2016 burned 16,700 acres of forest that included nine drainages to the Arkansas River: Hayden Creek (with South Prong tributary), Fox Canyon Creek, Big Cottonwood Creek (with tributaries Little Cottonwood Creek, Bitter/Butter Creek, and Wolf Creek), and Sullivan Creek (with tributaries Oak Creek and Mosher Creek). All creeks showed elevated levels of flow, sediment transport, and some damage to infrastructure, agricultural lands, and private property (Figure 2). In the first two years following the fire, The Arkansas River Watershed Collaborative (ARWC) and its partner organization Coalitions & Collaboratives (CO-CO) implemented early flood mitigation efforts and attempted to prepare the community and local government for the likelihood of severe post-fire flooding. These efforts were critically important, but wide-scale implementation was hampered by challenges in coordination with landowners, agencies, and local government. Without a coordinated process for responding to post-fire conditions in the community, obstacles occurred. With no significant flood during the first two years after the fire, concerns about post-fire threats dwindled until July 2018, when the first devastating flood rocked the community.

After the flood wreaked havoc on these systems and communities, a resurgence of post-fire mitigation emerged. ARWC, in partnership with River Science, & The Upper Arkansas Water Conservancy District (UAWCD) developed the Hayden Pass Fire Recovery Phases 1 and 2 (sponsored by the Colorado Water Conservancy Board (CWCB)) to help assist the community with flood recovery response and planning for the future. Work completed during these phases provided valuable post-fire flooding information, which ARWC and River Science heavily documented with elevation datasets, hydraulic modeling, and detailed hydrologic assessments to understand post-fire floods better and provide recommendations for recovery. A significant focus of these recovery efforts included extensive debris removal that lasted up to four years post-flood. As such, this area has provided a great deal of information and a Case Study for post-fire recovery. Five years have passed since the fire and three years since the most significant flood event, yet there remain many concerns to this area's infrastructure, community, riparian systems, and habitat.

In 2020, Colorado's wildfires burned approximately 625,000 acres or roughly 1% of its land. With 107,000 miles of rivers and streams, an estimated 1,003 miles of streams will have been within a burned watershed, and several more miles downstream will experience many post-fire impacts like Big Cottonwood Creek. As more fires rage across Colorado, and as these areas exit the immediate post-fire and flood stages (0-3 years post-fire), what resources, tools, and opportunities exist to assist in the necessary full recovery?

This report looks at the remaining issues of Big Cottonwood Creek and explores the need for restoration efforts after the flood risk has subsided. How can we help these systems and communities recover before a subsequent fire? How do we encourage the restoration of these devastated watersheds? The answers to these questions are crucial for this region and the State of Colorado, as many other communities and watersheds are now and will continue to face similar post-fire and post-flood recovery needs.

1.1. Focus Area

This report focuses on Big Cottonwood Creek and its tributaries of Little Cottonwood Creek and Bitter Creek (Figure 1 and 2) as they had the most devastating floods and continue to have issues to this day. These drainages experienced several significant flood events. The most extensive (full details in the case study and Hydrology and Hydraulics Report) was the July 24th, 2018, flood event. According to precipitation data, the flood was determined to be a 25-year rain-event with runoff estimates of 3,500 cfs of clear water. Field survey data and detailed hydraulic modeling showed strong evidence that this event behaved more like 10,200 cfs (4,000 cfs in the upper Big Cottonwood Creek, 2,200 cfs in Bitter Creek, and 4,000 cfs in Little Cottonwood Creek). The dramatic increase in flow was due to large amounts of debris distributed in the floodwaters from the burn scar.

Over the last five years, several groups, including Coalition for the Upper South Platte, ARWC, NRCS Emergency Watershed Protection (Fremont County), and River Science, have helped remove dangerous debris and help mitigate flood events. Work during this time was focused on protection of life, safety, and infrastructure. However, several issues persist in these drainages that demonstrate the need for more extended recovery help and assistance.

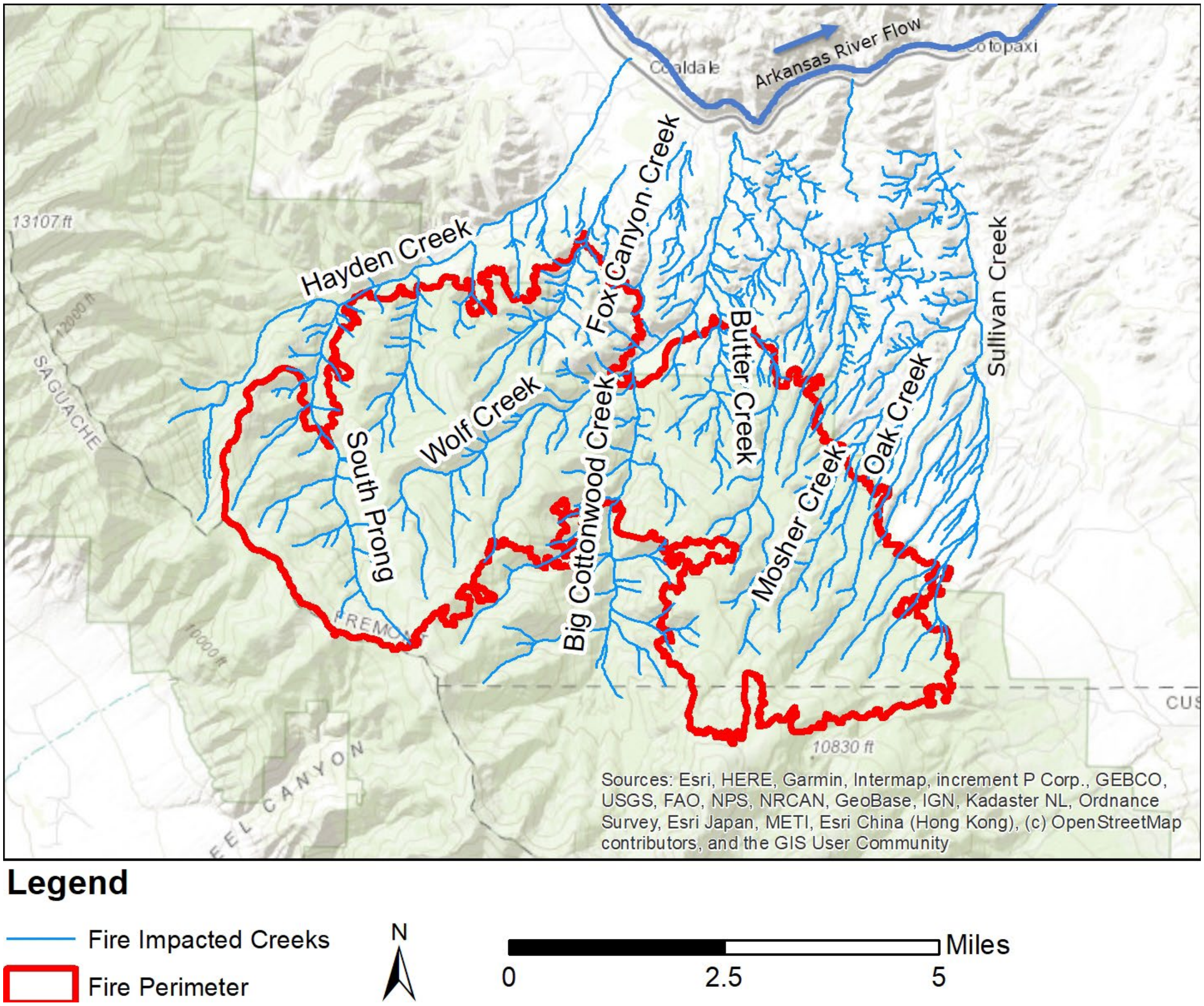


Figure 2: Hayden Peak Fire perimeter and the nine impacted creeks.

2. Existing Issues Affecting Full Recovery

As of the spring of 2021, there remain several concerns in these post-fire impacted creeks. These include threats to current Fremont County infrastructure, private property and infrastructure, irrigation structures, disconnected floodplains that exacerbate future floods (or fire and floods), and poor water quality and habitat conditions. These concerns are discussed in the following sections under general topics of infrastructure concerns and fluvial processes.

2.1. Infrastructure Concerns

2.1.1. Erosion Threats to County Road 40

Downstream of the intersection of County Road 40 (CR-40) and the Dinkle Ditch Road bridge crossing, there are large boulders (4-6 feet axis) placed on east bank of Big Cottonwood Creek. These boulders deflect water to the west (Figure 3A). These boulders constrict flow as well as push the concentrated flow directly toward the bank that supports CR-40. Hydraulic simulations show significant erosive power with high shear stress (Figure 3B) occurring at the toe of the bank supporting CR-40. This bank of CR-40 is steep and does not contain suitable vegetation or bank protection to resist future flooding erosion. Under the scenario of future flooding, bank erosion could prevent CR-40 access, and could prevent 14 different residents from escaping and/or returning home.

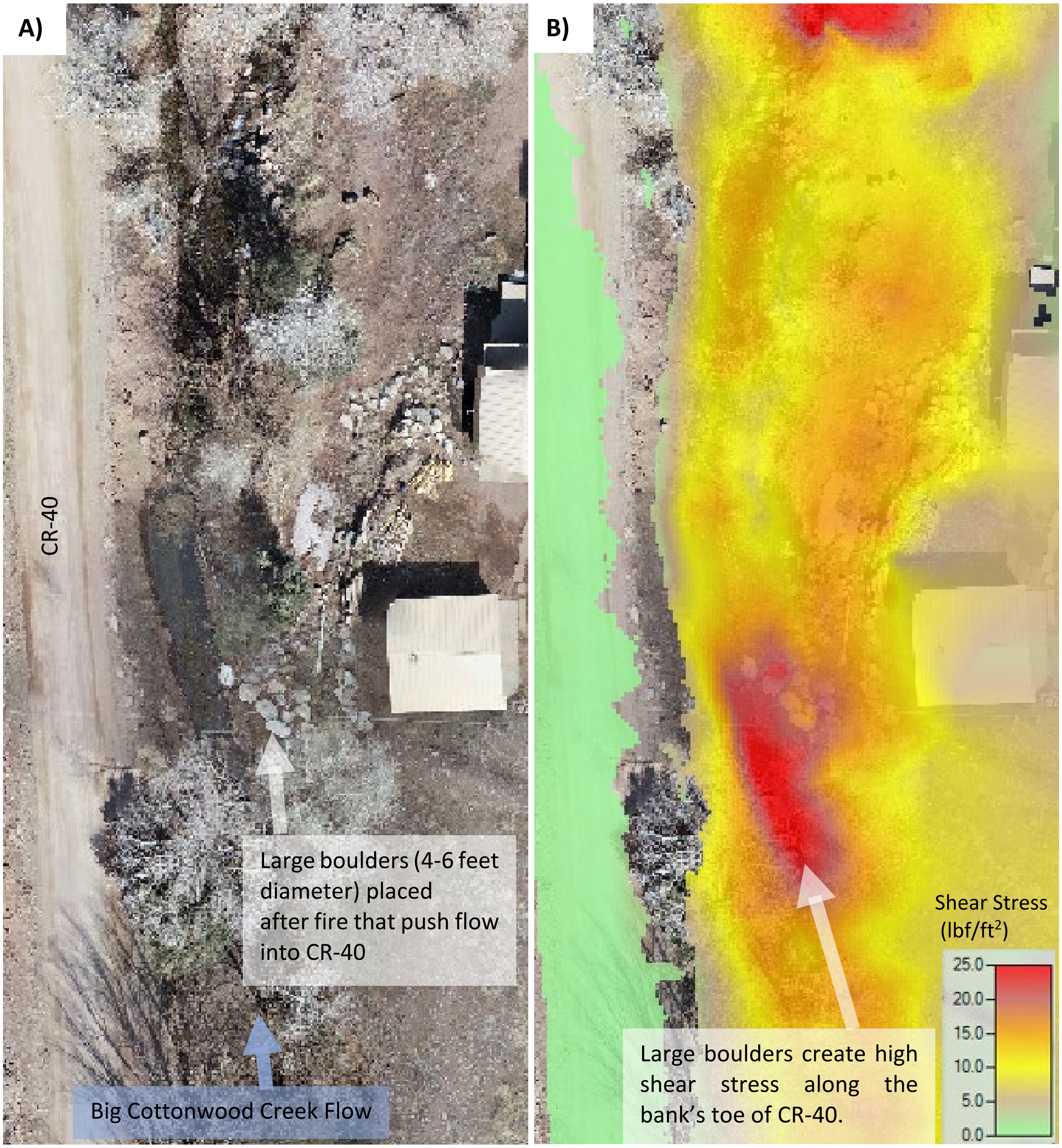


Figure 3: Large boulders have been placed along the eastern bank of Big Cottonwood Creek just downstream of where County Road 40 (CR-40) intersects with Dinkle Ditch Bridge. These boulders are: A) orientated to deflect flow away from the nearby housing and by doing so force greater flow toward the toe of CR-40's bank, which causes B) higher concenrtions of shear stress and erosion potential.

2.1.2. Harry Walker Dam

Harry Walker Dam is located at the downstream end of Big Cottonwood Creek where the CR-39 bridge crosses the creek (Figure 4A, pre-fire condition). Over the last several decades, the Harry Walker reservoir has been filling with sediment and losing capacity. However, the reservoir acted as a detention basin for the post-fire flood events and trapped large amounts of debris and sediment, protecting the Arkansas River just downstream. Since the

2018 flood event, this reservoir has filled with sediment and has become super-aggraded with several nearby sediment bars up to 5-6 feet above the dam crest elevation (Figure 4B, post-fire conditions). The result is that the Harry Walker Dam is constantly overtopping, and the dam crest creates a waterfall with a 15-foot vertical drop. Following the fire and 2018 floods, Fremont County officials and Colorado State Dam Safety officials reviewed the dam. According to Mark Perry, the Colorado Dam Safety Engineer, the Harry Walker Dam's "concrete apron below the dam, intended to protect the foundation, is being undermined [by flowing water] and is failing" where eventually the dam's fill foundation may be completely undermined "allowing a path for water and sediment under the dam" (personal communication, June 14, 2021). Mr. Perry went on to state that "it is not considered to be a serious dam safety issue [and] we do not expect the concrete gravity dam to fail catastrophically, and the downstream hazard potential is considered to be low". Despite this low hazard, the Colorado Dam Safety has made the dam owner aware of these issues and has required foundation repairs, which is the maintenance and liability of the dam owner.

In its current condition, the dam's infrastructure would not be able to act as a catchment basin for future flood events. Further, if the apron fails, the reservoir's trapped sediment will begin to flush downstream to the Arkansas River. As discussed in Section 2.2.2., the elevated post-fire sediment loads have already degraded the Arkansas River's fishery, recreation/tourism, and impacted water quality downstream of Big Cottonwood Creek. Allowing the dam to fail will have consequences to the Arkansas River and all those who rely on this resource. The current dam owner has expressed many times that he would like to restore the reservoir to its formal capacity. Although this is a private reservoir, we believe there should be a vested interest in rehabilitation by other parties for the purposes of protection of the Arkansas River and for future habitat improvements (discussed in Section 3).

Figure 4: Harry Walker Dam A) aerial image taken in 2016 pre-fire/flood showing capacity, and B) post-fire/flood showing sedimentation and braided channels overtopping the dam crest.

2.1.3. Damaged Irrigation Networks

Post-fire flooding damaged all irrigation diversions and filled in many areas of open channel ditches. Irrigated parcels are dependent upon Big Cottonwood Creek, which has suffered throughout this post-fire period. Five ditches were initially impacted, including (listed from upstream to downstream): State Ditch No. 1, Dinkle Ditch, Baker Potter Ditch, John Baker Ditch, A L Smith Ditch, A M Smith Ditch. To date, landowners have repaired most ditches; however, State Ditch No. 1, and A M Smith Ditch still do not have fixed diversions to provide water to water rights owners. The State Ditch NO. 1 suffered realignment of the Big Cottonwood Creek to the east, which washed out the diversion and the irrigation pipe that connects the ditch. The A M Smith Ditch diversion has also been washed away, and the channel incision has caused the creek bed to be 8 feet lower (Figure 5A). The A M Smith Ditch users are currently pumping water from the creek to the ditch (Figure 5B) in an area downstream;

however, this is both expensive and failing to meet their diversion needs. A M Smith Ditch users are preparing an NRCS EQIP application for partial repair funding that would require work to raise the creek bed by 3 feet and then trench several hundred feet downstream where a pipe can carry water to the appropriate ditch grade. In addition to irrigation, the A M Smith Ditch provides the only source of augmentation water for the evaporative loss associated with the Harry Walker Dam.

