Calwood Fire Recovery Grant – Final Report

Colorado Department of Natural Resources
Colorado Water Conservation Board
CMS Number: 169387
October 1, 2021

Aerial mulch drop in Unit 22, as seen from Landing 4, at Heil Valley Ranch Open Space, Boulder County, Colorado.

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Background

The Calwood Fire ignited on October 17, 2020, northwest of Jamestown, Colorado, and burned over 10,115 acres, becoming the largest fire in Boulder County history, destroying 20 homes, and damaging three others. The fact that there weren't any injuries or loss of life, nor additional structures lost, is a testament to the emergency responders, an efficient evacuation process, and minimal development due to conserved County Open Space and Federal lands within this part of Boulder County. The cause of the fire remains undetermined.

The landowner with the largest impacted acreage was Boulder County, with nearly 4,380 acres burned, most of that on the Heil Valley Ranch Open Space. Approximately 3,640 acres of this burn was on US Forest Service (USFS) lands and the remaining 2,100 acres was on private property, including the Cal-Wood Education Center, Denver Public School's Balarat Outdoor Education Center, and a large private inholding between Heil Valley Ranch and USFS lands. Nearly 1,400 of those acres were protected with conservation easements held by Boulder County.

After the fires, representatives from Boulder County Parks & Open Space (BCPOS), Public Works, and the Office of Emergency Management, the United States Forest Service, City of Longmont, St. Vrain and Left Hand Water Conservancy District, Left Hand Water District, the Cal-Wood Education Center, Left Hand Watershed Center (CWCB), Colorado Forest Restoration Institute (CFRI), Colorado Water Conservation Board designer engineers and others quickly mobilized to begin planning short and long-term recovery needs. This "Fire Recovery Team" worked to develop a fire-wide recovery plan and prioritize locations for aerial mulching, sediment catchment, and watershed restoration to protect downstream residents, municipal and agricultural water supplies, private and County roads, and County park infrastructure. To develop the overall recovery plan, the Fire Recovery Team collectively assessed burn severity, slopes, hillslope erosion potential, debris flow potential and consequence, post-fire hydrology, fluvial hazard zones, and treatment area suitability.

Initial funding for the above tasks was secured from the Natural Resources Conservation Service's Emergency Watershed Protection Program (NRCS-EWP), with Boulder County as the lead sponsor. EWP funding targeted 1,843 acres across 27 individual units, for aerial mulching of high and moderately burned slopes on County and private lands, utilizing wood shreds from trees on site (Figure 1). Additional EWP funded work included design and construction of sediment capture structures, and updates to rain gauges and an early warning system.

Many of the aforementioned stakeholders, including Saint Vrain and Lefthand Water Conservancy District, the Cal-Wood Education Center, and the Boulder Community Foundation contributed significant cash match to the CWCB grant, to assist with public outreach and community engagement, long term monitoring and adaptive management, and restoration on private properties affected by not only the Calwood Fire, but the Lefthand Canyon Fire.

Mulching hillslopes has been shown to be one of the most effective post-fire treatments to reduce hillslope erosion and sediment transport to streams. It effectively replaces the ground cover lost to the fire, protects the soil from raindrop impact, increases hydraulic roughness and flow path length, reduces the kinetic energy of overland flow, and increases soil moisture retention. This in turn increases

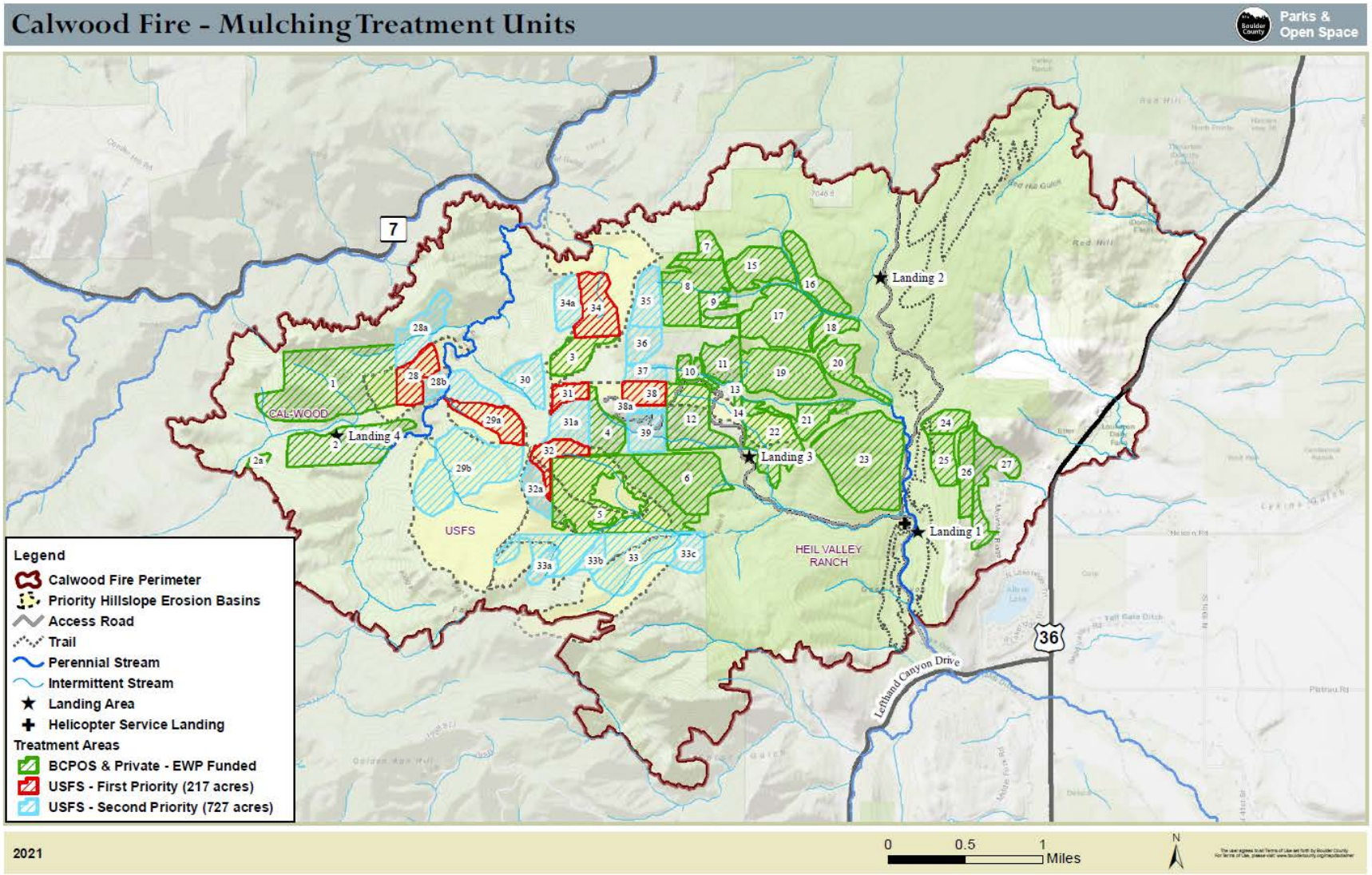


Figure 1. Calwood Fire – Map of Priority Sub-basins and Mulching Units.

infiltration, enhances vegetative recovery, decreases run-off and sediment transport, and ameliorates peak flows (Bautista, 2009; Robichaud, 2013a, b).

Federal lands are ineligible for EWP funds, which left a large portion of the watershed at risk. These areas, left untreated, would contribute to sediment delivery downstream and could potentially compromise adjacent mulching treatments (Figs. 1,2). Recognizing the high need for funding across the state following an unprecedented 2020 fire season, the Fire Recovery Team realized it needed to tailor its funding request by prioritizing a small subset of USFS lands in both the Geer Creek and Central Gulch watersheds that would most benefit from treatment.

The USFS Burned Area Emergency Response (BAER) report formed the initial basis for assessing the severity of the fire and identification of potential risks. Following this, CFRI used their Revised Universal Soil Loss Equation (RUSLE) hillslope erosion model to provide evaluations of hillslope erosion in individual sub-basins. Additionally, initial hydrologic modeling was completed by Enginuity which served to inform the elevated level of risks associated with increased runoff and flooding due to the effects of the fire. That modeling showed a potential for a six to eightfold increase in flows on Geer Greek, with a post-fire ten-year rain event equating to a pre-fire 100-year flood event, which is similar to what the watershed experienced during the 2013 flood. This amount of flow may have catastrophic consequences to the residents and infrastructure immediately downstream along Lefthand Creek.

Using the USFS burn severity maps and a slopes analysis completed by BCPOS, the team was able to identify areas which were suitable for mulching treatments, namely on slopes between 20 and 60%, in areas of moderate and high soil burn severity. Following the initial suitability analysis, the Fire Recovery Team worked through a prioritization exercise to identify the areas on USFS lands that were most likely to benefit from mulching. This analysis was aided by additional modeling provided by CFRI, which for each sub-basin in the burned area, estimated the reduction of sediment delivery out of the basin due to mulching of the suitable areas. This was coupled with a cost analysis which ranked sub-basins and treatment areas based on the amount of sediment avoided per dollar spent. Additionally, prioritization relied on on-the-ground knowledge, field assessments, and qualitative evaluations of in-channel sediment transport to further refine the priority sub-basins for potential treatment.

Figure 2. An example of a high priority unit in the Geer Creek watershed. Unit 38 with very little vegetative recovery in early June, was situated above NRCS treated private parcels.

This exercise highlighted five top priority sub-basins within each of the two watersheds (Geer Creek and Central Gulch) as well as

approximately 217 acres on USFS lands where mulching would have the greatest, and most cost-effective, impact on reducing sediment delivery to downstream municipal and agricultural water users, transportation infrastructure, and residents in and adjacent to the stream corridor.

After receiving approval for the CWCB funding, additional time was spent on site, with the regional USFS soil scientist and BAER Program Coordinator, as well as a contracted design engineer providing technical assistance to survey some of the priority areas in June. It became apparent that there was more acreage that would benefit from treatment. Without enough funding to cover all the priority basins, adjustments were made to previously identified units by removing acreage taking into account recent green up of vegetation (lower slopes of Unit 38), rocky substrates or steep terrain (Units 29 and 34), or slopes that drained into perched alluvial meadows that would likely capture any transported sediment (Unit 31) (Figs. 1, 11).

Figure 3. Looking across meadow in Unit 5 to Unit 33c showing completely bare soils above Geer Creek in early June.

In the end, we kept most of the original priority basins, but removed treatments from some of the uppermost ridges of basins in Units 31 and 32, to focus on Unit 33 that had a much more direct nexus to Geer Creek. From anecdotal evidence, it appeared that the north slopes that comprised Unit 33 were recovering much more slowly than south facing slopes and were contributing more sediment directly into the creek than the more remote upper units that had longer flow paths to the waterway. This was likely due to the thick stands of timber on the north slopes, the accompanying deep litter layer that burned extremely hot, and the lack of pre-fire understory vegetation. To that end we identified some small areas directly along Geer Creek, within the suitable slope range for mulching (Units 33a, b, and c – Fig. 3).