Figure 5: A M Smith Ditch shown A) at diversion area with significant channel incision and B) with current pumping that is not capable of supplying enough flow for all water users' needs.

2.2. Fluvial Processes

Pre-fire, Big Cottonwood Creek was a healthy riparian system with a narrow, winding, and slow-moving creek. Landowners reminisce about the creek's beauty and abundant wildlife (16 beaver dams, brook trout, bears, etc.). Functionally, this creek's natural beaver ponds created several natural grade controls that slowed flows, trapped sediment, and tied it to the floodplain and groundwater system. Today the creek shows little evidence of ever being a small, winding creek with a connected floodplain. The post-fire flood events have carved deep incisions throughout the Big Cottonwood Creek channel. Such conditions have, and will continue to, cause several hydrologic, hydraulic, and habitat concerns discussed in the sub-sections below.

2.2.1 Hydraulic and Hydrologic Concerns

Numerous areas have deep incisions (8-12 feet shown in Figures 6A, 6C, 6D), undermined banks and trees, and significant head cuts that continue to propagate upstream (Figure 3B). These massive head cuts and deep incision causes steep and unstable banks that are dangerous to private landowners and the public. Hydraulic concerns are focused on the incised channels and increased sediment transport due to concentrated flows. These concentrated flows continue to cut the channel down, cause bank failures, and deliver enormous amounts of sediment downstream (including to the Arkansas River). While the fire burned several thousand acres above these drainages, several thousand acres of unburned forest still exist upstream. The potential for future fires and flooding is of concern to this already degraded system which would exacerbate future flood conditions and damages.

Figure 6. Post-fire flood events on the Big Cottonwood Creek have caused: A) large head cuts that continue to cause incision, and B) numerous areas of incision that range from 8-12 feet, C) large numbers of undermined trees, and D) significant bank erosion and sediment sources.

Hydraulic model simulations were used to explore the stream's changes. Simulations were performed in the same low-flow conditions with the pre-fire elevation data of 2016 and current 2021 elevation data (Figures 7 and 8). Model results show a drastic reduction in the existing topography's ability to spread flow and significantly higher shear stress values. Calculating the total inundation area pre-fire, Big Cottonwood Creek had 11.1 acres inundated with 1.95 acres ponded. Post-fire and flood show 6.3 acres inundated and 0.3 acres ponded. This equates to a ~40% reduction in low flow inundation and ~85% reduction in ponded areas.

As shown in Figures 7A and 7C, the 2016 channel geometry had several areas of floodplain connectivity and lower shear stress values compared to the 2021 conditions shown in Figures 7b and 7D. Similar results are shown in

Figures 8A-8D for a different reach. Inundation extent changes for all sections of Big Cottonwood Creek below USFS Wilderness designation are shown in Appendix A. These hydraulic conditions will continue to cause deeper incisions and bank failures, which will increase sediment generated and transported (diminishing water quality). As much of the upstream watersheds remain unburned, this area can experience another wildfire. The post-fire flood events could be more devastating in the future, given these creeks confined and concentrated flows. Further, the riparian system is not prepared to withstand future post-fire flooding.

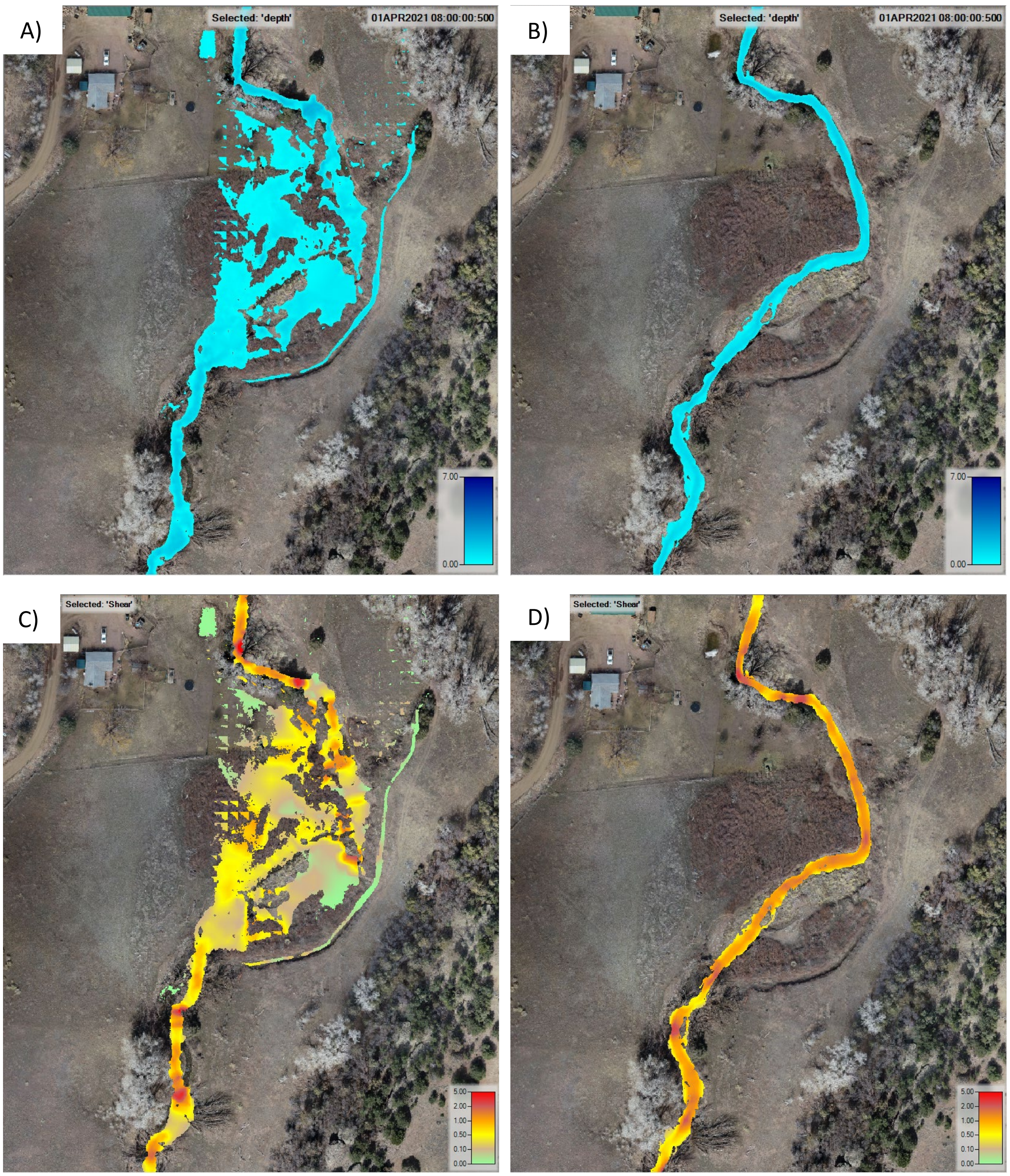


Figure 7. Hydraulic modeling results that show: A) pre-fire and flood events depth and C) shear stress, and post-fire and B) flood depth and D) shear stress.

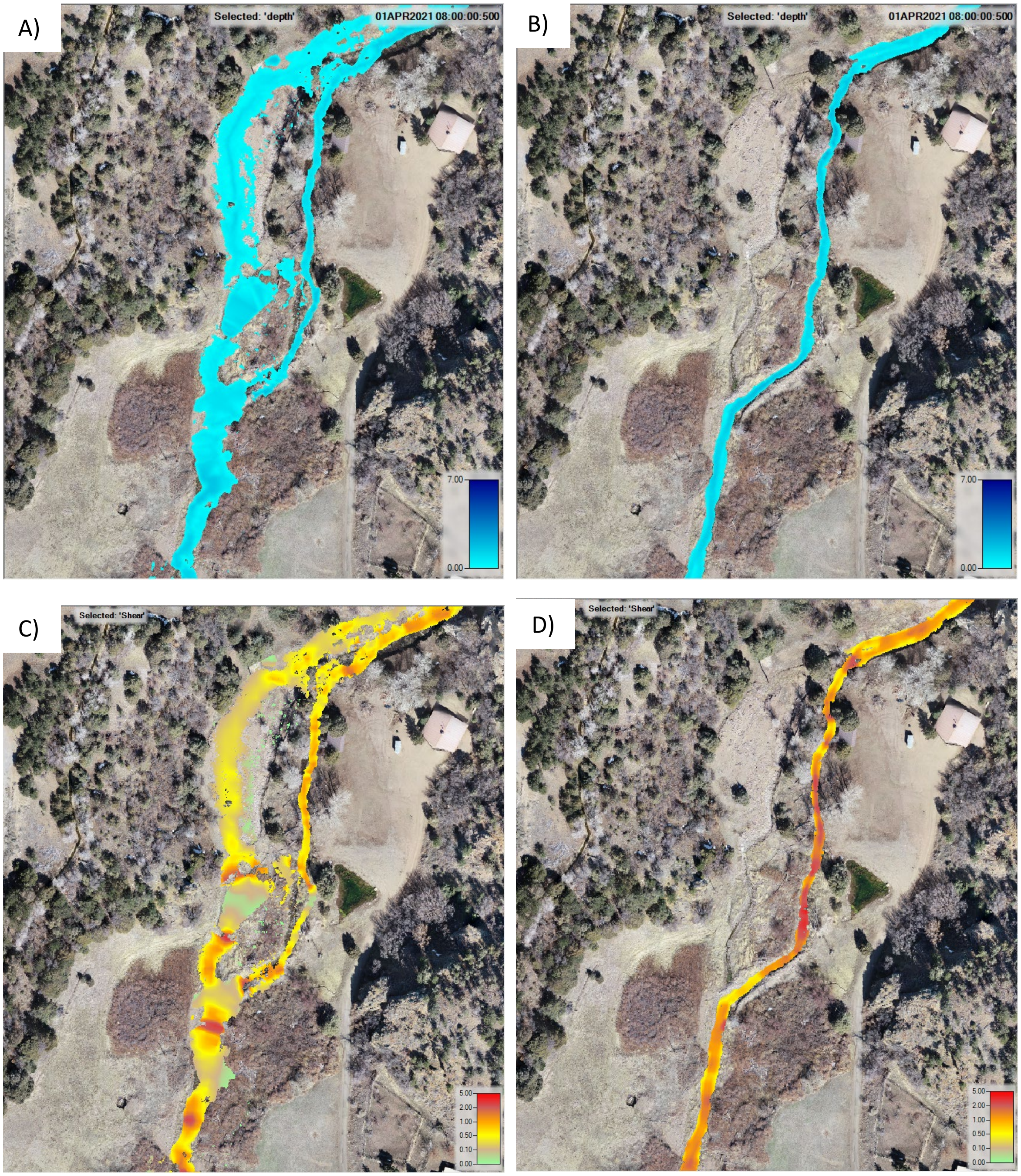


Figure 8. Hydraulic modeling results that show: A) pre-fire and flood events depth and C) shear stress, and post-fire and B) flood depth and D) shear stress.

Hydrologic concerns of this creek are centralized around the residence time of the passing water, groundwater infiltration, and groundwater storage. While incision has caused the channel bed to become several feet lower in most areas, it will naturally draw groundwater faster and lower the water table. A lowering water table will create impacts to residents on wells (many already reporting degraded water quality from their wells) as well as agriculture fields that rely on sub-irrigated lands. Further, the complete lack of channel structure or geomorphic units (i.e., pools, large boulders, and riffle-pool runs), this creek's flow is faster with less residence time to fill/replenish the aquafer and less timing available to irrigators.

2.2.2. Riparian Health and Habitat

As discussed in the section above, the hydraulic simulations of pre-and post-fire topographic conditions showed that the area of inundation was reduced from 11.1 acres to 6.3 acres, respectively. This reduction in available habit quantity is a striking difference and a metric to highlight the significant incision. However, habitat quality is another concern. The hydraulic conditions that exist create high amounts of fine sediment loads into the system (i.e., bank failures) and high amounts of sediment transport due to the concentrated flows. Recent field observations showed a total lack of pools upstream of the Harry Walker Dam to the USFS property (a 4-mile stretch) created by large amounts of sediment in the system that fills in any temporary pool. The creek is consistently alternating between riffle and run sections with very fast-moving waters along these miles.

Water quality has been documented on Big Cottonwood Creek over the last three years as part of River Watch of Colorado. Typical parameter readings (pH, dissolved oxygen, alkalinity, and hardness) show the creeks' water quality is within acceptable parameters, but with room for improvement. However, sediment loads are related to post-fire as fine sediments fill in the channel substrate voids, which degrades habitat for macroinvertebrates (the backbone to larger aquatic life and health). Field data in Big Cottonwood Creek and the Arkansas just downstream of the Big Cottonwood confluence showed significant impacts on aquatic life following the 2018 flood events. Results of macroinvertebrate kick net sampling in 2019 show that the Arkansas River upstream of the fire impacts consisted of a diverse and healthy population of macroinvertebrates with 1,153 bugs counted. The same sampling was done in the Arkansas below Big Cottonwood Creek confluence with smaller diversity and a count of 416 macroinvertebrates. Within Big Cottonwood Creek and tributaries, 2019 sampling found no macroinvertebrates. This was attributed to the lack of suitable substrate due to high loads of fine sediment and high-velocity conditions due to a complete lack of typical structure (i.e., downed trees, large boulders, pools, etc.). Today, macroinvertebrates (Mayfly and Caddisfly) have been identified in Big Cottonwood Creek, but these poor stream conditions still exist and will likely continue as the frequent bank failures generate large amounts of fine sediment that blanket the bottom substrate and fill in any temporary pools.

Further, as there is no area for sediment to deposit, this sediment continues down to the Arkansas, impacting the fishery. This area used to be Gold Medal Trout Waters that stretched 24 miles downstream of Big Cottonwood Creek to Parkdale, CO. However, this area, and the recreational economies that depend on the fishery, have been significantly impacted.

3. Current Needs, Opportunities, & Recommendations

The sections below focus on the infrastructure needs, riparian needs, opportunities and recommendations.

3.1. Infrastructure Needs & Recommendations

The three main infrastructure issues of Big Cottonwood Creek are the erosion threats to CR-40, Harry Walker Dam, and irrigation for State Ditch No.1 and A M Smith Ditch.

The issues of CR-40 should be reviewed by the Fremont County officials and to consider possible options for protecting CR-40. Removal of the boulders or bank protection along CR-40 should be reviewed to ensure the bank's toe is not eroded during future flood events.

Harry walker Dam's overtopping was initially reviewed and determined to be no concern, but the dam's apron is being undermined, which will eventually lead to failure whereby sediment will flush out of the dam. While it is the responsibility of the current dam owner, this dam should be reviewed by Fremont County officials on a regular basis to ensure that the concrete outlet and CR-39 bridge abutments are withstanding the waterfall's erosive power and to monitor the apron's integrity. Allowing the dam's apron to fail will release large amounts of fine sediment into the Arkansas River. Such large amounts, and the extended time to flush the sediment trapped behind the dam will greatly degrade the fishery for several years, potentially create hazard. While dredging the reservoir would be expensive (historic estimates done by the local NRCS were well above $500,000), this reservoir could provide improvements for sediment storage for improved water quality to the Arkansas as well as valuable future aquatic and terrestrial habitat.

Restoring the A M Smith Ditch will require piping the flow into a downstream section of the ditch where the elevation would then flow to the downstream users. However, for this system to work, the creek bed elevation would need to rise vertically 3 feet. This would require either a large diversion structure to raise the water surface elevation or raising the riverbed elevation and a minor diversion. Once diverted, the ditch will be piped several hundred feet to meet the appropriate elevation and grade to continue to flow water in the existing ditch. Estimates are not finalized for this work but are expected to cost several thousands of dollars.