We also added a severely burned north slope within Unit 39 (Fig. 4), that abutted previously mulched areas on three sides, as well as two small areas (Units 40 and 7c) (Fig. 11) that were adjacent to larger NRCS funded units and helped to extend the mulch coverage to the top of a ridgeline, assuring the full slope was protected. These three units, totaling 37.4 acres, were the only units not within the top 5 priority sub-basins of each watershed. Final acreage for each unit is included in Table 1.

Field observations after a series of rain events revealed that even a small, un-mulched area above previously mulched units did increase run-off and negatively impacted the mulch downslope. In one instance, a small un-mulched area of approximately 11 acres, on a low gradient slope above Units 7 and 8 was large enough to contribute to rilling and the displacement of mulch downslope. This area had multiple high intensity storms and appeared to consist of hydrophobic soils, which likely contributed to the outsize impacts from such a small contributing area. This additional acreage was added to the scope of work as Unit 7c.

In the end, total acreage treated increased from the original 217 acres to 249 acres. This was increased to 272 acres when accounting for slope and topography, and that number was used for total quantities of mulch applied in the units themselves (Table 1).

Figure 4. View of what became Unit 39 on far hillslope. Mulching this small unit (17.9 acres) addressed a severely burned, north facing hillslope, above a drainage, with little regeneration, that was adjacent to treated areas on three sides.

Table 1: Mulch Units and Acreage

Unit	Original Priority Acres	Adjusted Ground Acres	Slope Adjusted Acres
7c	Added	10.6	11.3
28	41.3	36.4	40
29	44.4	47.1	51.7
31	17.5	Removed	Removed
32	29.7	Removed	Removed
33a	Added	20.0	22
33b	Added	23.3	25.2
33c	Added	6.75	7.5
34	57.1	59.0	65
38	26.6	21.6	23
39	Added	16.3	17.6
40	Added	7.8	8.5
Totals	**216.6**	**248.9**	**271.8**

Boulder County Aerial Mulch Contract

Nearly all the CWCB grant funds were applied to aerial mulching with wood shreds produced from hazard trees and others harvested on site at Heil Valley Ranch and the Cal-Wood Education Center. The intent was to supplement the work already contracted and implemented by the NRCS funding that began on April 28, 2021. Fortunately, the efficiency of collaboration between CWCB, Boulder County, and the USFS, enabled this project to move forward at a quick pace and minimize costs by piggy-backing onto that existing aerial mulching contract. In short time, the various agencies were able to approve grant agreements, sign intergovernmental agreements to permit Boulder County and their contractor to work on USFS lands, and complete contract amendments to the existing NRCS funded aerial mulching work, all prior to the contractor moving to new staging areas. This removed the need for the contractor to re-mobilize to any one landing area, thereby reducing costs. The contractor's unit rates were also favorable, and together with the lack of mobilization costs, allowed us to add additional acreage to the scope of work. Final contracted costs are detailed in Table 2.

Table 2: Itemized project costs.

Task	Unit Price	Quantity	Total Cost
Mobilization	$10,000.00	1	NA
Bond Increase	$16,500.00	1	$16,500.00
Tree Harvesting	$2,517.90	58.79	$148,027.35
Aerial Mulching	$1,358.00	271.8	$369,104.40
Mulching Subtotal			**$533,631.75**
Test & Integrate API calls to Zentra for rain gauges	$3,200	1	$3,200.00
VIP integration for display, query and graphing of soil moisture and rain gauges	$6,400	1	$6,400.00
Rules Manager modification for sensors and gauges	$4,800	1	$4,800.00
Rain Gauge/Soil Moisture Sensor Subtotal			**$14,400.00**
Project Total			**$548,031.75**
Grant Funding			**$550,000.00**
Balance			**$1,968.25**

Communications and Safety

For an operation this size and scope, effective communication is a necessity. The rugged terrain of the fire area made communications across much of the project site impossible. Furthermore, the contractor found that the dedicated radio frequencies they use out of state did not guarantee a dedicated channel along the Front Range of Colorado. Frequent use by other parties on the same frequency led the contractor to change channels multiple times in the early stages of the project, which made communication even more difficult. Thankfully, the Boulder County Sheriff's Office (BCSO) Communication Division, working with a local radio representative, and with permission from the USFS, was able to install a radio repeater atop Fairview Peak that allowed for communications across the project site, and across the two watersheds (Figs. 5a,b). Additionally, the BCSO donated 20 radios to BCPOS, programmed with the repeated channel, two dedicated channels, an internal Boulder County channel, and dispatch for emergency situations. The radios were used by staff and checked out to contractors and sub-contractors working on site, and despite some ongoing 'traffic' on the dedicated channels, allowed for nearly seamless communications between all parties across the entire fire footprint.

Safety is paramount when working with aerial operations and heavy equipment in a severely burned landscape during the summer months that is prone to flash flooding and debris flows. A dedicated safety officer was on site daily. All visitors to the project site signed in at a job site safety box, along with their contact info and destination within the property. Additionally, visitors checked in with the safety officer, or BCPOS staff, and if needed, radios could be issued to assist with communication. Contractors and staff received daily notifications from the Mile-High Flood District's daily Flash Flood Prediction Program, as well as alerts from Boulder County ODM, when rainfall thresholds on site were triggered. Signage was posted along existing trails as flood evacuation routes, to direct anyone on Heil Valley Ranch to safe areas to wait out potentially dangerous situations.

Figures 5a,b. Radio repeater equipment (upper right) and solar panels atop Fairview Peak.

Mulch Quality

Much has been written about the size and quality of wood mulch. Ideal mulch can be described as long, linear, and angular. Typical specifications call for no more than 30% fines, and the remaining material to be from 2-8" in length. BCPOS staff used a ½" x 1" wire mesh screen to sift sample buckets of mulch (Roubichaud, P. 2013c) (Fig. 6). Fines that passed through the screen were caught on a tarp and then placed back into the bucket to measure against a line denoting 30% of the bucket's volume. The initial grinder on site produced wood shreds that easily met the specification, with some of the batches measured with as little as 12-20% fines. That grinder, a Morbark Woodhog 3400XT, had two mechanical failures, which led to nearly two weeks of down time for grinding operations. The second mechanical failure was severe enough that the contractor had to source a new grinder. The second grinder, a Bandit 3680XP, initially appeared to produce mulch that was finer than the Morbark grinder. Fine mulch is much more susceptible to washing downslope in storm events.

Figure 6. Screen for wood shred mulch quality control.

Dealer representatives from Denver as well as company representatives from Michigan, spent two days on site, removing screens, adjusting speeds, and replacing cutter teeth with shredding 'cats-claw' teeth in order to produce the highest quality material (Fig.7). In the end, rather than a 5" and 4" screen we used a single 4" screen. Despite these modifications, many samples of mulch were just at or under the 30% fines ratio. It appeared that the trees themselves had more impact on the finished size of the material than did adjustments to the grinder.

Drier trees, as well as larger trees, that fed more slowly through the grinder, produced more fines. Wetter trees and smaller diameter trees that fed through quickly, produced larger and stringier shreds. The contractor was also encouraged to feed trees singly or staggered into the grinder, rather than 3-4 small trees at once, which tended to mimic a larger tree and hence feed more slowly. Small adjustments such as these helped produce better material.

Figure 7. Quality and size of wood shred at Landing 3.

Wetter material, however, requires more tonnage dropped on the slopes, as the volume per weight is less. An ideal situation might be to shred greener trees, and then let the pile dry out, thereby producing quality shreds and a higher volume per weight. This would, however, entail gauging a wet weight of trees to harvest that will produce enough dry weight of mulch required to meet the overall project quantities.

Mulching Implementation and Monitoring

The contractor utilized two landing areas that were already in use for the larger project. Landing 3 was located at Heil Valley Ranch, and targeted lands within the Geer Creek/Lefthand Creek watershed. The other, Landing 4, was located on Cal-Wood Education Center lands and used to treat acreage within the Central Gulch/South St. Vrain watershed. Harvesting and processing trees on-site, as this operation did, was the only feasible solution to treat the units from Landing 4, as transporting material in from off-site would not be possible due to the remote location and difficult access (Fig. 8).

Figure 8. Net of mulch ready for aerial application. Landing 4, Cal-Wood Education Center.

Mulching of USFS lands began in the Geer Creek Watershed on June 28, and continued through July 26, intermixed with work on EWP funded acreage. Boulder County Parks & Open Space (BCPOS) staff was responsible for quality assurance to verify that the mulch was applied to contract specifications. These specifications called for an average of 70% coverage across each unit. Staff utilized randomly generated points within each treatment unit as a transect start point. From that point, a direction, either left or right across slope, was randomly chosen, and a cover plot utilized every ten paces, for a total of ten plots per transect. Plot data was collected utilizing a Wood Straw cover grid (Forest Concepts LLC, Auburn, WA) (Fig. 9). In addition to the wood shreds, live vegetation, and rock larger than 1.5" was included as cover. In all, 29

Figure 9. Mulch coverage monitoring grid (Forest Concepts LLC, Auburn, WA).

transects were completed, comprising 290 data plots. Average cover for each individual unit is shown in Table 3 below. Individual monitoring spreadsheets, including plot data and transect photos for each unit are included in Appendix A.

Table 3. Mulching Units and Percent Mulch Coverage

Unit	Slope Adjusted Acres	% Cover	Mulch Added Post Monitoring	Final Tons/Acre	Notes
7c	11.3	N/A	NA	5.3	Small Acreage added above Units 7 & 8
28	40	67.5%	48.1 tons	5.6	Additional mulch added on two occasions. Likely more than necessary.
29	51.7	70%	NA	5	Very remote, not physically visited. % cover assumed
33a	22	72%	NA	4.2	
33b	25.2	72%	NA	5.1	
33c	7.5	66%	Unknown	5.1	29.7 tons of additional mulch attributed to all 33 units on7/1.
34	65	67%	21.4 tons	4.85	Additional mulch targeted in two areas of lower coverage
38	23	70%	NA	4.15	
39	17.6	80%	NA	3.85	High cover of mulch despite lowest rate dropped during the project.
40	8.5	78.5%	NA	5.5	Small acreage added to 132 acres of Unit 2. % cover and tons/acre representative of that entire unit
Total	**271.8**	**70.6**		**1326.76**	**4.88 tons/acre average**

BCPOS staff made every effort to visit units immediately after mulching. This became an even greater necessity due to the wet monsoonal summer, which saw rain events occurring sometimes daily across the project area. While light precipitation had little effect on the mulch and could actually help embed it into the soil, high intensity storms did impact the mulch coverage. If monitored post storm event, the data would be skewed, and not representative of what the contractor may have applied. In the event a unit did not meet the required coverage specification, the contractor was directed to add additional mulch, typically 0.5 ton/acre depending on previous percent cover. Figure 10 shows an example of good, consistent cover, in this instance, a transect of 79% on Unit 28. These units were not typically re-monitored, as earlier repeat data collected on the NRCS funded units showed 0.5 tons/acre of additional mulch sufficient to raise cover 5 to 10% and bring a unit to specification if original cover was in the mid-60% range.

Figure 10. Good, consistent mulch coverage within Unit 28, Central Gulch watershed.

Points dropped on Avenza Maps and shared with the contractor, or hard copy drawn maps, helped pinpoint areas where mulch coverage may have been inadequate. Staff also utilized orange targets, highly visible to the pilots to highlight areas on the ground for additional mulch drops (Figure 11).

Staff physically monitored 7 of the 10 units. Two small units that were added above previously mulched slopes (Units 40 and 7c) were not monitored due to their small size and were in effect captured within the larger unit data (i.e. Unit 2 for Unit 40) (Fig. 12). Unit 29 was the most remote unit within the project area (both NRCS and CWCB funded), and very difficult to physically reach (Fig. 13). Mulch was applied at five tons/acre within this unit, which on average, in our experience on site, was the amount of mulch required to get us to our 70% cover.

In total, 272 acres were mulched, which was 52 acres more than originally identified in the scope of work. The final acreage includes a slope factor ranging from 6-10% for each individual unit. The additional work was possible due to the competitive pricing from the contractor and the lack of re-mobilization costs. Figure 12 shows the originally defined high priority areas and the final areas where mulching was completed. The total cost was $533,631.75. This equates to $1,961.88/acre, which is slightly less than the per acre price for aerially applied wood shred mulch from both the Waldo and High Park Fire projects in 2012 (Robichaud, 2013c). This pricing was also inclusive of removing hazard trees from roads, trails and other sites to provide the raw material for mulch, which was an additional critical post-fire task for safely re-opening the sites to the public.

Figure 11. Visible target for pilot to spot areas for touch up mulch drops.

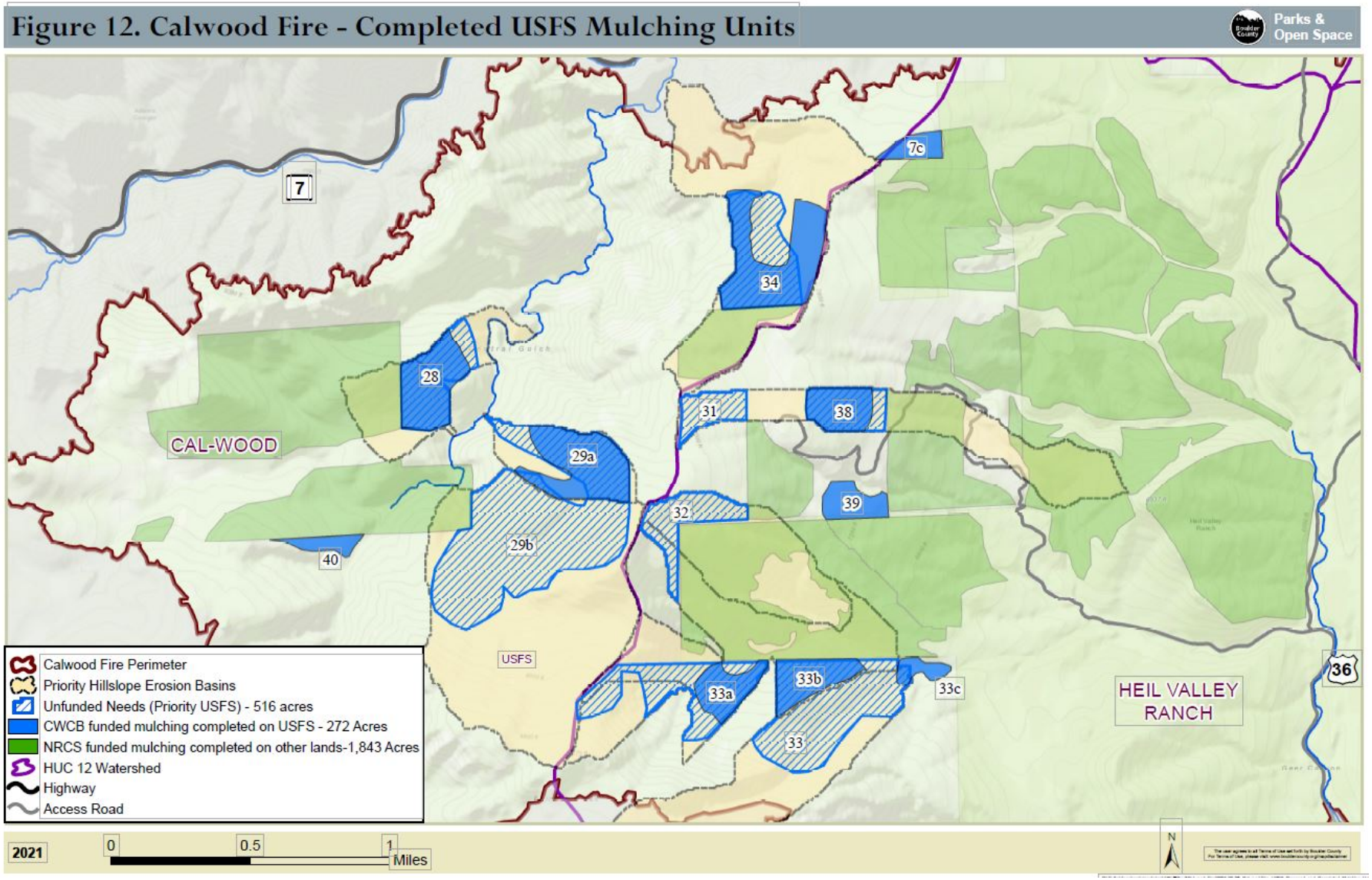


Figure 12. Calwood Fire – Map of Completed USFS Mulching Units

Figure 13. Distant view of mulch application within Unit 29 in Central Gulch watershed. Basin includes slopes below high point on ridge and behind knoll in foreground.

No staging areas or helicopter landings were situated on USFS lands. Three of the landings as well as the aerial service landing were located on Heil Valley Ranch, and the fourth on the Cal-Wood Education Center. The contractor was responsible for rehabilitation of the landings post project. Typically, that entailed cleaning up slash and dispersing it in nearby areas. However, at Landing 4 materials were left behind and consolidated into a slash pile that will be burned as weather permits by Lefthand Fire District and Cal-Wood staff. Other landings have been utilized by BCPOS staff working on road and culvert improvements, as well as by another contractor building sediment structures and will be reclaimed when those tasks are complete. BCPOS staff is utilizing volunteers to seed Landings 2 and 3 in October with native species, including many locally collected by BCPOS and Wildland Restoration Volunteers.

Weather

The Calwood burn area saw significant moisture throughout the project, beginning with a very wet May, followed by monsoonal moisture in June, July, and into August. Some surrounding areas logged their average annual precipitation within the first six months of the year, and in Boulder, records showed over 20” of precipitation by the Fourth of July, the third only occurrence of that since record keeping began in 1897. Precipitation during the mulching operation ranged from approximately 10.5” to 11.5” over a 14-week period. At the Boulder weather station there were 43 days of precipitation during the period of

aerial mulching (April 27 – August 9). Twenty-two days had greater than 0.10”, 15 days over 0.25”. Eight days experienced over 0.50” of rain, and five days over 1.00”.

Figure 14. Clogged culvert and sediment deposition following May 30 rain event on Heil Valley Ranch.

A severe storm occurred on May 30, prior to much mulch being applied. This led to plugged culverts along Geer Canyon Drive that overtopped the road in multiple locations, and black water in both Lefthand and Saint Vrain Creeks (Figs. 14,15,16). Additional high intensity storms occurred on June 25 and July 31 (Fig. 17), with multiple other rain events in between, though none saw the impacts to culverts and roadways like the May storm, perhaps a testament to the efficacy of the mulch. Since mulching on the USFS parcels began on June 28, the earlier storms had no impact to that work. Storms that occurred after that date, however, did have impacts to mulch coverage. High intensity storms were able to displace the mulch on the ground (Figs. 18,19), and in some units that saw repeated, high intensity storms, particularly along the

Figure 15. Ash laden flows from May 30 rain event at the Lefthand Water District intake on Lefthand Creek.

north ridge line of the two watersheds, mulch cover was reduced each time, with the impact greatest on the steepest slopes. It appeared that very little of the mulch made its way into the creeks, but rather re-sorted itself into smaller debris dams downslope or in lower gradient areas.

Figure 16. Ash laden flows in the mainstem St. Vrain Creek in Lyons, Colorado during the May 30 rain event.

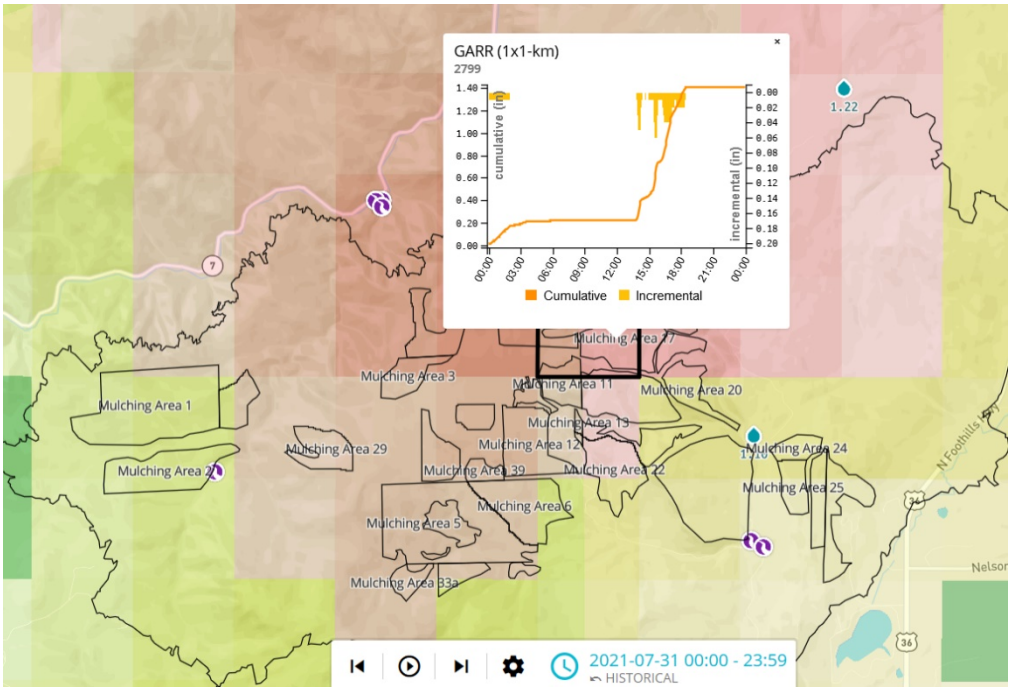


Figure 17. Screenshot of the Vieux platform showing Gauge Adjusted Rainfall Radar (GARR) for the July 31 rain event showing significant rainfall over the north central portion of the project area.