3.2. Riparian Needs & Opportunities

The post-fire flood events have caused Big Cottonwood Creek to become deeply incised. Resulting in:

- A disconnected floodplain and unable to spread and slow down flood waters (poor conditions for future post-fire landscape)
- frequent bank failures and large amounts of fine sediment
- a reduced low-flow inundation extent (initially 11.1 acres and now 6.3 acres)
- a total lack of structure and geomorphic diversity (i.e., pools, slow moving water, ponded areas)
- higher velocity and poor aquatic habitat
- large areas of deep incision that are likely lowering the water table
- steeper grades and faster flows reducing water residence time and infiltration
- reduction in habitat for aquatic and terrestrial wildlife
- dangerous bank conditions for private and public access
- inability for A M Smith Ditch diversion

Following the Stream Evolution Model shown in Figure 9, Big Cottonwood Creek may likely widen and aggrade overtime to one day become a well-connected floodplain. However, this evolution from the current stage (2 or 3) to pre-fire conditions (ranging from stage 7, 8, 0, and 1) may take hundreds, possibly thousands of years. During this time, Big Cottonwood Creek would continue to suffer from the impairments listed above. However, targeted restoration aimed at accelerating this stream evolution could be done with cost-effective process-based restoration (PBR) methods as outlined by Wheaton et al. (2019).

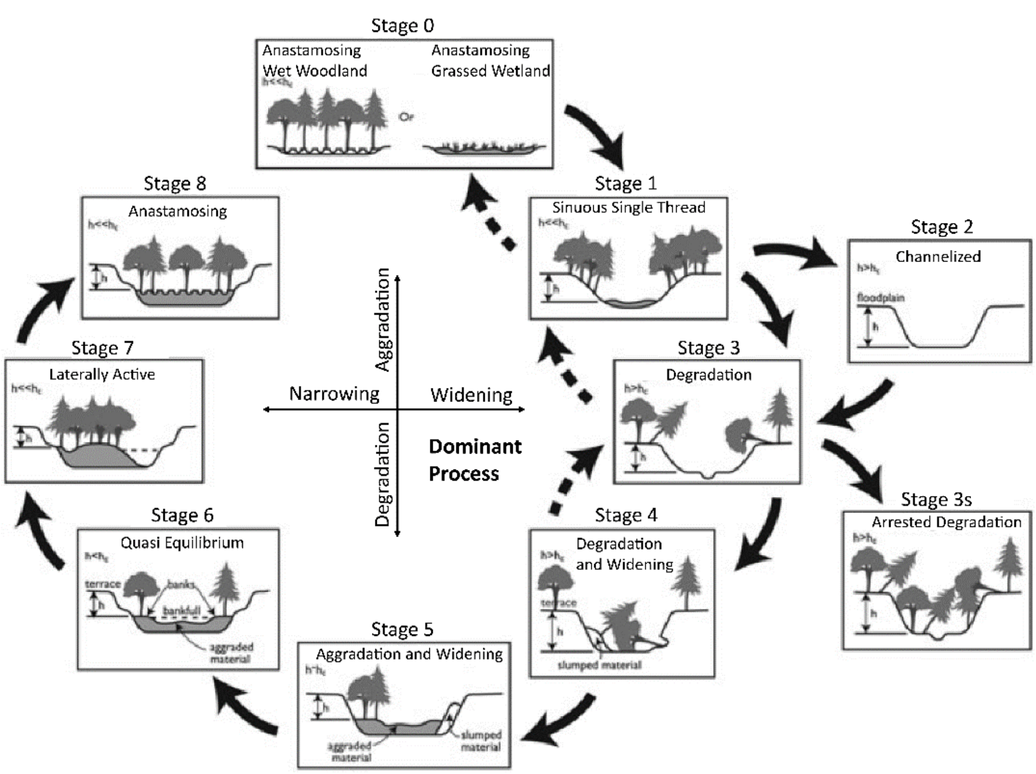


Figure 9. Stream evolution model (SEM) proposed by Cluer and Thorne (2014) illustrating approximate stages and pathways associated with recovery to Stage 0. Restoration in Big Cottonwood Creek could accelerate recovery trajectories.

According to Joe Wheaton and Stephen Bennet, PBR uses simple, cost-effective, hand-built structures that mimic beaver dams (beaver dam analogs) and large wood accumulations (i.e., post-assisted log structures). When strategically introduced to a stream, these structural elements can amplify natural hydrologic, geomorphic, and biological processes that accelerate the recovery of incised creeks and address limiting factors. Specifically, these treatments can widen the incised channel and use that generated material to lift, or aggrade, the channel bed. With many of the creeks' hydraulic, hydrologic, and habitat issues stemming from the deep incision, PBR offers a way to accelerate this channel bed aggradation and a chance to improve the conditions in a few years as opposed to hundreds of years.

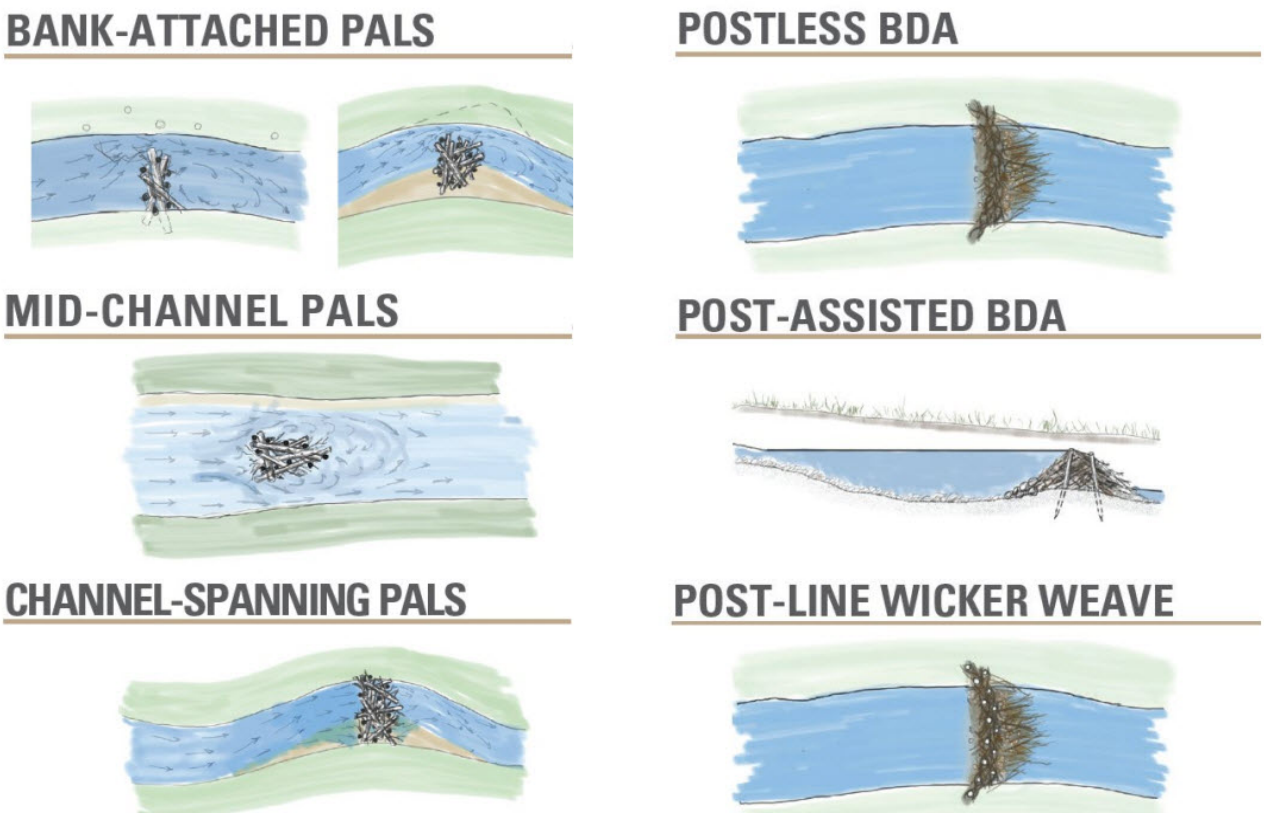
A significant component in post-fire impacted drainages is the social aspect of when the residents who have experienced flooding are willing to transition away from flood mitigation and into creek restoration. In talking with several landowners and seeing new land modifications (i.e. field preparation, restoration of old ponds, and some introduction of rocks to make pools), many landowners have transitioned into a restoration desire. Many current concerns are about continued bank erosion, water rights, property values, the missed beauty of the riparian area, missing ponds, local wildlife, and habitat. While the risk of severe flooding is less likely with every passing year following a fire event, these elevated flows that persist actually benefit PBR. The larger than typical flow rates and high sediment transport help make PBR work faster through the processes they enable.

Aside from local interests to restore this area, several partners (including River Science) are interested in Big Cottonwood Creek becoming a secondary creek for the threatened Greenback Cutthroat Trout, Hayden Creek lineage. These fish are rare, and CPW only puts them in streams with a physical barrier to prevent crossbreeding with other trout. Big Cottonwood is a timely opportunity since the Harry Walker Dam is a fish barrier with minimal (if any) current fish population and is close to the species native area. Restoration of this creek could be a valuable habitat to this fish that many other creeks do not offer or would require significant capital and improvements to make viable.

Lastly, fire and the State of Colorado’s water are inseparable. As fire becomes more prevalent and drought persists, our State must examine how many post-fire impacted rivers and streams negatively influence our State’s hydraulics, hydrology, water quantity, and water quality. As outlined above, there are several issues of degradation caused by post-fire flooding that have left the creek’s processes and habitat lacking. Providing little to no recovery immediately post-fire and flood leaves many streams and rivers degraded for a significant amount of time. In an age where we must better manage our water and watersheds, we must consider restoring post-fire flood conditions and help return creeks to their proper health and hydrological function.

3.3. Restoration Elements (Process-Based Restoration Techniques)

PBR focuses on using the creek's flow and stream power to help perform the restoration labor. Through carefully planned treatments, hand-built structures in series can be used to restore the lacking geomorphic processes. For example, using local and natural materials, a channel spanning treatment (Figure 11 and Figure 12C, D, F, H) can be used as a grade control structure. The structure would trap sediment, raise the channel bed elevation, slow the flow's velocity, and reduce fine sediment. Other treatments can force flow into banks (Figure 11 and Figure 12 A, B, E, and G) that accelerate bank erosion and migration that can supply downstream the channel spanning grade control structures with new sediment sources, which helps widen and aggrade the channel. Such treatments provide much-needed structure to the creek by providing pools, shelter, slower water for the struggling macroinvertebrate life, and potentially future habitat and quality conditions necessary for the Greenback Cutthroat Trout. These treatments that aim to widen and aggrade the channel will also help to reduce the issues listed above in section 3.2. (Riparian Needs and Opportunities section).



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DOI: [10.13140/RG.2.2.28222.13123/1](https://doi.org/10.13140/RG.2.2.28222.13123/1)

Figure 11: Depiction of the basic PBR treatments of PALS (Post Assisted Log Structures) and BDAs (Beaver Dam Analogs).

Figure 12: Images of PBR treatments that show Channel-Spanning BDAs and PALS, bank-attached PALS, and mid-channel PALS.

3.4. Restoration Timing & Water Rights Considerations

In situations such as Big Cottonwood Creek, post-fire flooding has dramatically changed the landscape, hydrology, and riparian habitat. Although in recent years, a focus on post-fire flooding has emerged to address the protection of life, property, and landscapes within the 1–5-year post-fire period, there remains a lack of consideration for long-term, full recovery of these degraded systems. As we see in the Big Cottonwood drainage, significant issues persist many years after the fire. Post-fire recovery takes a substantial amount of time during which landowners, waterways, and habitats suffer considerably. We believe that the introduction of PBR will help speed up the recovery process and assist these vulnerable watersheds in reaching a level of normalcy.

Although there remain many unanswered questions concerning PBR implementation timing post-fire and water rights, we believe there is a unique opportunity to consider PBR treatments in the medium-term post-fire recovery period (5+ year post-fire). We typically do not recommend PBR treatments directly after a fire (depends on the fire and landscape) as these hand-built structures may not have the stability to withstand post-fire flood forces (1-5 years post-fire). The landscape needs time to start its initial recovery processes, such as revegetation of the burn scar. After an appropriate time has passed and the landscape has begun to heal, we feel that PBR can be highly beneficial in accelerating recovery processes.

Due to the unique nature of an altered landscape post-fire, opportunities exist to implement PBR treatments that will not interfere with traditional water rights. Our current understanding is that recovery measures intended to bring a water system back to its original (pre-fire) state would not interfere with water rights. These treatments could significantly benefit water rights holders who have been negatively impacted by post-fire flood damages (i.e., incisions, destruction of diversions, bank failures). If the PBR treatments are implemented within the footprint of pre-existing conditions, there should exist no impacts associated with water rights administration. If it is determined that treatments should expand outside the pre-existing conditions, water rights must be considered. In this case, a detailed water rights study should be conducted to examine any potential impacts on water rights and offer mitigation options and solutions to these impacts.

3.5. Resources and Partners

During the fire and floods, this region and creek have received a lot of attention from local stakeholders such as the Arkansas Basin Roundtable, local businesses, US Forest Service officials, NRCS officials, Colorado Parks and Wildlife officials, Arkansas River Headwater Association, and Colorado Trout Unlimited. Many of these groups have a shared interest in seeing the restoration of this creek for various reasons. As we consider funding resources, several grants and funds exist for habitat enhancement of aquatic habitat (CPW), beaver enhancement, and rare or declining habitats (USDA NRCS), watershed restoration (CWCB).

3.6. Restoration Recommendation for Full Recovery

Restoration of Big Cottonwood Creek could extend from Harry Walker Reservoir up through private property and the public lands of BLM, State Landboard, and USFS before entering USFS Wilderness areas. This project area is shown in Appendix Figure B1. Figure B2 provides a reference map of the individual reaches as well as a project objective map that shows the treatment goals for a particular section of river (i.e. incision recovery, lateral connectivity, no treatment). Figure B3 provides a parcel map of the various private and public land. Within each of the ten reaches, River Science has prepared potential restoration treatments that would target a specific reach's degradation. These treatments are shown in Figures B4-13. These treatments were placed/designed using available elevation datasets to strategically increase the current post-fire inundation from the 6.3 acres back to the pre-fire conditions of approximately 11 acres. Figures B4-B13 show the estimated valley bottom (i.e. the active and inactive floodplain), the envisioned treatments, and the treatment's hydraulic and geomorphic Zone of Influence (ZOI). The ZOI is not a representation of post-treatment low-flow inundation and not meant to be compared to the Figures of Appendix A. Rather, the ZOI is a generic representation of possible channel migration and how treatments will deflect water during small frequent floods. As shown in Figures B4-13, bank attached and channel spanning PALS and/or BDAs are alternated in relatively close proximity. This approach is designed to quickly cause channel migration to generate materials that will be quickly trapped downstream by channel spanning PALS and/or BDAs to cause frequent channel widening and trapped sediment for channel aggradation.

These treatments would require several iterations and several years to reach their full potential. However, the tradeoff in time is the benefit of low-cost restoration.

4. Conclusion

This report highlights Big Cottonwood Creek's continued struggles 5-years post-fire. These include infrastructure concerns (CR-40, Harry Walker Dam, and A M Smith Ditch) and significant hydrologic, hydraulic, and habitat concerns that start in this creek, but extend into the Arkansas River and the economies that it supports. Specifically, the deep and pervasive channel incision (8-12 feet deep) causes significant concerns to human safety, degradation to our water quality and quantity, and a total lack of habitat. As outlined in this report, the restoration of this creek is important to landowners and several other stakeholders (e.g., CO Parks and Wildlife, Trout Unlimited, etc.). The identified restoration would aim to widen and aggrade the creek's channel, thereby reducing incision. In addition, restoration and habitat planning could provide a viable habitat for the nationally threatened Greenback Cutthroat Trout. The Harry Walker Dam provides the necessary fish barrier to protect this species from crossbreeding while providing a habitat near this species native habitat. However, the Harry Walker Dam currently needs some maintenance and repairs.

Finally, this report illustrates Big Cottonwood Creek as an example of post-fire and flooding conditions. In recent years, Colorado fires have added several hundred (or more) miles of creeks every year that will experience flooding like Big Cottonwood Creek. With Colorado's finite water and the continued stresses on these resources, we must consider the hydrological degradation of our water sources and look to opportunities to restore such systems for our water, economy, recreation, and habitat. Given the identified needs, the support of landowners and partners, and the opportunity to add a valuable habitat for the Greenback Cutthroat trout, the restoration of Big Cottonwood Creek is a viable project and could be used as a demonstration project for post-fire full recovery.

5. References

Cluer, B., & Thorne, C. (2014). A stream evolution model integrating habitat and ecosystem benefits. River research and applications, 30(2), 135-154.

Wheaton, J.M., S.N. Bennett, N. Bouwes, J.D. Maestas and S.M. Shahverdian (Editors) 2019, Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Utah State University Restoration Consortium, Logan, Utah. 286 pp. DOI: 10.13140/RG.2.2.19590.63049/1

Appendix A: Low flow hydraulic conditions of pre-fire and post-fire.

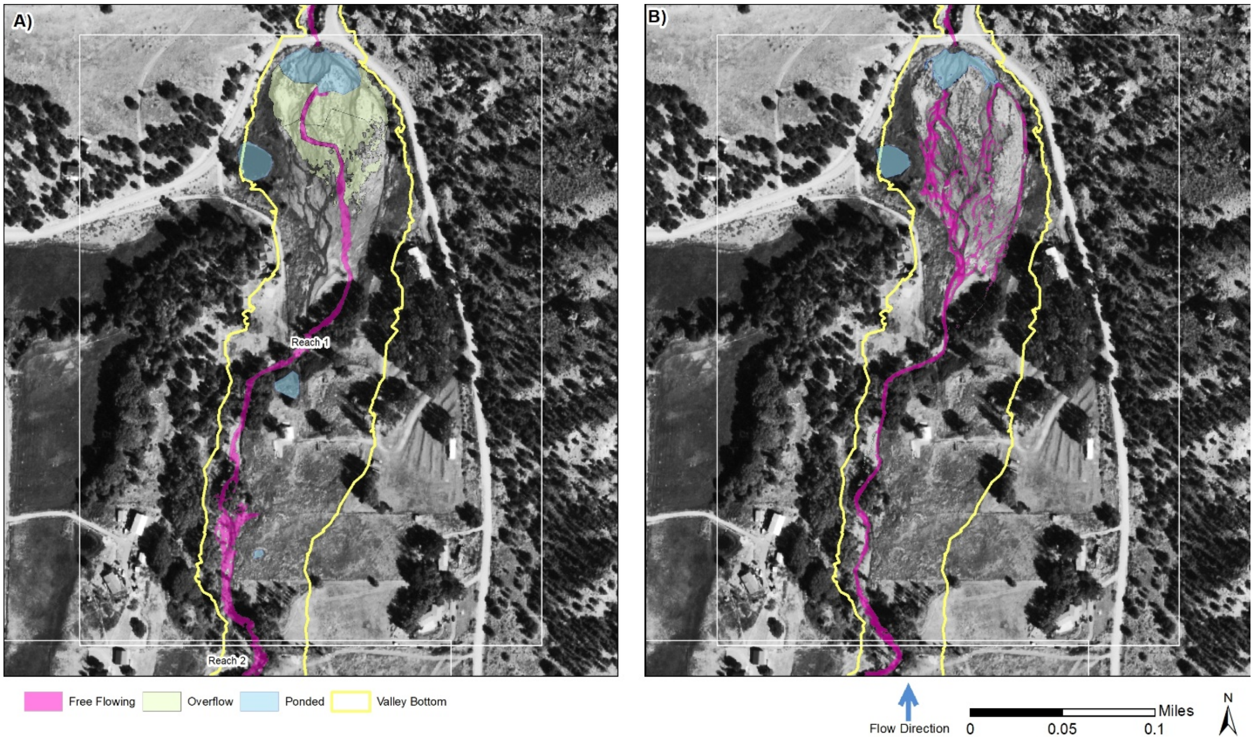

Figure A1: Reach 1 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

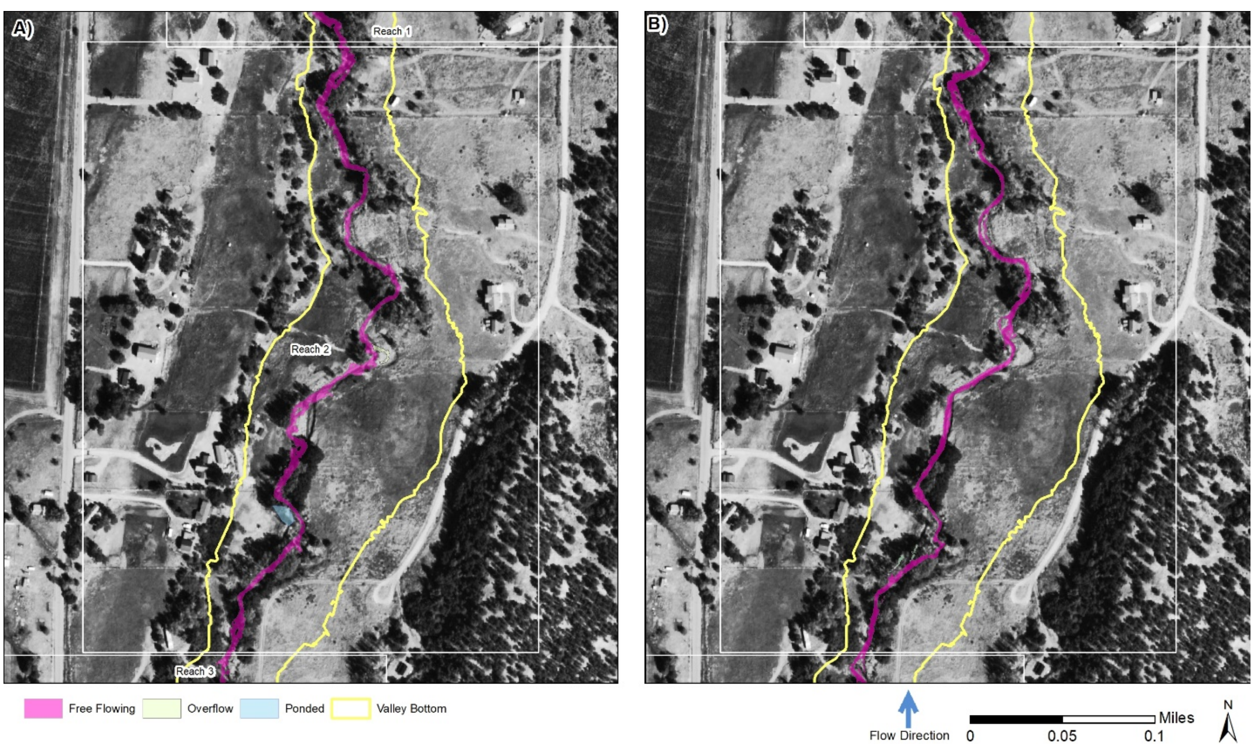

Figure A2: Reach 2 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

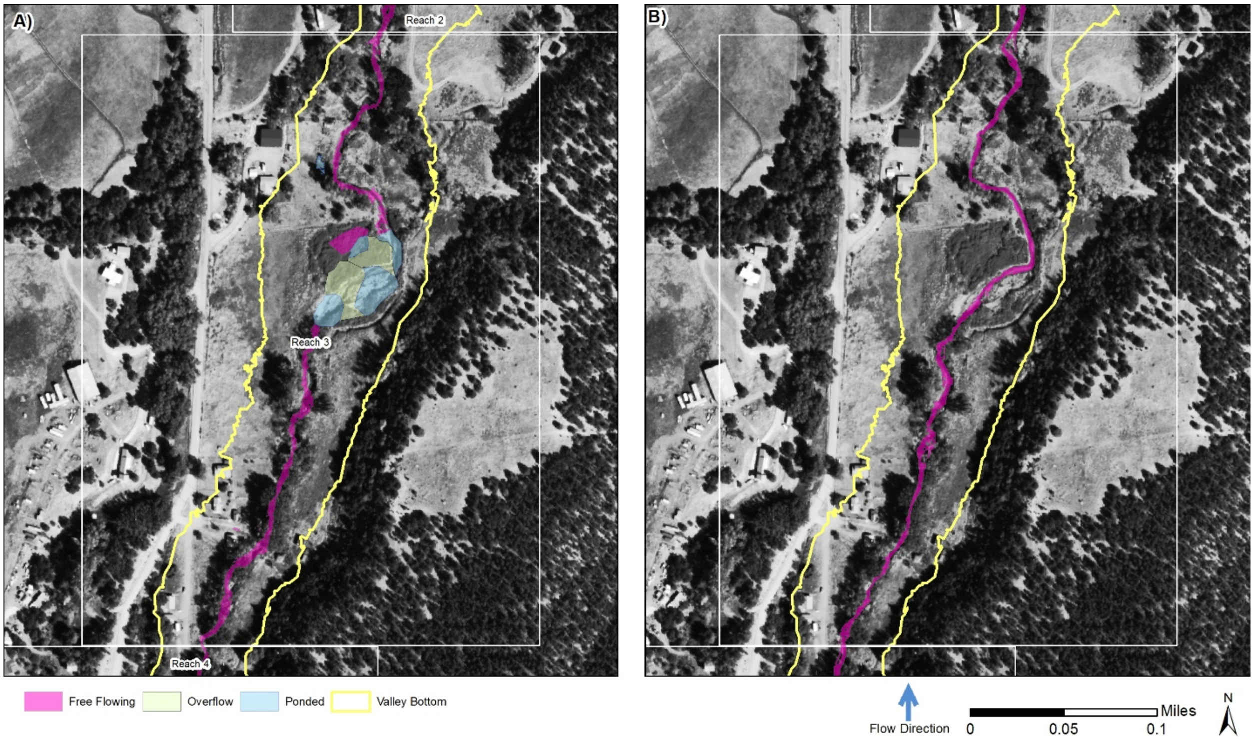

Figure A3: Reach 3 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

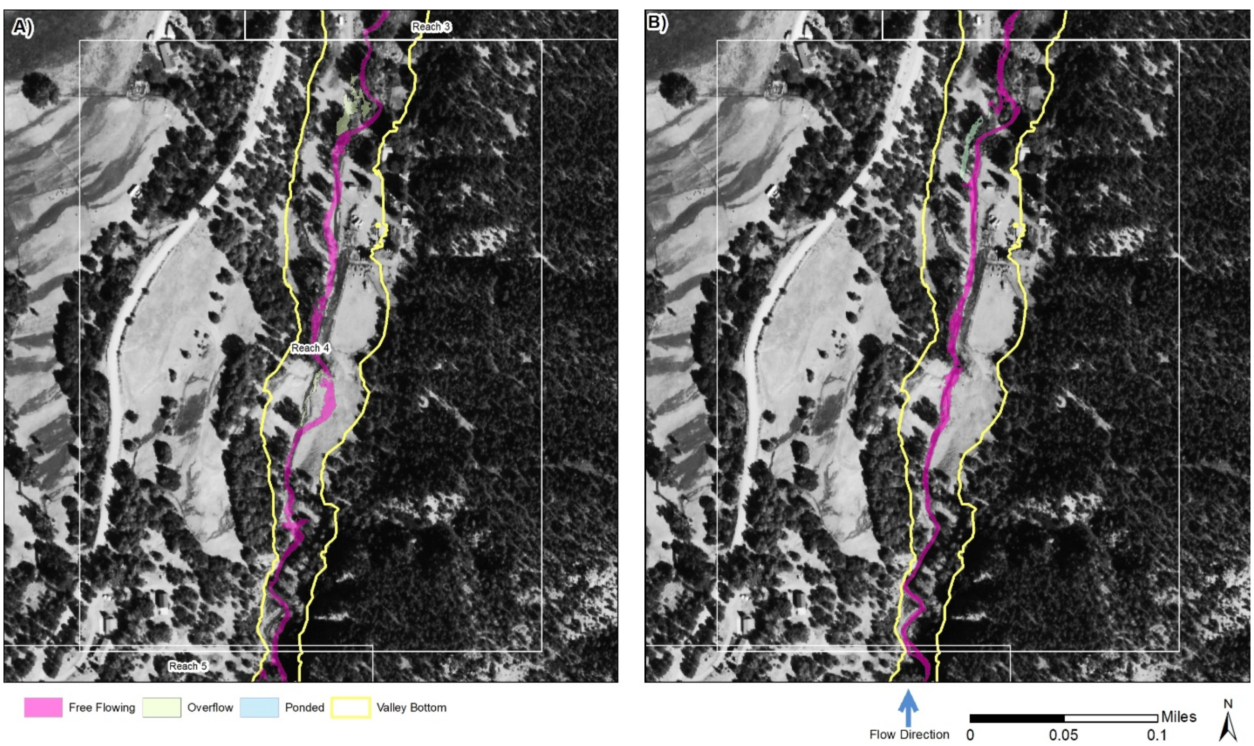

Figure A4: Reach 4 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

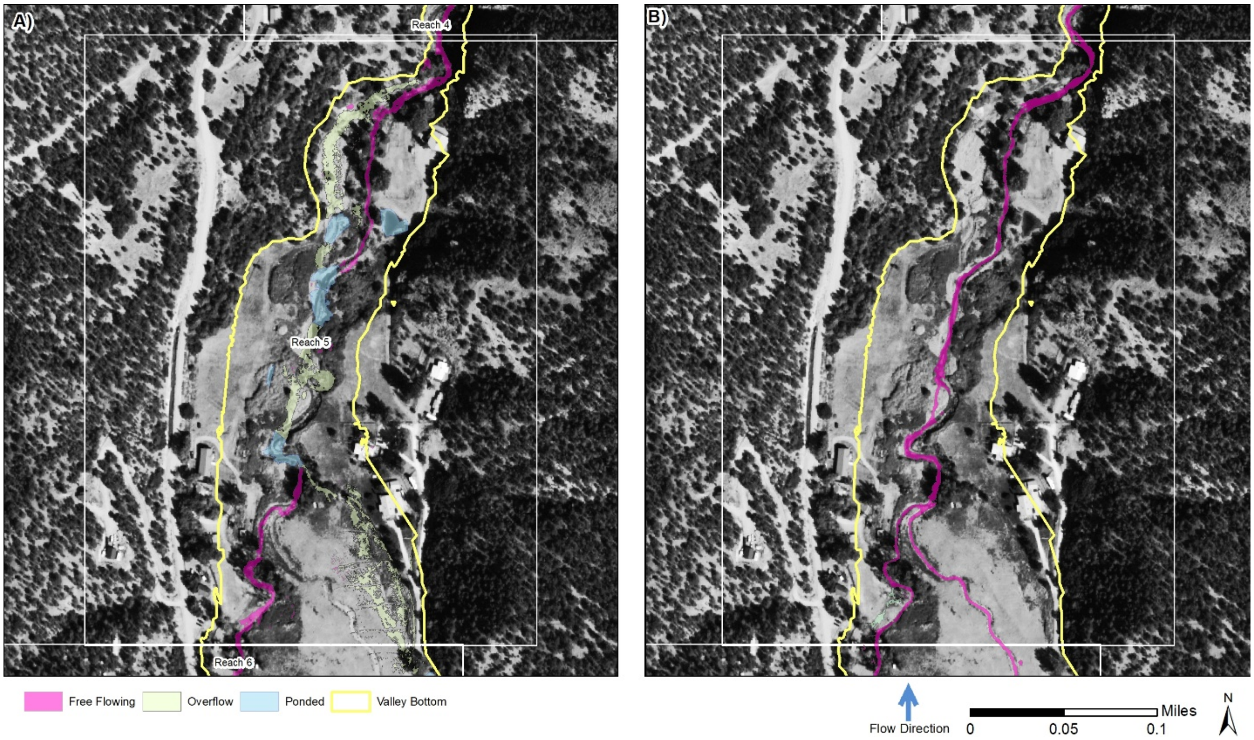

Figure A5: Reach 5 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

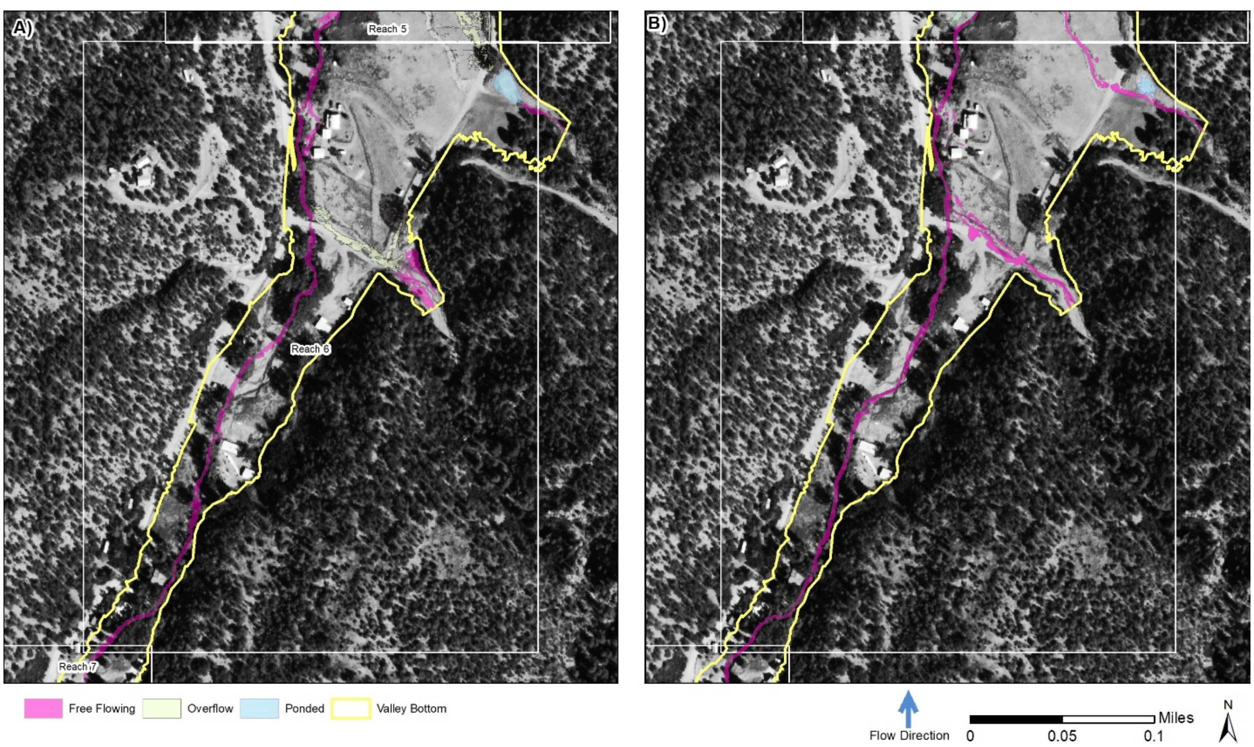

Figure A6: Reach 6 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

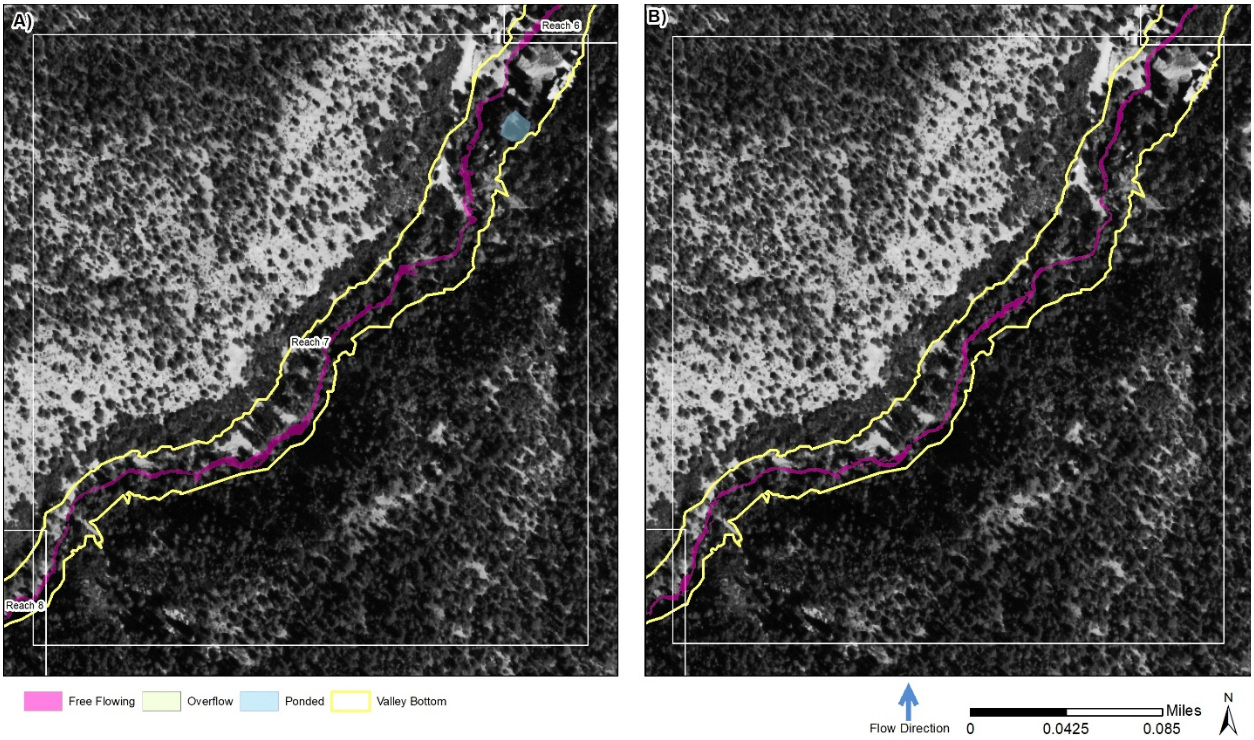

Figure A7: Reach 7 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

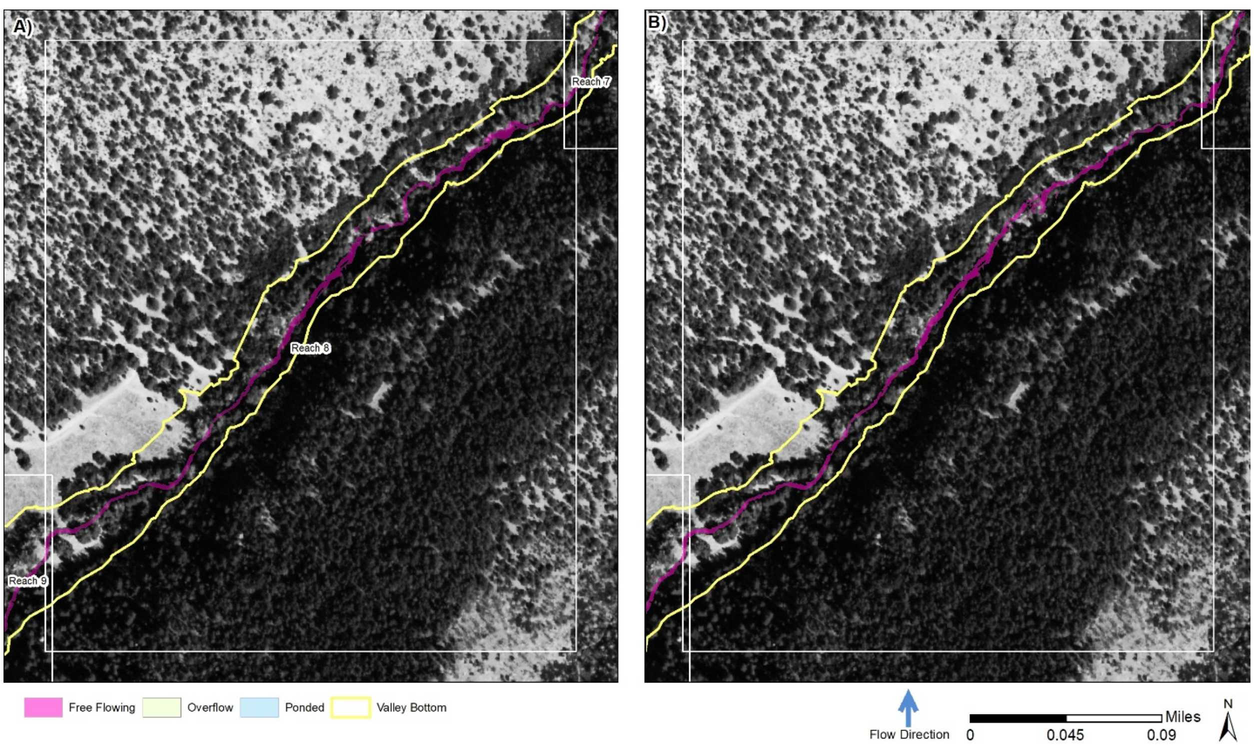

Figure A8: Reach 8 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

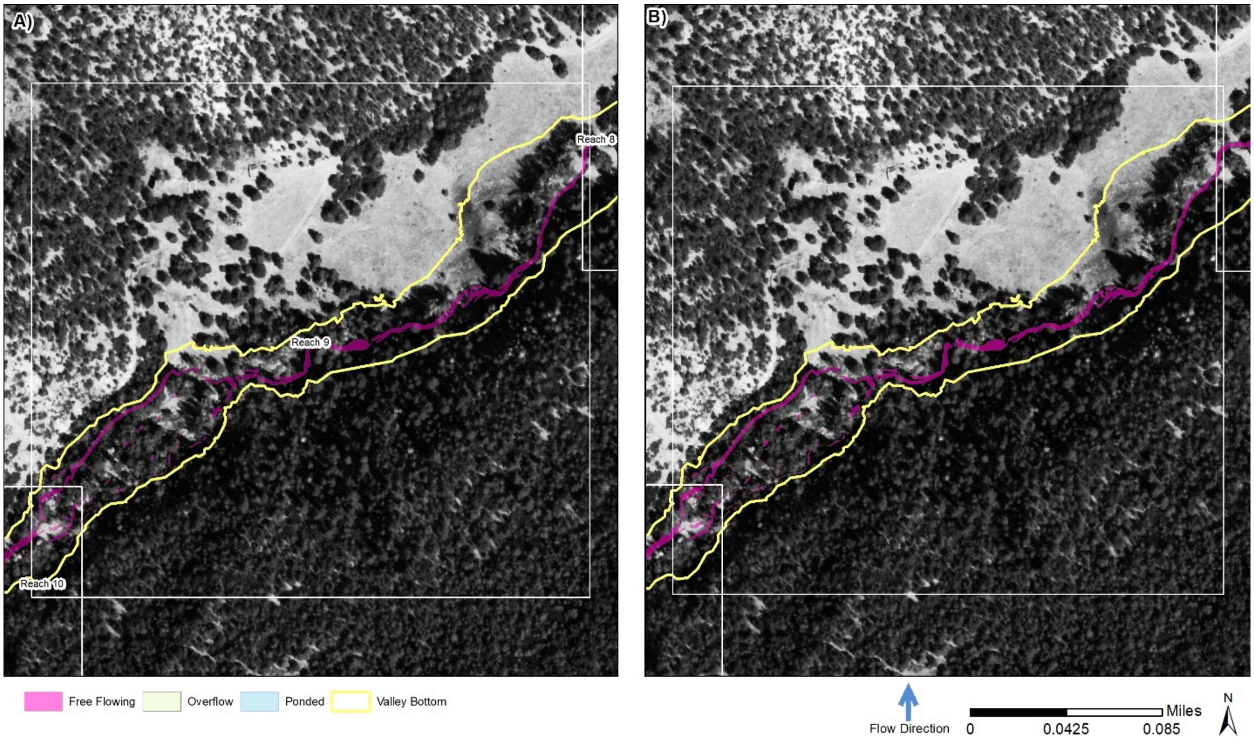

Figure A9: Reach 9 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

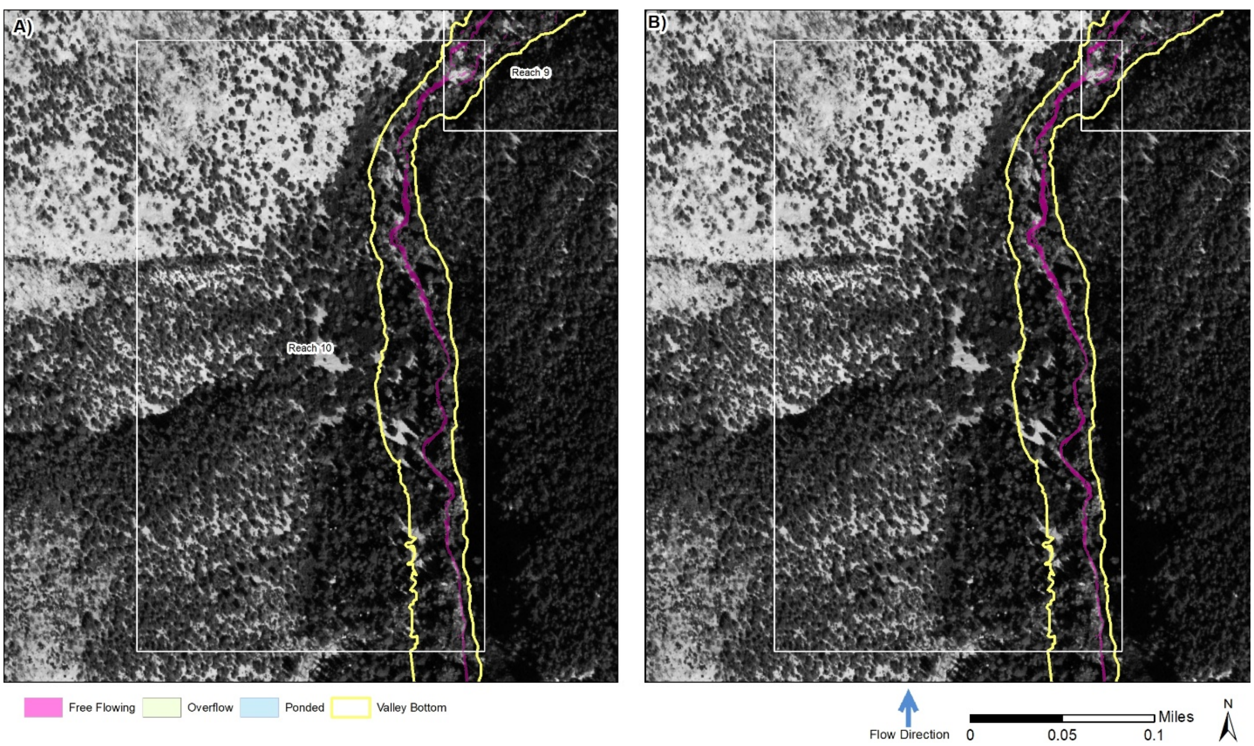

Figure A10: Reach 10 showing A) pre-fire conditions, B) post-fire conditions, and C) the valley bottom and potential restoration treatments and zone of influence of such treatments.