Figure 18. Evidence of minor mulch displacement after June 25 rain event on Unit 5 within Heil Valley Ranch. Not a CWCB funded USFS unit.

Figure 19. Evidence of more extreme mulch displacement on steeper slopes of Unit 5 on Heil Valley Ranch. Not a CWCB funded unit.

Soil Moisture Sensors and Rain Gauges

With funds remaining after the aerial mulching work, Boulder County spent $14,400 to fund the data integration from three additional rain gauges and soil moisture sensors near debris flow prone areas of the fire footprint at Heil Valley Ranch and USFS lands into the Boulder County Advanced Warning System. Site 1 was the chosen location on the USFS land, with another unit above the main trailhead of Heil Valley Ranch (Fig. 20). Exact coordinates of the third site are currently unknown. This work is a collaboration between Boulder County, Colorado Geological Survey, Colorado School of Mines, and the Boulder Watershed Collective. This work supplements previously installed sensors and gauges on USFS lands on the Calwood Fire, as well as others within the Fourmile Fire, and will enable higher precision, real-time soil moisture and soil strength measurements to better predict potential debris flows.

Tensiometers and volumetric water content sensors were installed at three depths (30, 50, and 80cm) (Figs. 21,22) and along with an associated rain gauge will report data to off-site computers. Data is available through the Zentra Cloud web interface, and via an app that is accessible from a phone in the field. The additional sensor units will provide further points of calibration for the hydrologic modeling that drives the larger overall warning system (Vflo) for Boulder County emergency operations. Ultimately this data will directly feed into the National Weather Service and the Boulder County Office of Disaster Management's (ODM) Advanced Warning system to provide 10 to 15 minutes of advanced warning to emergency responders and to the public in potential debris flow paths, to allow them to safely evacuate.

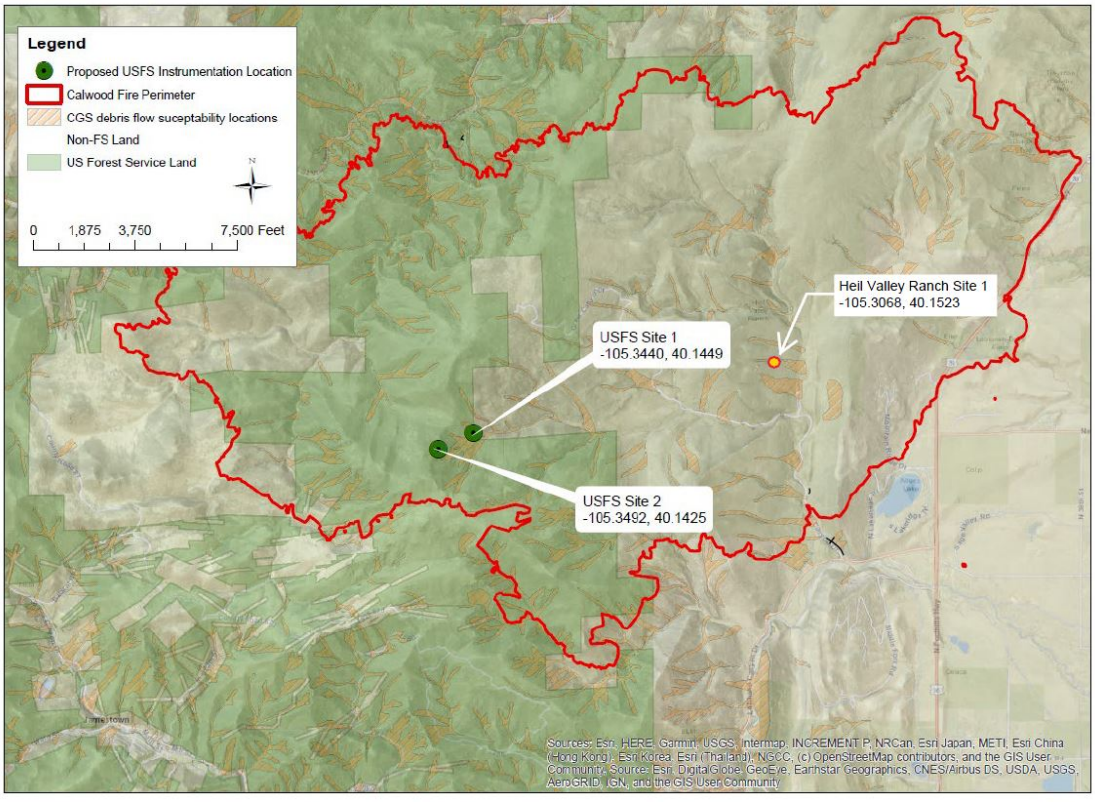


Figure 20. Approximate locations of instruments located within the Calwood burn perimeter. Site 1 was the chosen location on USFS land.

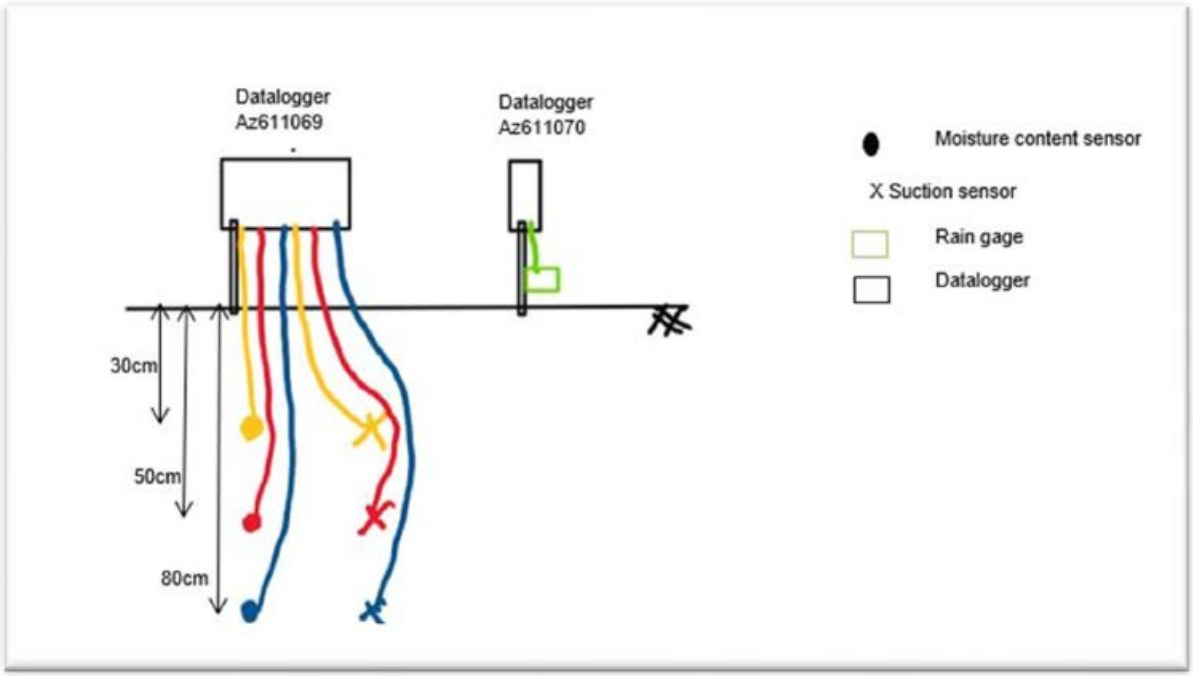


Figure 21. Schematic of subsurface instrumentation.

Figure 22. Installed data logger and rain gauge in mulching Unit 23, at Heil Valley Ranch.

Media Publicity, Stakeholder Engagement, and Research

Throughout the project, Boulder County staff provided access and informational tours to a variety of media and stakeholders (Fig. 23), to highlight past forest mitigation projects and how they influenced fire behavior, as well as the logistics and benefits of the post-fire funded recovery work. Media exposure included spots with:

- CBS-4 Denver
- Denver 7 News
- Denver 9 News
- Fox KDVR 31
- Denver Post
- Longmont Times Call
- Longmont Leader
- Lefthand Valley Courier
- National Geographic

Stakeholder tours included:

- Boulder County Commissioners
- Boulder County Parks & Open Space Advisory Committee
- Wildfires Matter State Legislative Committee
- Post Fire Tree Regeneration and Recovery Work Shop (CSU/RMRS)
- Undersecretary of Science and Water for the Dept. of Interior (USGS)
- Colorado Water Conservation Board
- North Central Region Colorado Recovery/CIP Committee

Additionally, the County held multiple community meetings during the spring to local residents most at risk from flooding downstream of the fire. The publicity and tours served to educate the public, stakeholders, and Local, State, and Federal representatives, not only of the post-fire associated elevated risks and what was being done to mitigate those risks, but also to showcase the success of pre-fire forest mitigation work and discuss constraints and opportunities for further collaboration and funding.

Figure 23. Wildfire Matters State Legislative Tour at Heil Valley Ranch.

Boulder County Parks and Open Space has long promoted and permitted research on its properties, with Heil Valley Ranch being a focus for many fire, forestry, and understory vegetation

research projects. The fire provided an opportunity for researchers to revisit previously established research plots where they had collected pre-fire data in the past, allowing for comparative data analysis in a variety of fields. Some of the research funded in 2021 by Boulder County included studying the impacts of the fire on soil carbon in relation to fuel treatments; the impact to understory plant communities and tree mortality in relation to pre-fire forest structure; and vegetative changes within the fire footprint previously treated for cheatgrass using Esplanade herbicide.

Lessons Learned

- Aerial operations move fast, and as such require enough staff to adequately monitor mulch applications as well as cutting operations if those are part of the project. Cost efficiencies are met by providing multiple staging areas to minimize helicopter flight times. This in turn requires that all areas are monitored and signed off on prior to the contractor moving to another landing. Delays of even a day can be costly, so staff need to be available on short notice to QA/QC sites.
- Trees with higher moisture content produced the highest quality wood shreds, but also had the highest weight to volume ratio and therefore required more trips to reach the specified cover of 70%.
- The moisture content, size, and species of tree appeared to have more influence on the finished wood shred product than did screen size and operation of the grinder. Still, most previous evidence and evidence on this project, points to a 4" screen and a grinder run at high speed, produces the optimal shred size. Trees from 8 to 18" in diameter also appeared ideal.
- Five tons per acre is a good starting point for 70% cover. This contract specified 4-6 tons/acre of mulch to get to 70% ground cover. Often the pilots would determine a unit to look good and 'complete' at a lower rate, only to find upon transect monitoring that it required additional mulch. To minimize return trips to a unit and the time of the monitoring crews, we dictated 5 tons/acre before any initial monitoring. A slightly heavier application of mulch would not negatively impact plant growth and would likely increase soil protection. Six tons/acre may be worthwhile, though that information should be conveyed during the bidding process and will likely increase costs.
- We targeted mulch on 20-60% slopes, but anecdotal evidence pointed to higher displacement of mulch on slopes approaching 60%. Though it is hard to ignore steep slopes with no vegetation,50% may be a better top range, in terms of balancing costs and benefits.
- Rain events of 0.50" or more in 15-20 minutes displaced mulch, especially the smaller material, but very little ended up in drainages or waterways, instead creating debris dams in lower gradient slopes downhill or behind rocks.
- Using aerial operations to haul cut trees to multiple landings allows mulching operations to work out of areas that would be otherwise inaccessible to semi-trucks hauling wood mulch from off-site. This allows for shorter helicopter flight times and can significantly reduce project costs.
- Direct communications with the pilots, if possible, is essential. The pilots in this project typically started flying at 5:30 a.m. and were not present at the weekly meetings because of that. In-person communication can occur during their fueling breaks as well as directly via radio. However, having them present at the morning briefing, at least weekly is advised.
- Dedicated radio commmunications for all staff and contractors is essential, and utilizing repeaters in rough terrain may be the only method to ensure all parties can communicate across

long distances on large projects such as these.

Dueling helicopters at Landing 4 on the Cal-Wood Education Center. When and where feasible, one helicopter would transport logs to a landing for processing while another simultaneously flew mulch onto hillslopes.

References

Bautista, S.; Robichaud, P.R.; Blade', C. 2009. Post-fire mulching. Chapter 13. In: Cerda, A; Robichaud, P.R., eds. **Fire effects on soils and restoration strategies.** Enfield, NH: Science Publishers: 353-372.

Robichaud, Peter R.; Lewis, S. A.; Wagenbrenner, J.W.; Ashmun, L.E.; Brown, R.E.; 2013a. **Post-fire mulching for runoff and erosion mitigation: Part I: Effectiveness at reducing hillslope erosion rates.** Catena. 105: 75-92.

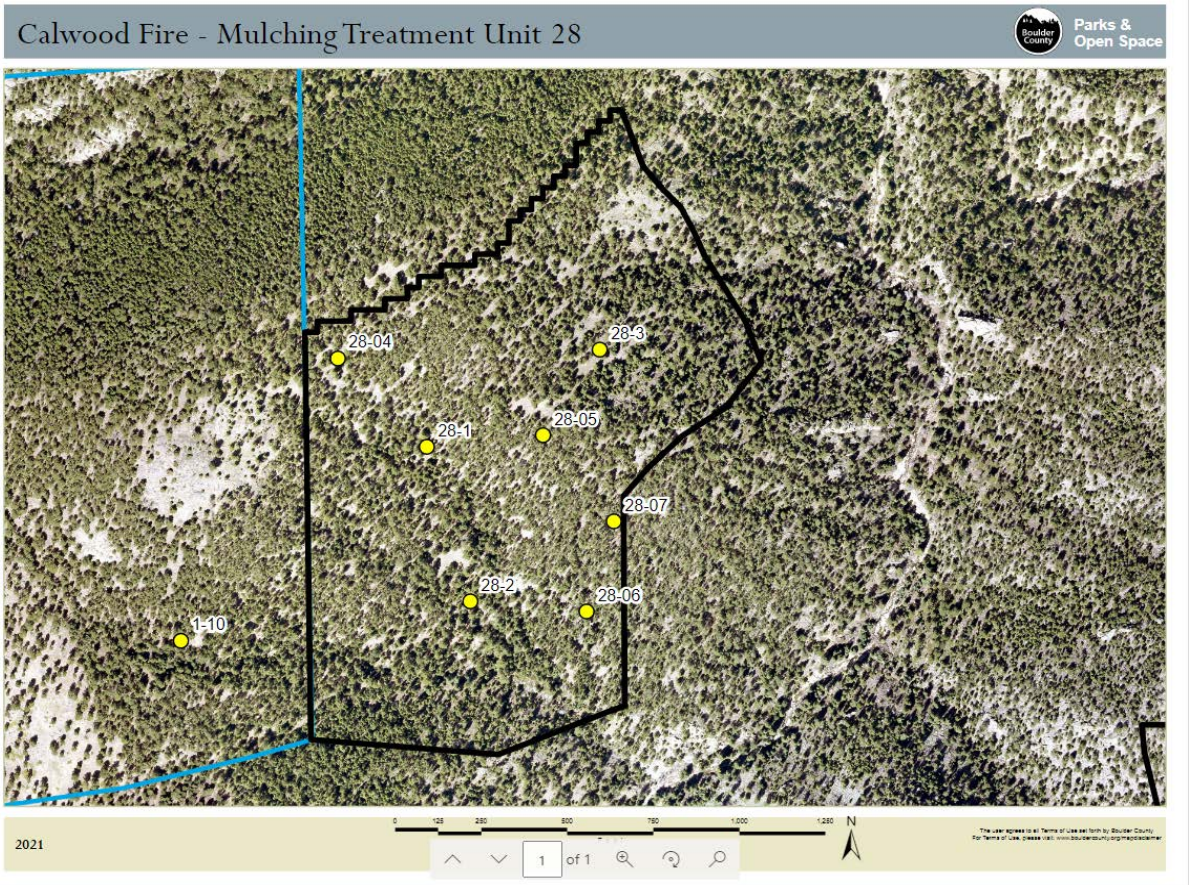
Robichaud, Peter R.; Wagenbrenner, J.W.; Lewis, S. A.; Ashmun, L.E.; Brown, R.E.; Wolgemuth, P.M.; 2013b. **Post-fire mulching for runoff and erosion mitigation: Part II: Effectiveness in reducing runoff and sediment yields from small catchments.** Catena. 105: 93-111.

Robichaud, Peter R.; Ashmun, Louise E.; Foltz, Randy B.; Showers, Charles G.; Groenier J. Scott; Kesler, Jennifer; DeLeo, Claire; Moore, Mary. 2013c. **Production and aerial application of wood shreds as a post-fire hillslope erosion mitigation treatment.** Gen. Tech Rep. RMRS-GTR-307. Fort Collins, CO; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 31 p.

Appendix A: Individual Unit Mulch Coverage Monitoring Sheets

Treatment Unit: 28			Monitors: KB, SB, DH							Date: 7/14/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	L	35%	71%	71%	62%	29%	52%	27%	62%	79%	90%	57.8%
2	Both	81%	48%	42%	19%	31%	56%	83%	75%	29%	33%	49.7%
3	R	83%	67%	69%	63%	96%	56%	81%	59%	63%	75%	71.2%
4	R	50%	75%	77%	60%	88%	65%	69%	88%	85%	77%	73.4%
5	R	69%	56%	73%	85%	92%	85%	52%	46%	44%	31%	63.3%
6	R	56%	98%	83%	85%	90%	83%	54%	92%	75%	65%	78%
7	L	88%	88%	83%	77%	85%	88%	77%	69%	67%	67%	79%
2 Repeat	Both	78%	71%	67%	33%	54%	78%	88%	80%	81%	77%	71%
Averages												67.9%

Notes: Mulch pieces in this unit seemed finer than in other units. New materials combined with drier conditions could be leading to this. On many of the transects, the presence of rocks helped increase cover percentages. It seemed like mulch was missed or not dropped on many of the N/NE facing slopes in the unit around transect 2. Additional mulch was applied twice over identified spots to pilot, totalling an additional 48 tons. This was far more than necessary, but the final cover is captured in two added transects 6 and 7 and a repeat of transect 2, whose coverage averages 76%.




40°9'36"N -105°21'39"W
236° SW
HVR_Calwood_Mulch_28-01
Jul 14, 2021 11:31:18 AM


40°9'31"N -105°21'37"W
232° SW
HVR_Calwood_Mulch_28-02L
Jul 14, 2021 11:54:08 AM


40°9'31"N 105°21'37"W
62° NE
HVR_Calwood_Mulch_28-02R
Jul 14, 2021 11:53:54 AM


40°9'38"N 105°21'33"W
355° N
HVR_Calwood_Mulch_28-03
Jul 14, 2021 10:21:45 AM

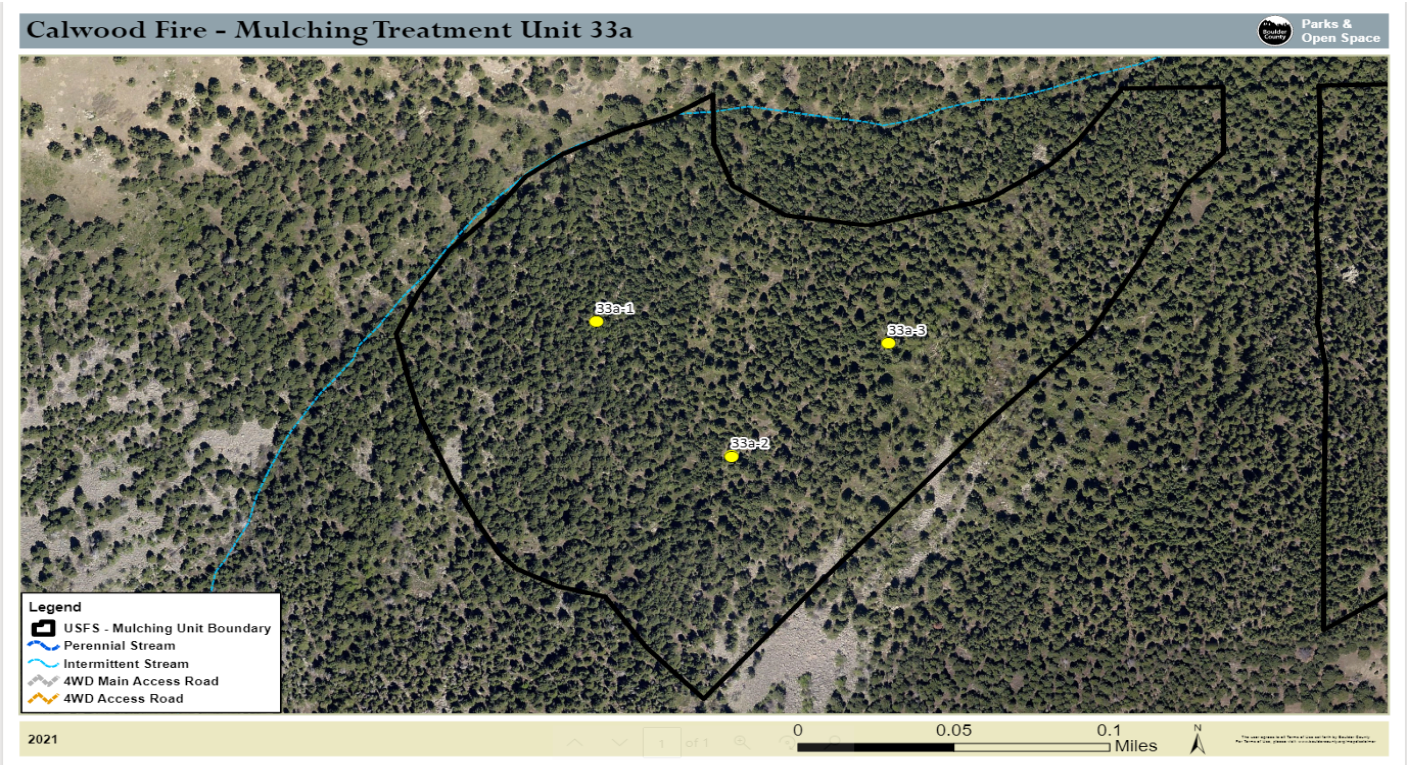

40°9'39"N -105°21'42"W
43° NE
HVR_Calwood_Mulch_28-04
Jul 14, 2021 9:48:16 AM


40°9'36"N -105°21'35"W
78° E
HVR_Calwood_Mulch_28-05
Jul 14, 2021 10:58:17 AM


40°9'32.38044"N -105°21'34.86332"W
64° NE
Cal-wood Mulch Unit 28-06
7/20/21 1:29 PM