Appendix B: Potential Complex Design

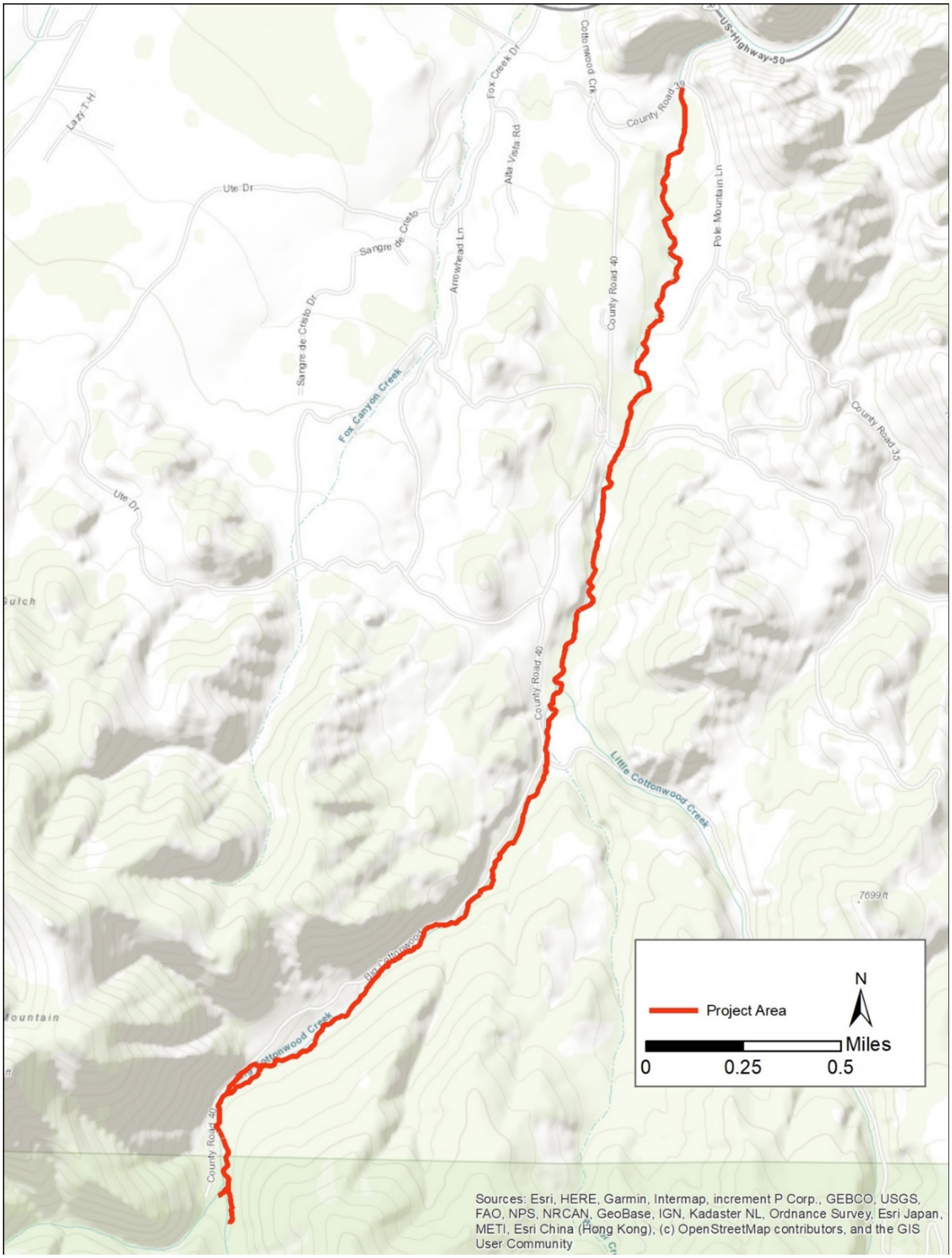

Figure B1: Project area of Big Cottonwood Creek Shown in red with the topographic map.

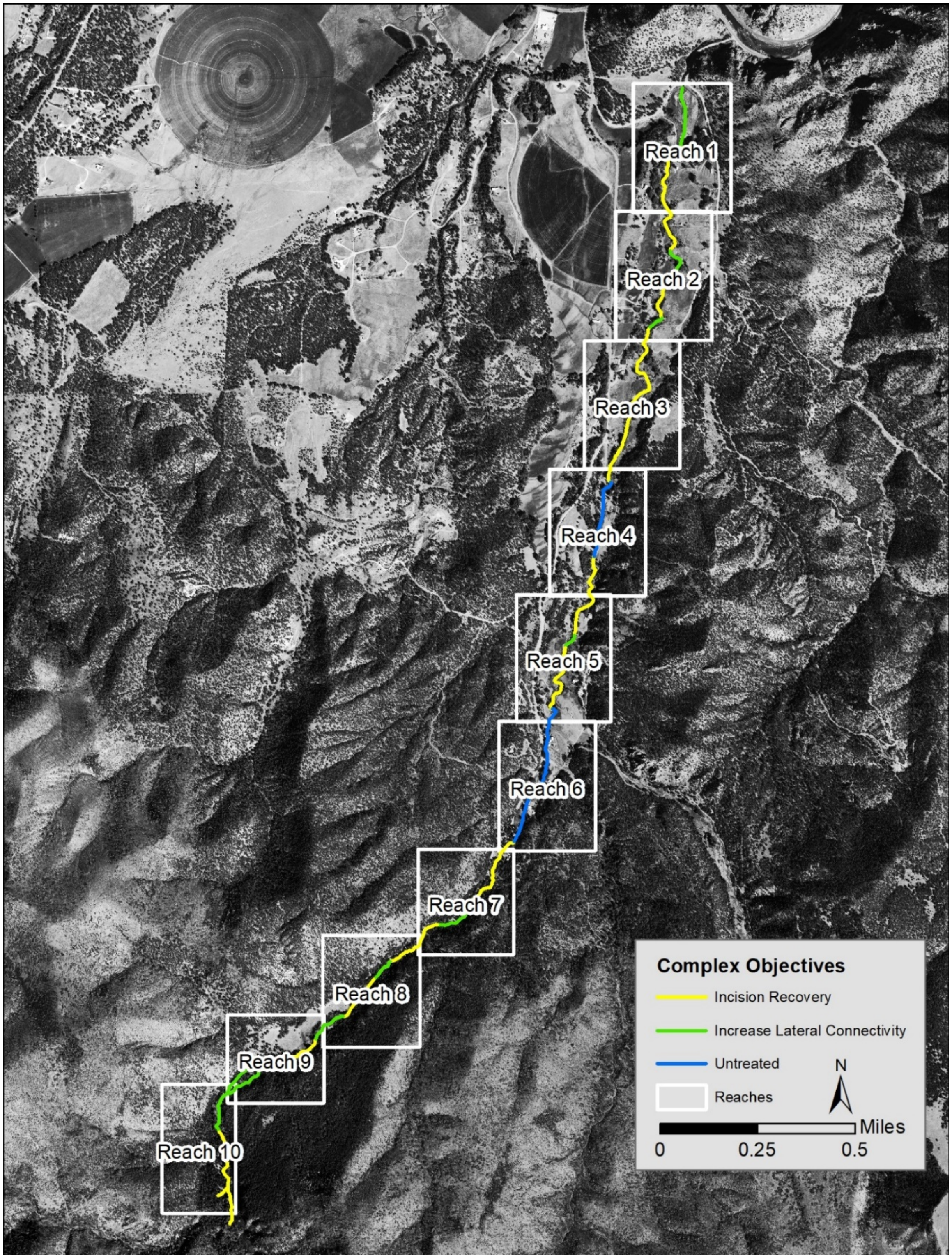

Figure B2: Reference map of individual reaches with restoration complex objectives shown.

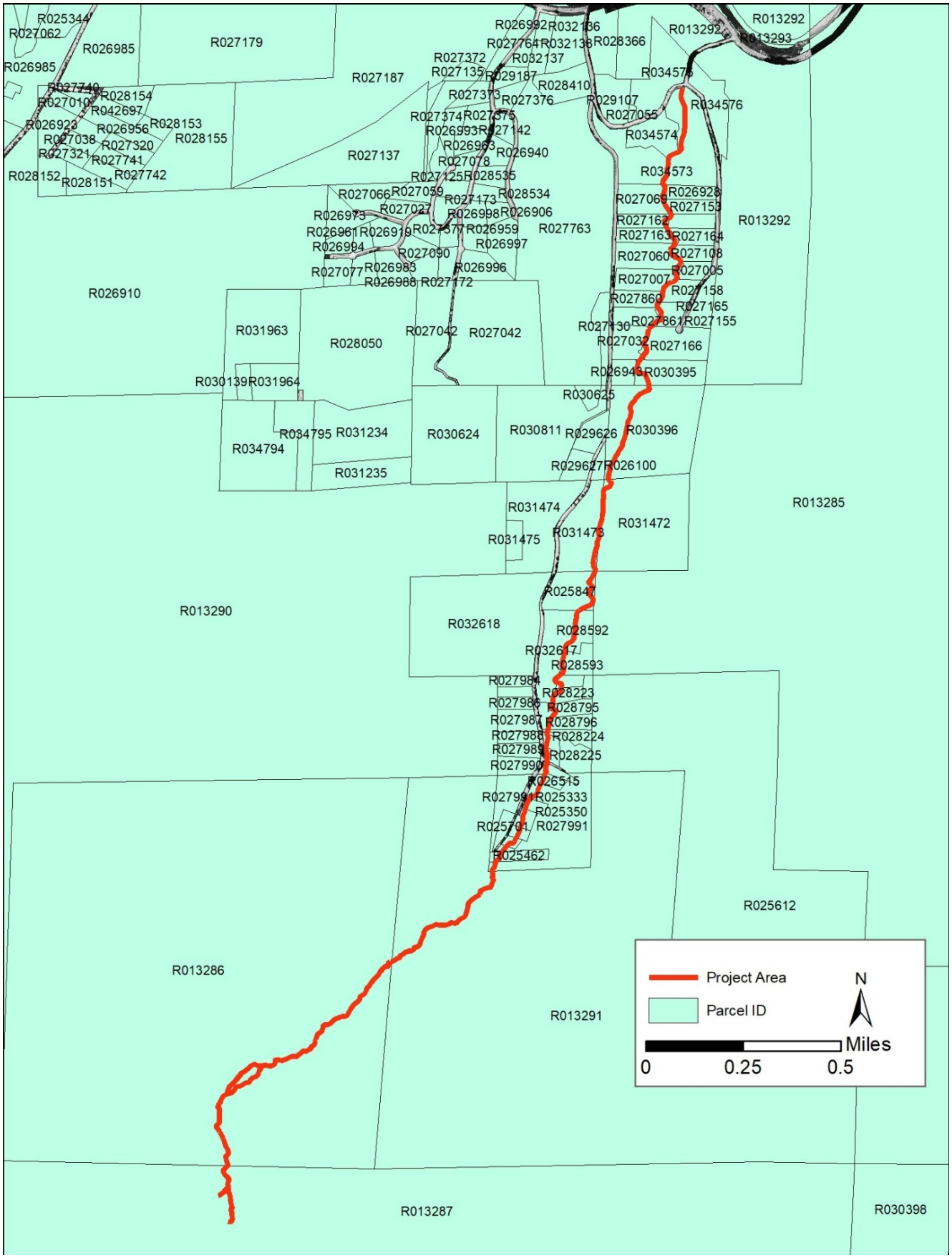

Figure B3: Parcel map overlaid on the project area to distinguish private property and public lands.

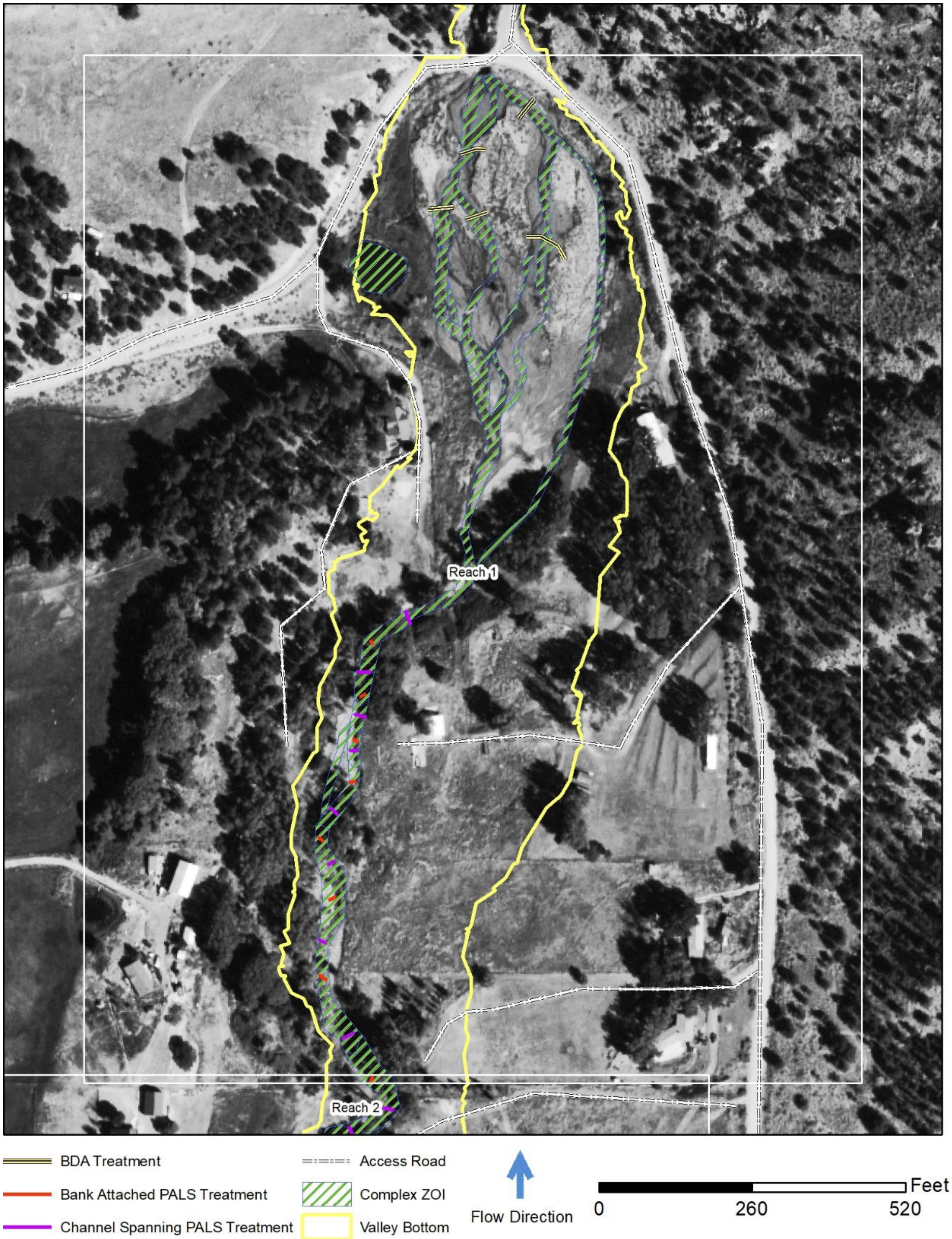

Figure B4: Reach 1 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

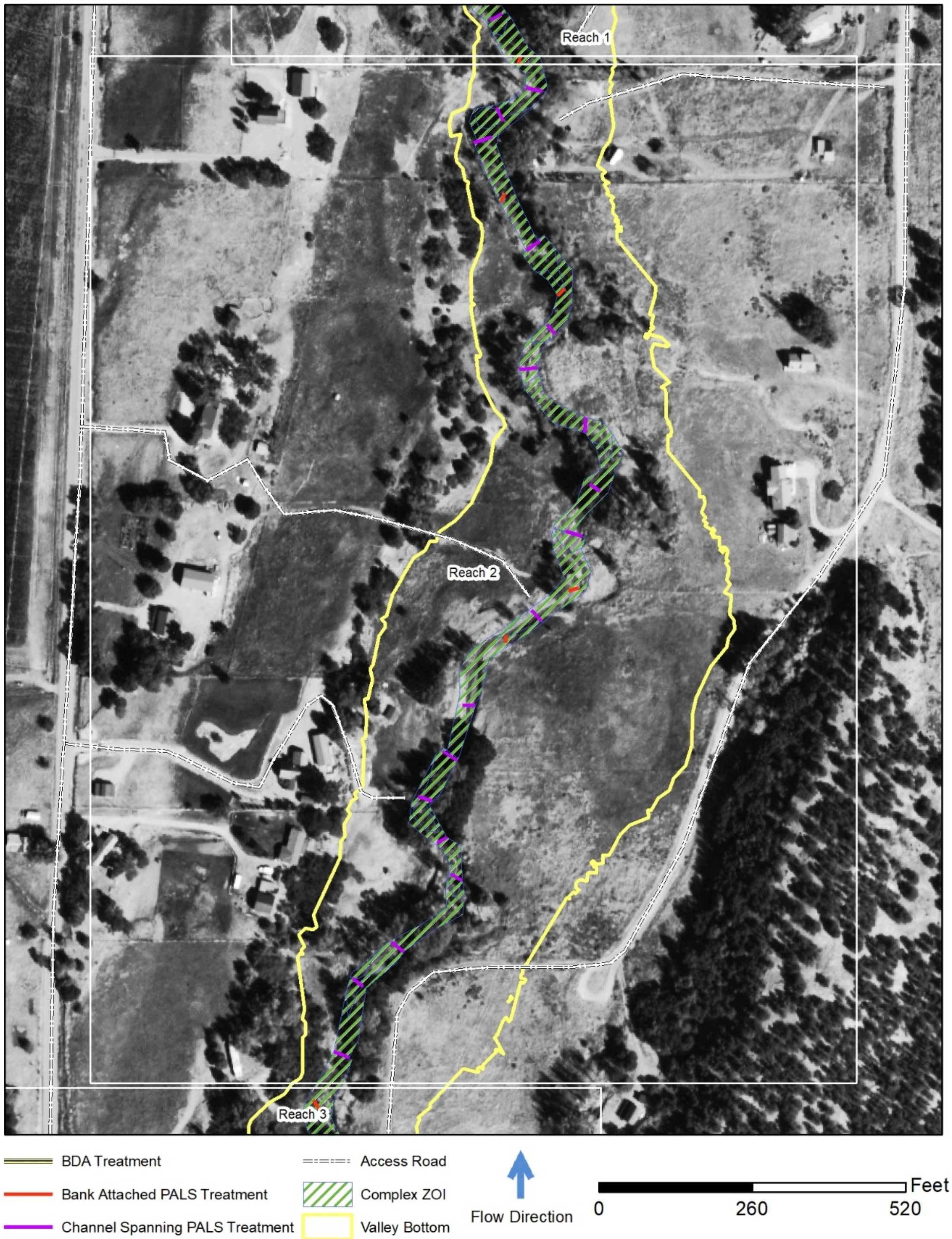

Figure B5: Reach 2 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

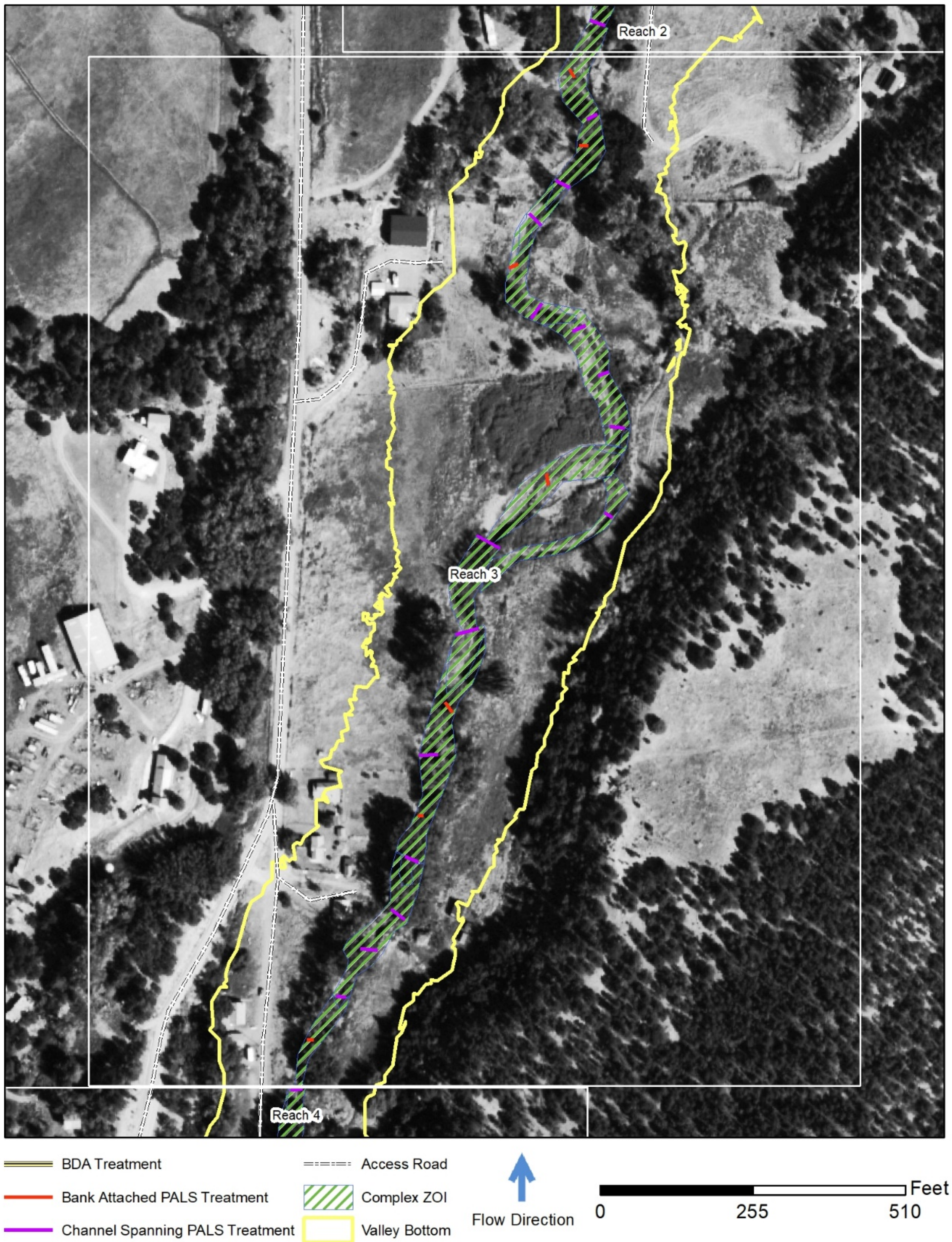

Figure B6: Reach 3 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

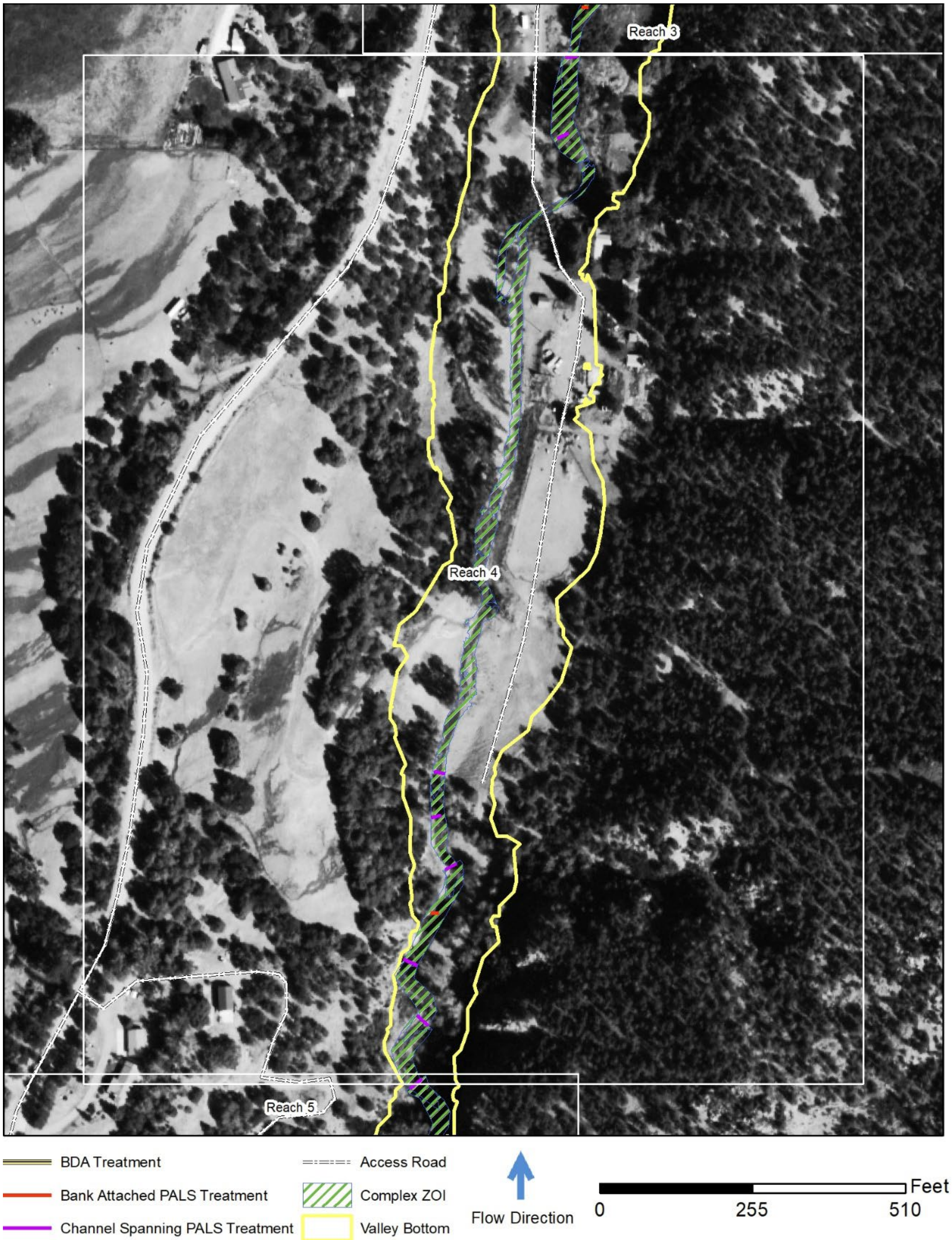

Figure B7: Reach 4 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

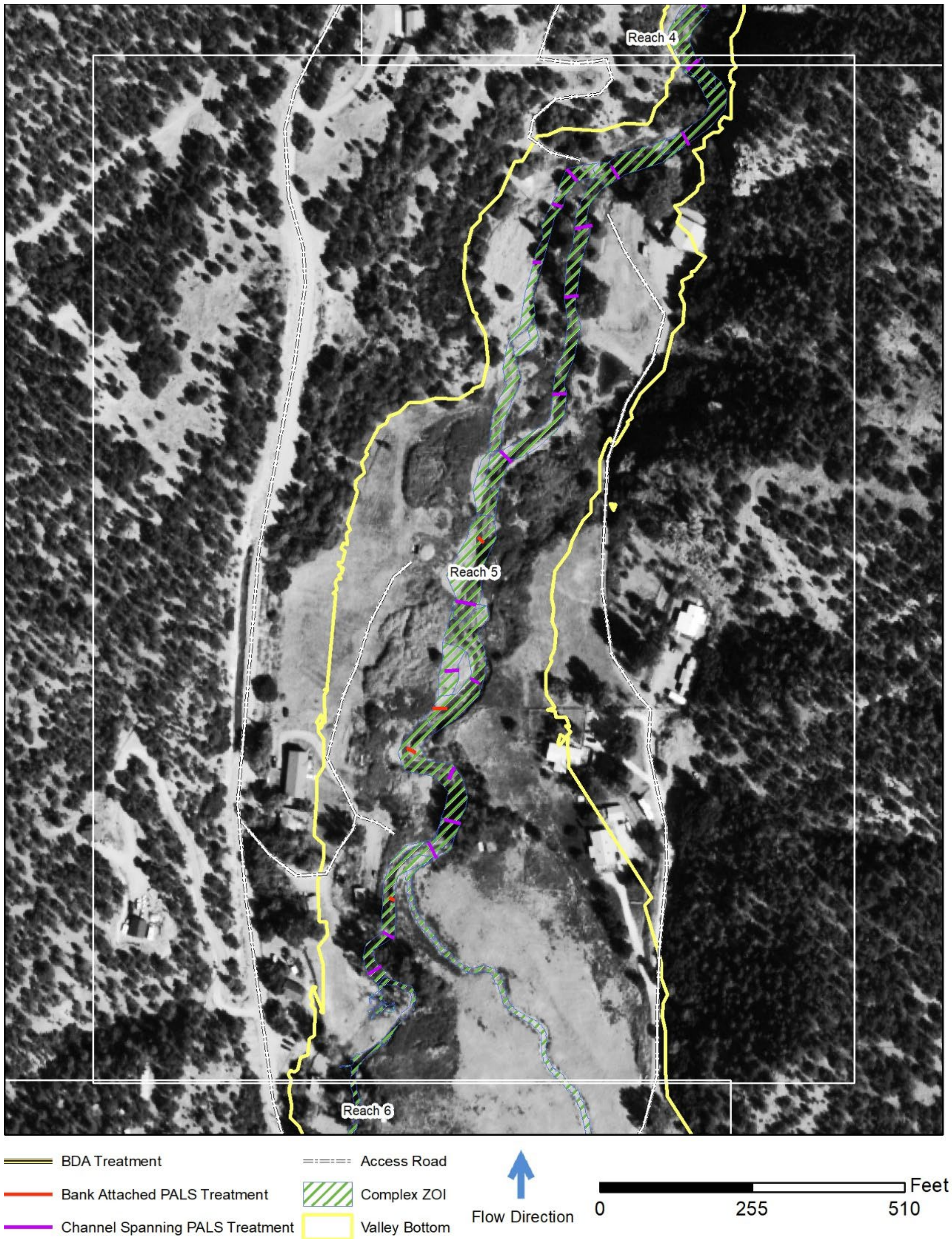

Figure B8: Reach 5 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

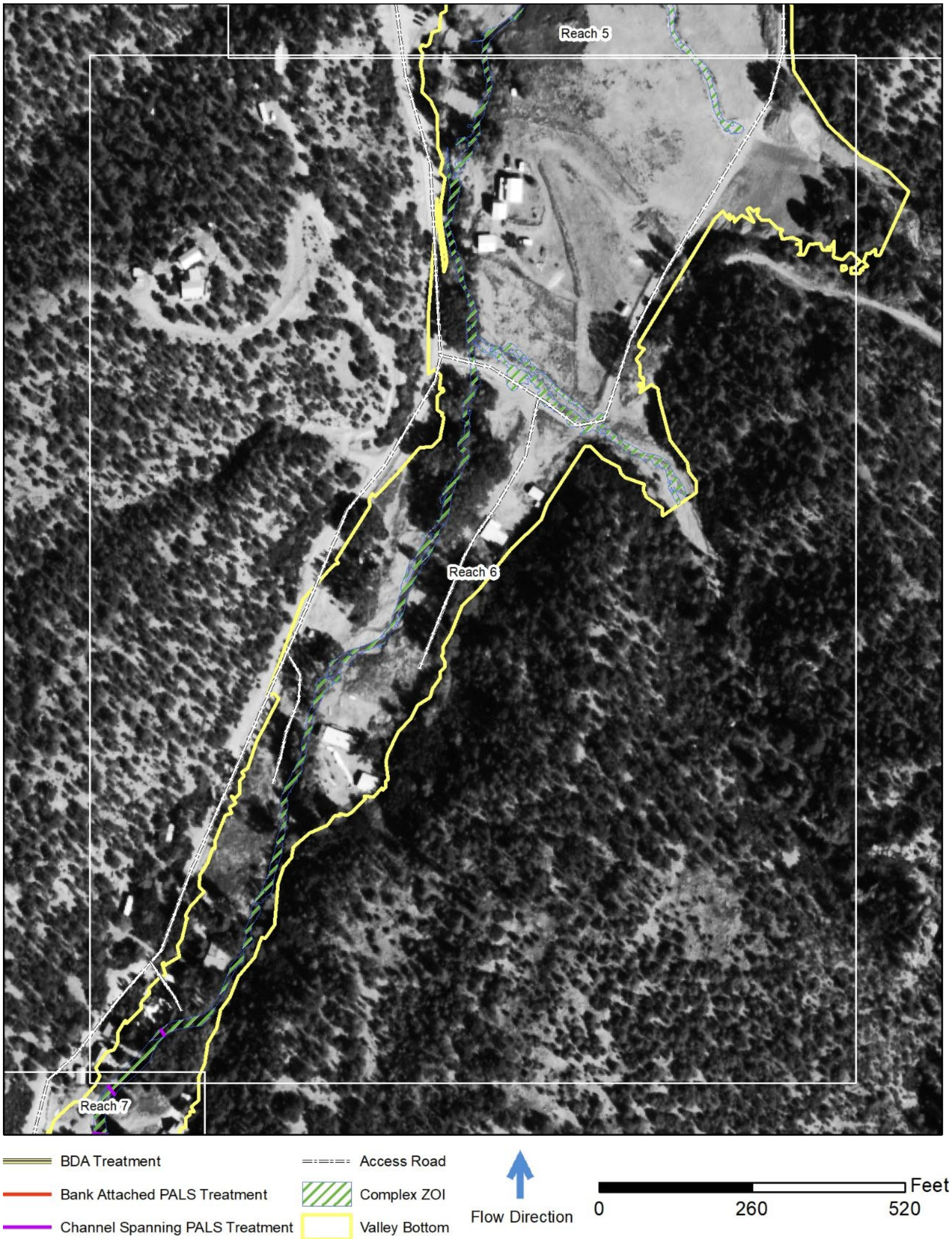