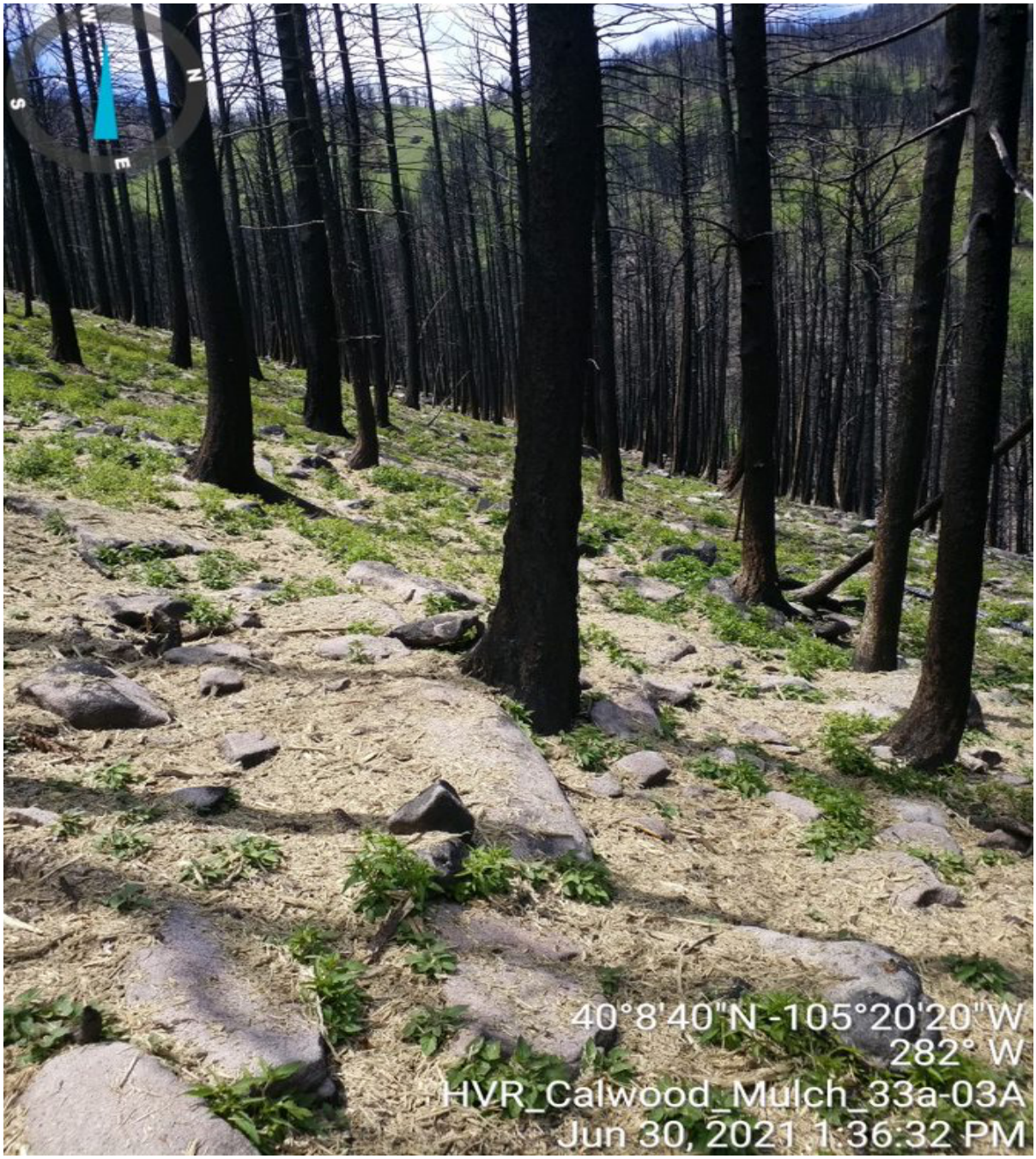

40°9'33.14899"N -105°21'31.76044"W
258° W
Cal-wood Unit 28-7
7/16/21 10:45 AM

Treatment Unit: 33A			Monitors: SH,SB							Date: 6/30/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	L	83%	56%	33%	75%	88%	98%	85%	90%	67%	56%	73%
2	R	100%	98%	96%	100%	92%	65%	54%	81%	60%	44%	79%
3	R	100%	100%	54%	60%	48%	79%	79%	35%	52%	27%	63%
4												
5												
6												
7												
8												
9												
10												72%
Averages												



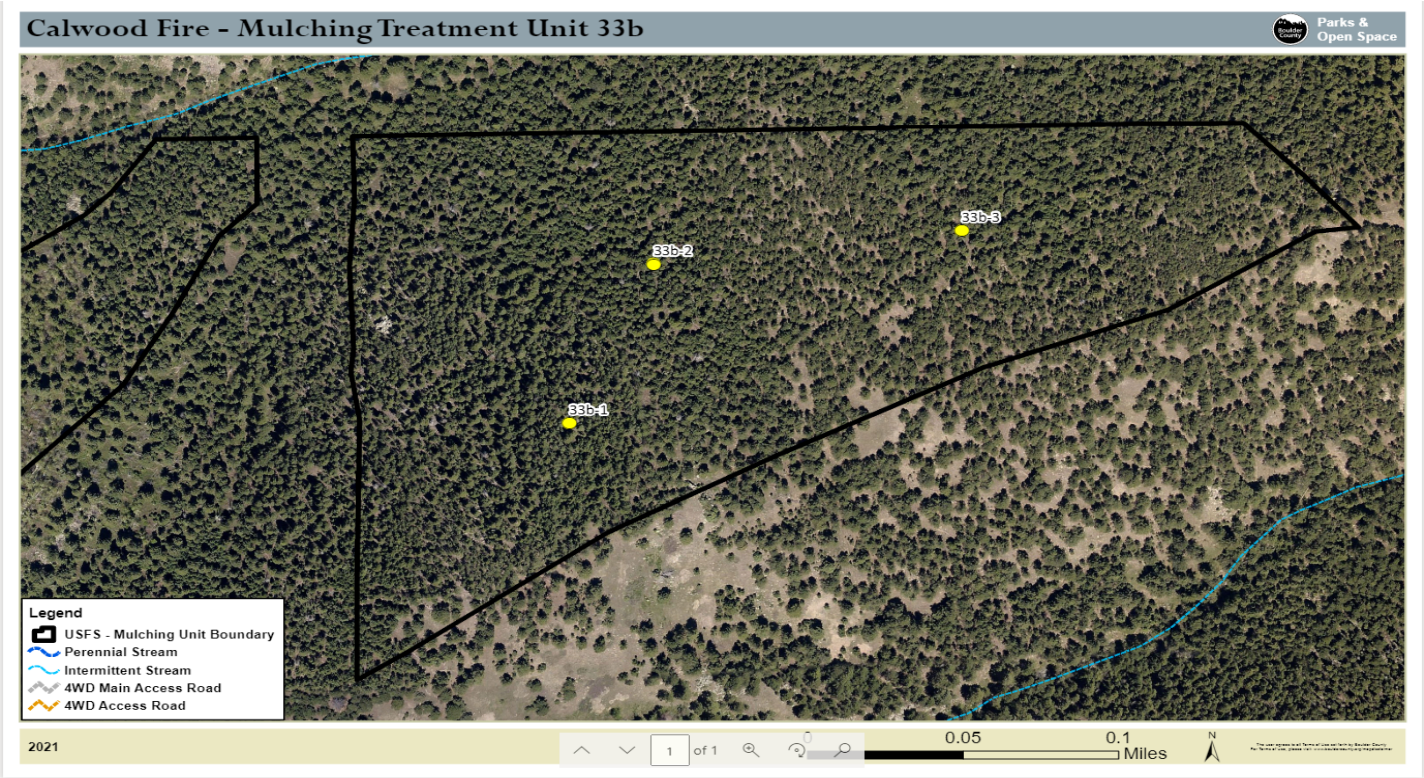

40°8'39"N -105°20'27"W
86° E
HVR_Calwood_Mulch_33a-01
Jun 30, 2021 1:04:12 PM


40°8'37"N -105°20'25"W
276° W
HVR_Calwood_Mulch_33a-2
Jun 30, 2021 12:09:29 PM


N
E
S
40°8'40"N -105°20'20"W
282° W
HVR_Calwood_Mulch_33a-03A
Jun 30, 2021 1:36:32 PM

Treatment Unit: 33B			Monitors: SB,SH							Date: 6/30/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	R	85%	63%	23%	56%	81%	98%	21%	25%	69%	79%	60%
2	L	92%	96%	94%	94%	90%	79%	100%	96%	96%	98%	93%
3	R	54%	65%	65%	46%	58%	77%	54%	52%	71%	75%	62%
4												
5												
6												
7												
8												
9												
10												
Averages		77%	75%	61%	65%	76%	85%	58%	58%	79%	84%	72%

Notes: 33B-03 added 2 points at the end of the transect to replace points 8 & 9 (original plots: 03-08 = 27 & 03-09 = 12) which landed in bare spots not representative of the area.