Figure B9: Reach 6 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

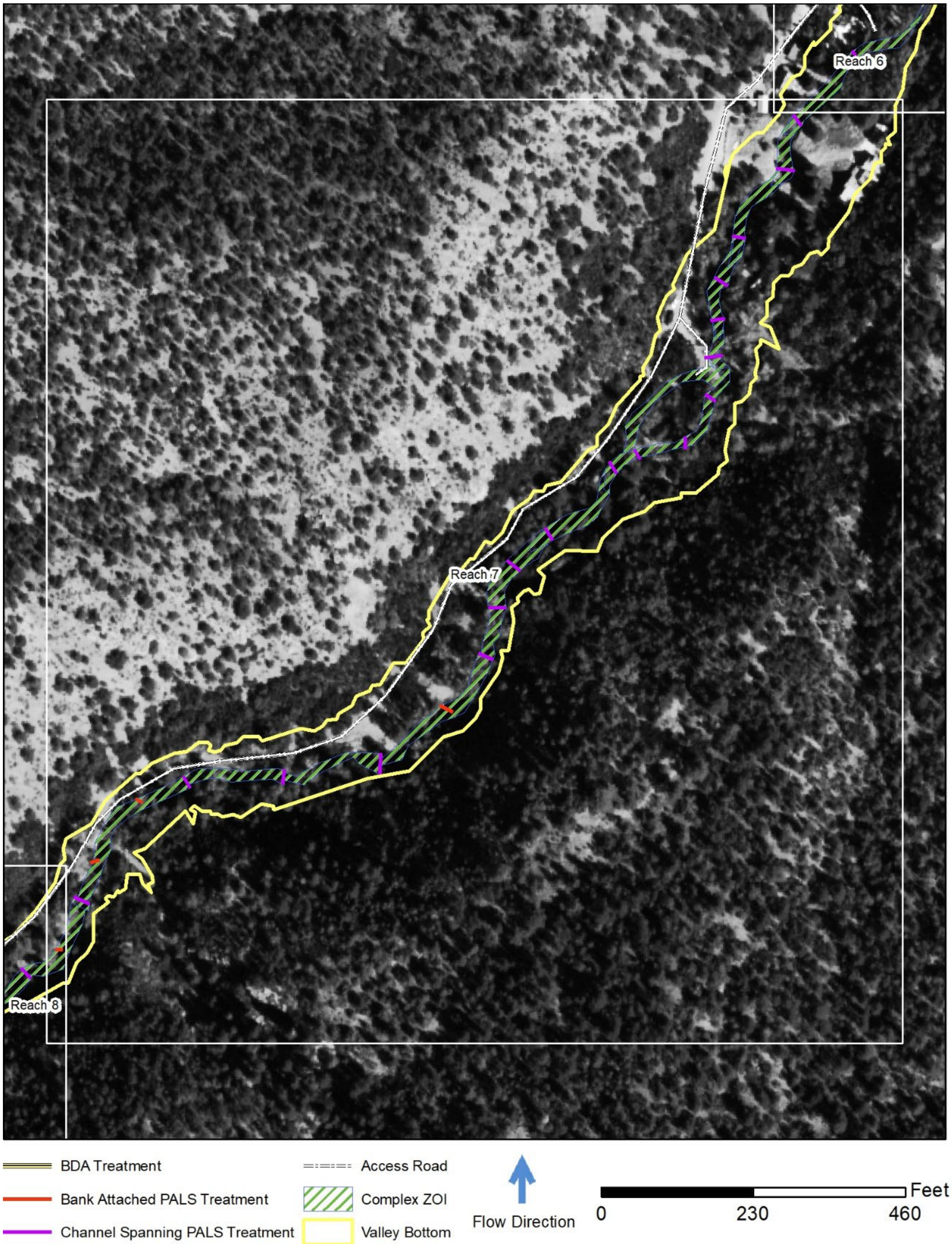

Figure B10: Reach 7 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

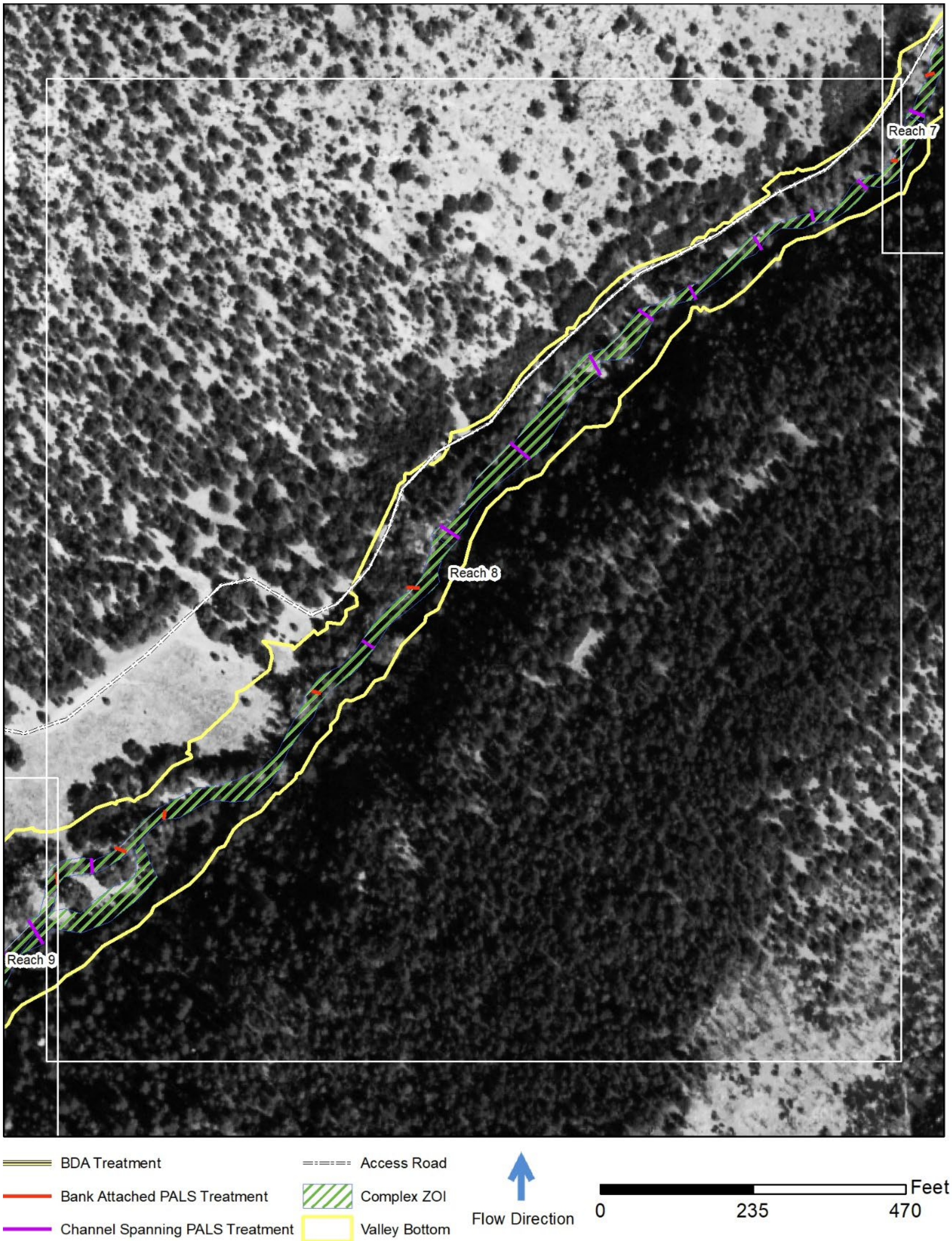

Figure B11 Reach 8 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

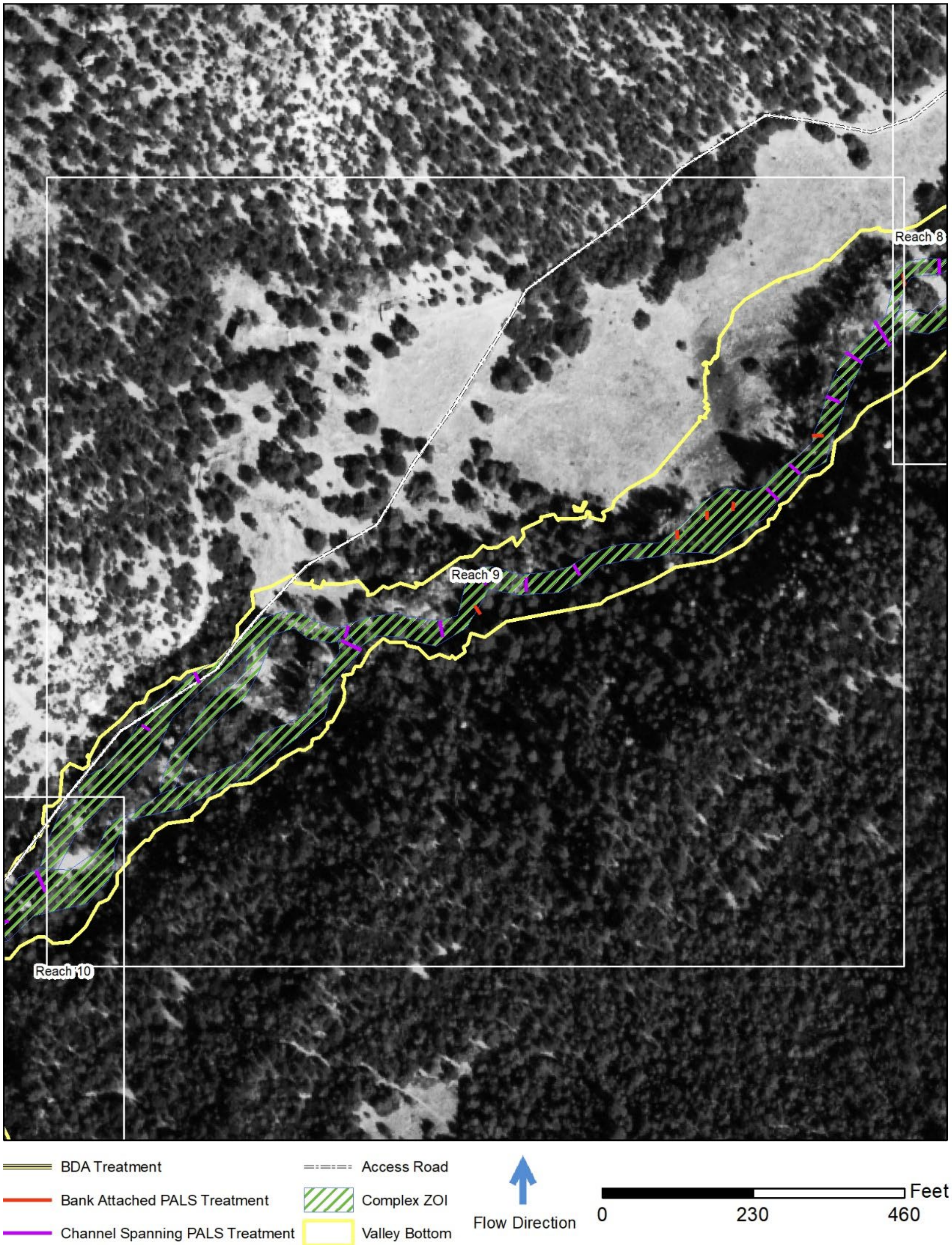

Figure B12: Reach 9 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).

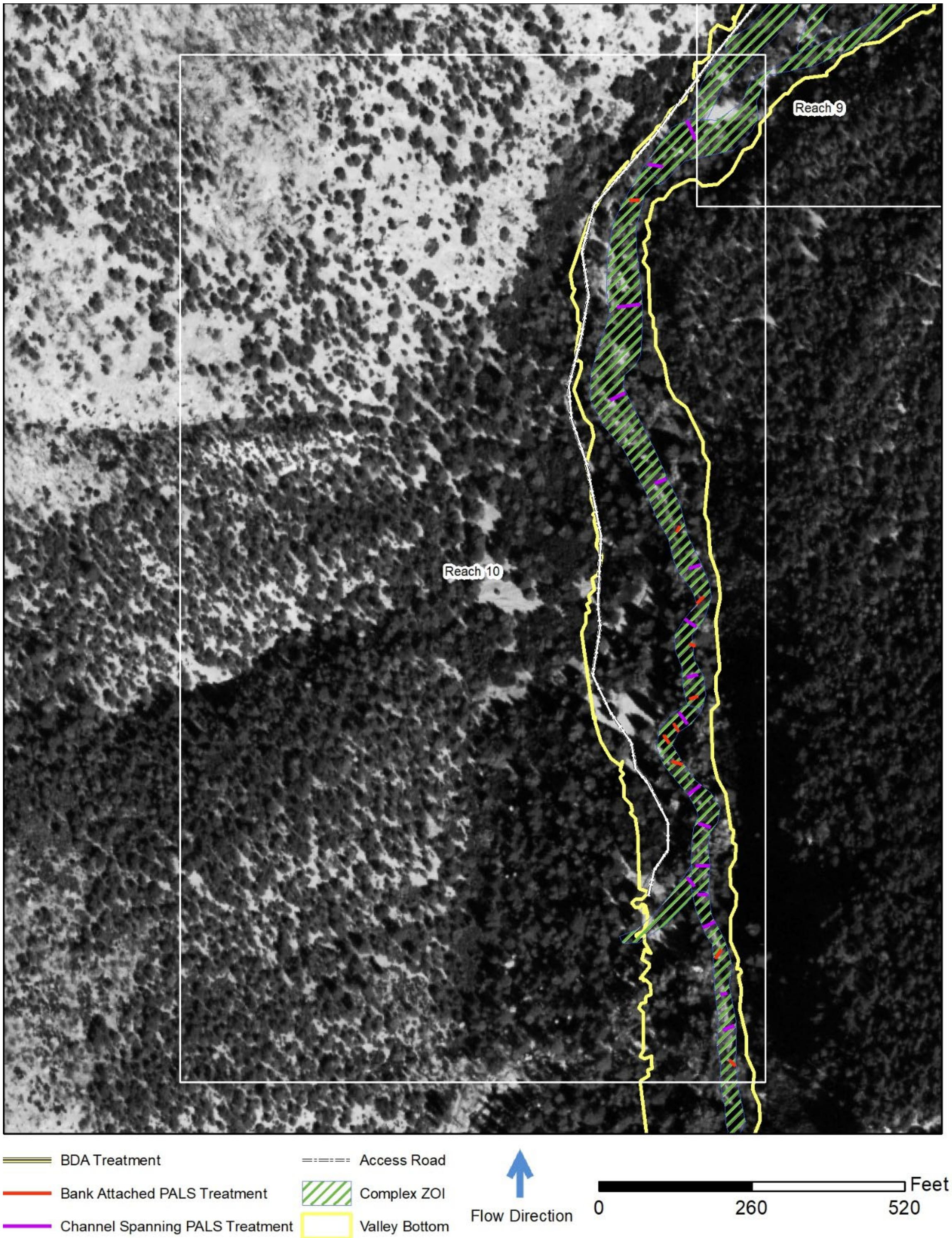

Figure B13: Reach 10 showing the valley bottom, potential restoration treatments, and the hydraulic and geomorphic zone of influence (ZOI).