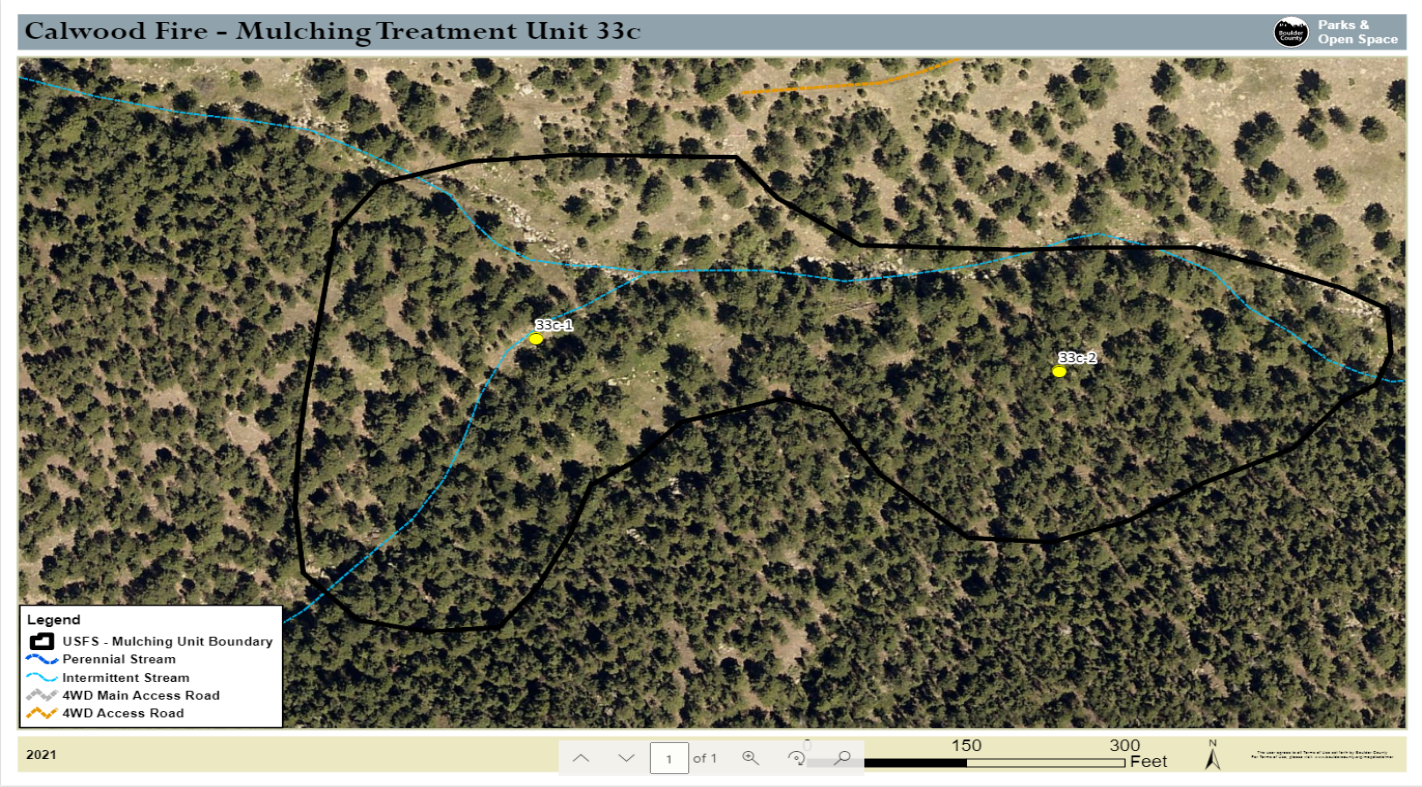

40°8'38"N -105°20'7"W
271° W
HVR_Calwood_Mulch_33b-01
Jun 30, 2021 11:29:13 AM


40°8'41"N -105°20'5"W
78° E
HVR_Calwood_Mulch_33b-02
Jun 30, 2021 11:04:54 AM


N
E
S
W
40°8'42"N -105°19'58"W
320° NW
HVR_Calwood_Mulch_33b-03
Jun 30, 2021 10:36:02 AM

Treatment Unit: 33C			Monitors: SB,BW,CB,KB							Date: 6/29/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	R	79%	100%	75%	19%	52%	67%	83%	88%	75%	59%	70%
2	R&L	75%	77%	56%	21%	42%	69%	75%	63%	79%	75%	63%
3												
4												
5												
6												
7												
8												
9												
10												
Averages		**77%**	**89%**	**66%**	**20%**	**47%**	**68%**	**79%**	**76%**	**77%**	**67%**	**66%**

Notes: 33C-01 moved 10 paces from origin to avoid creek. 33C-02 had to take points to the right and left of the origin to avoid leaving the boundary. Small acreage of unit required only another 4 tons of mulch to bring up to specification. No record of additional drops, but may have been included in helicopter logs for extra mulch dropped in 33a.




40°8'42"N -105°19'40"W
294° NW
HVR_Calwood_Mulch_33c_01
Jun 29, 2021 3:57:30 PM

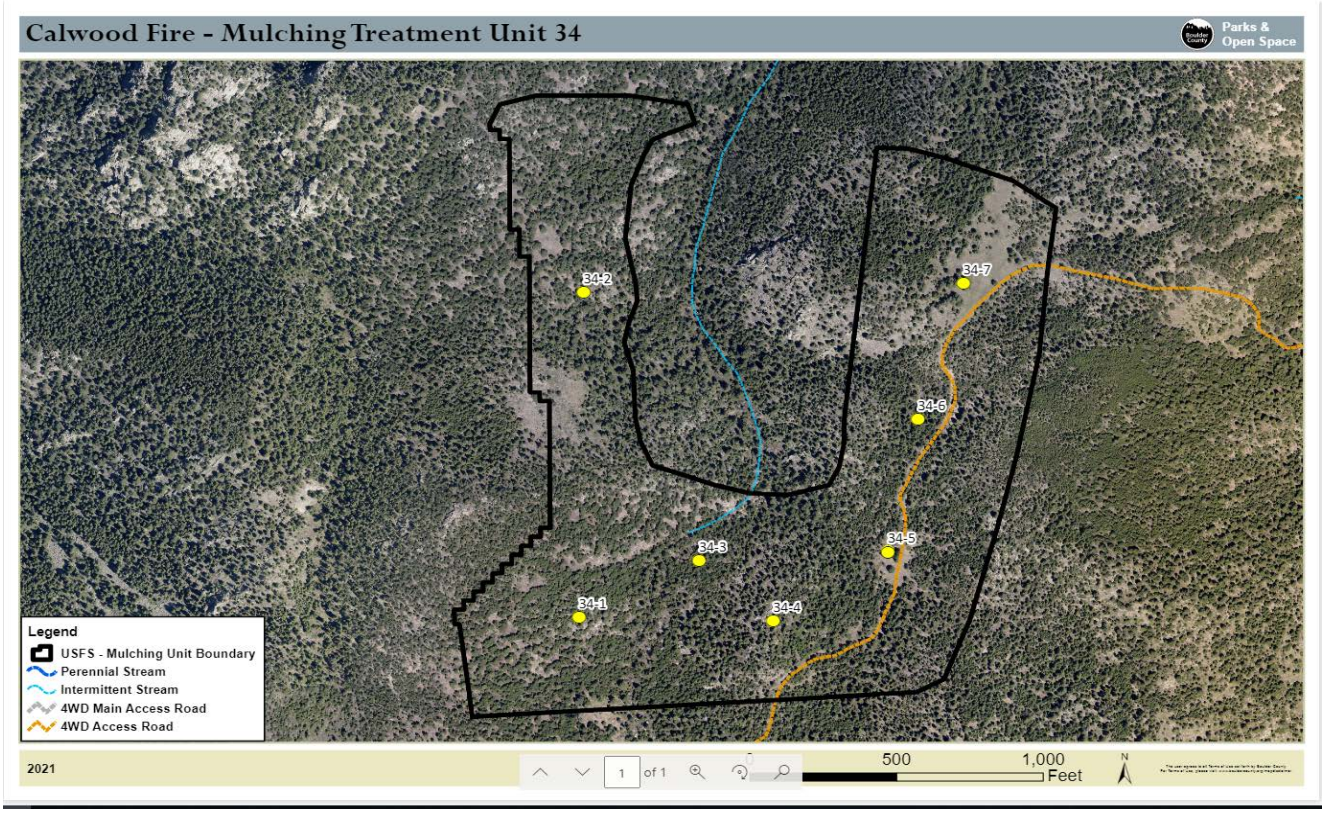

40°8'43"N -105°19'40"W
294° NW
HVR_Calwood_Mulch_33c_01
Jun 29, 2021 4:00:03 PM


E
N
S
W
40°8'42"N -105°19'33"W
94° E
IHVR_Mulch_Monitoring_33c-02l
Jun 29, 2021 3:56:15 PM


W
N
S
E
40°8'42"N -105°19'33"W
276° W
HVR_Mulch_Monitoring_33c-02r
Jun 29, 2021 3:55:52 PM

Treatment Unit: 34			Monitors: KB, SB							Date: 7/9/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	R	85%	88%	73%	65%	63%	71%	90%	71%	79%	42%	73%
2	L	60%	77%	40%	52%	77%	79%	63%	46%	79%	73%	65%
3	R	92%	85%	46%	58%	75%	79%	35%	75%	73%	71%	69%
4A	L	25%	73%	83%	69%	63%	40%	63%	33%	88%	96%	63%
5	L	46%	69%	81%	44%	73%	98%	65%	58%	65%	88%	69%
6	R	42%	21%	96%	94%	81%	94%	69%	46%	29%	25%	60%
7A	R	65%	96%	92%	69%	92%	71%	79%	60%	42%	75%	74%
Averages												67%

Notes:4.5 tons per acre were dropped in this unit. On transect 1, the origin of the transect was moved upslope 10 paces to avoid a hazard tree. On transect 04, the origin of the transect was moved 20 paces east and 20 paces north to avoid large bands of rock. On transect 4, points 9 and 10 were moved 15 paces ahead along the transect line in order to avoid a large patch of vegetation. Transect 5, point 8 was moved 10 paces downslope in order for the transect to fall in a more representative area. Transect 7 was relocated 20 paces east of the road to add variation to the location of the transects and because the original point landed in a meadow.




40°9'53"N 105°20'20"W
337° NW
HVR_Calwood_Mulch_34-01
Jul 9, 2021 10:00:48 AM


40°10'5"N 105°20'20"W
186° S
HVR_Calwood_Mulch_34-02
Jul 9, 2021 9:28:27 AM

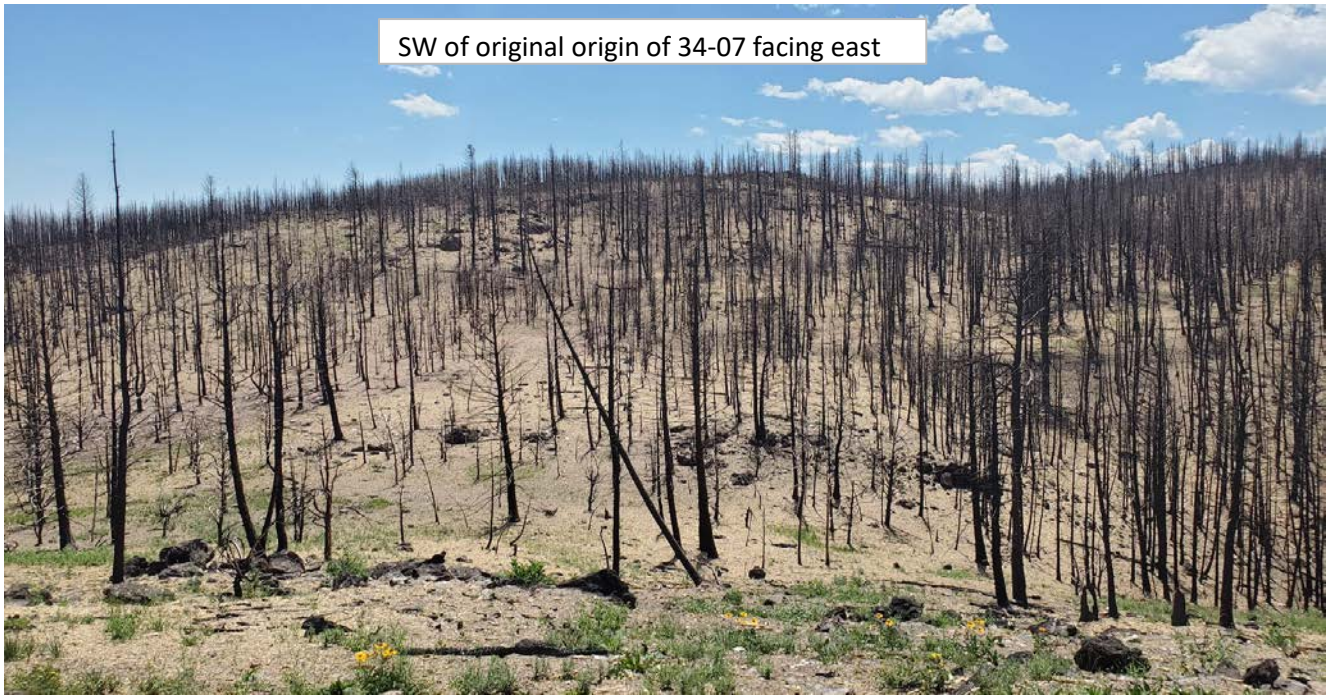

40°9'55"N -105°20'15"W
239° SW
HVR_Calwood_Mulch_34-03
Jul 9, 2021 8:51:10 AM


40°9'54"N -105°20'11"W
99° E
HVR_Calwood_Mulch_34-04A
Jul 9, 2021 10:45:38 AM


N
W
E
S
40°9'56"N -105°20'7"W
359° N
HVR_Calwood_Mulch_34-05
Jul 9, 2021 11:11:16 AM

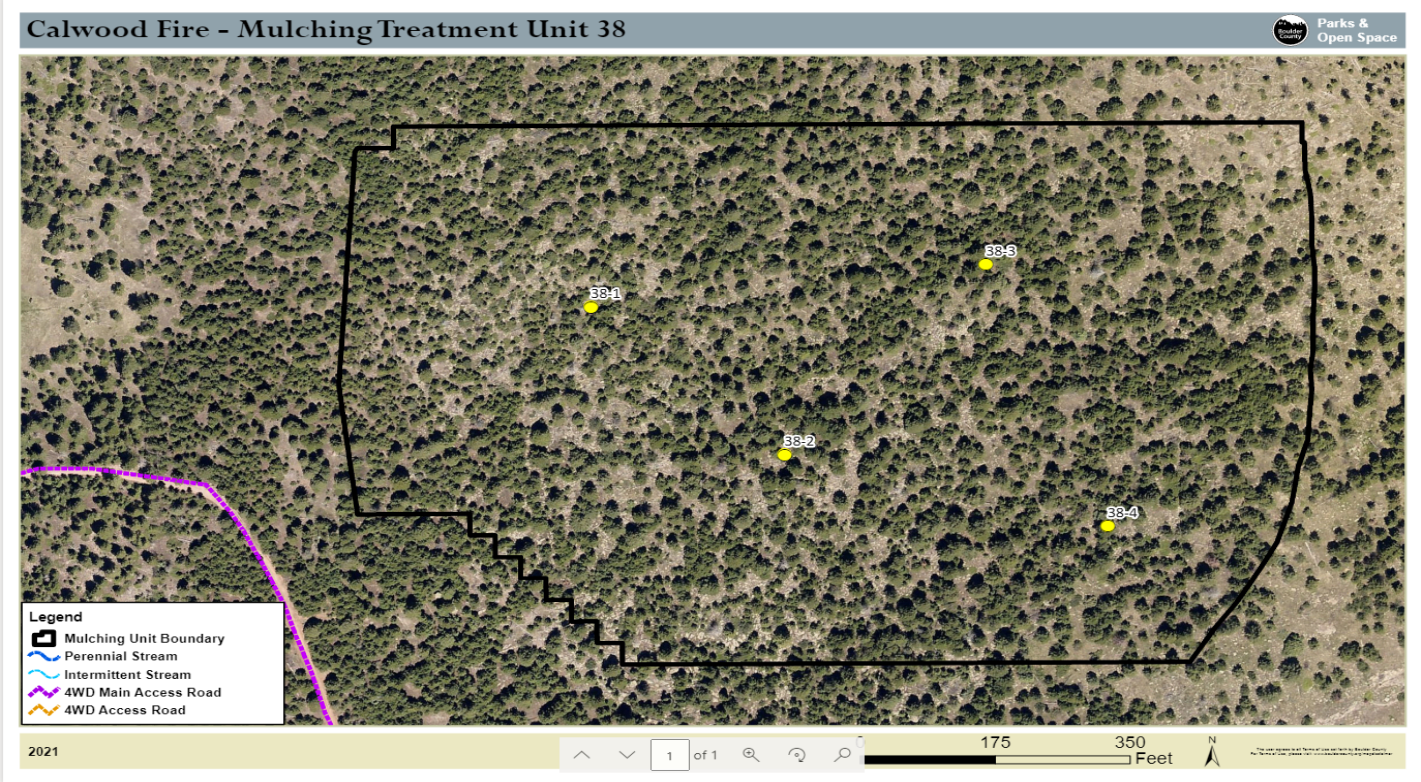

S
W
E
N
40°10'0"N -105°20'5"W
213° SW
HVR_Calwood_Mulch_34-06
Jul 9, 2021 11:32:00 AM


40°10'4"N -105°20'2"W
216° SW
HVR_Calwood_Mulch_34-07A
Jul 9, 2021 11:54:47 AM


SW of original origin of 34-07 facing east

Treatment Unit: 38			Monitors: BW,SB,CB,KB							Date: 6/29/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	L	63%	98%	35%	85%	50%	48%	52%	100%	54%	83%	67%
2	L	50%	85%	96%	98%	94%	100%	85%	100%	33%	88%	83%
3	R	63%	69%	54%	88%	85%	79%	71%	69%	63%	65%	71%
4	R	29%	44%	81%	90%	96%	27%	25%	63%	75%	85%	62%
5												
6												
7												
8												
9												
10												
Averages												70%

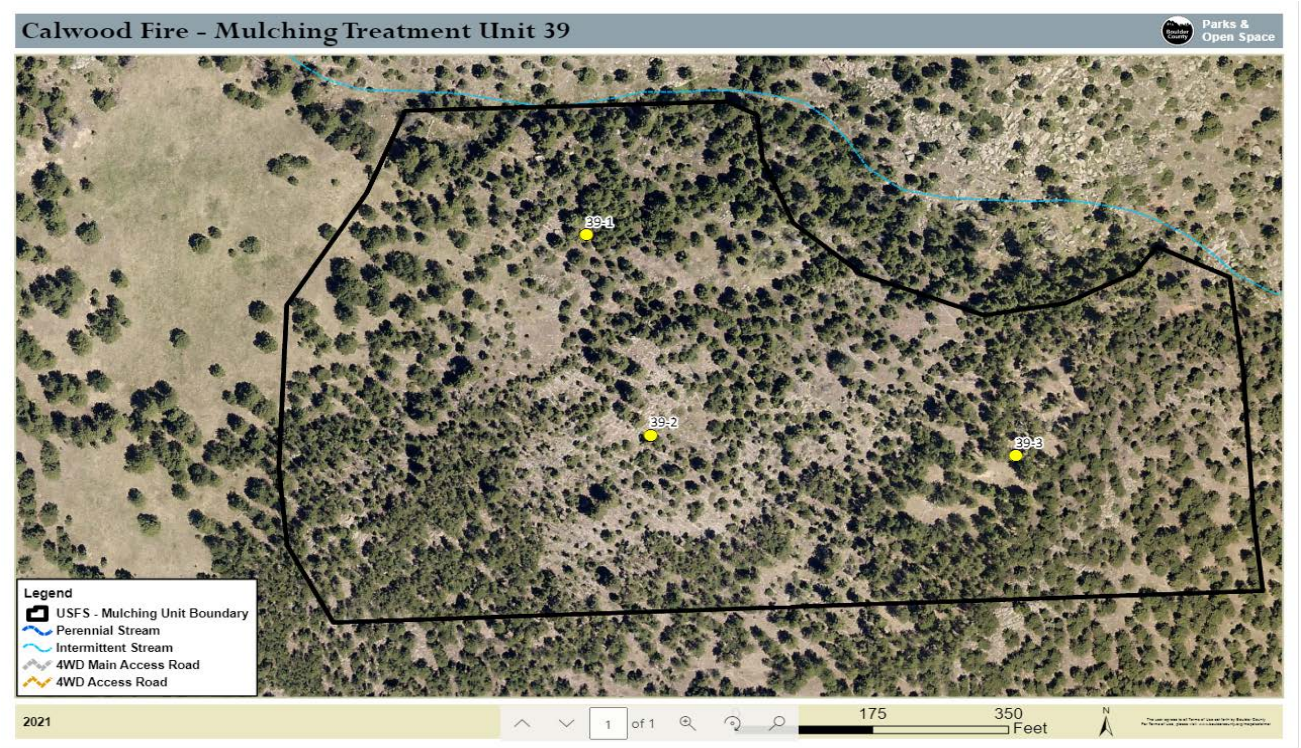
Notes: 38-01 3 & 4 at edge of rocky area that seemed missed, added 1 point to the end to replace 4 (orginal =27).38-02 reached the unit boundary and there was no mulch, so we added the last plots onto the right of the origin. 38-04 went right to avoid leaving the unit. Missing photos for Transect 2 & 4 due to tablet failure; may be able to recover at later date.




40°9'32"N -105°20'0"W
167° S
HVR_Calwood_Mulch_38-01
Jun 29, 2021 10:05:30 AM


40°9'33"N -105°19'54"W
351° N
HVR_Calwood_Mulch_38-03
Jun 29, 2021 10:26:06 AM

Treatment Unit: 39			Monitors: KB,CB							Date: 6/29/21		
Transect #	L or R	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average % Cover
1	L	94%	88%	90%	92%	96%	90%	79%	61%	79%	88%	86%
2	L	50%	77%	100%	81%	88%	88%	96%	65%	46%	96%	79%
3	R	67%	77%	88%	69%	90%	65%	65%	67%	92%	88%	77%
4												
5												
6												
7												
8												
9												
10												
Averages												80%
Notes:												




40°9'16"N -105°19'56"W
178° S
HVR_Calwood_Mulch_39_01
Jun 29, 2021 12:35:08 PM

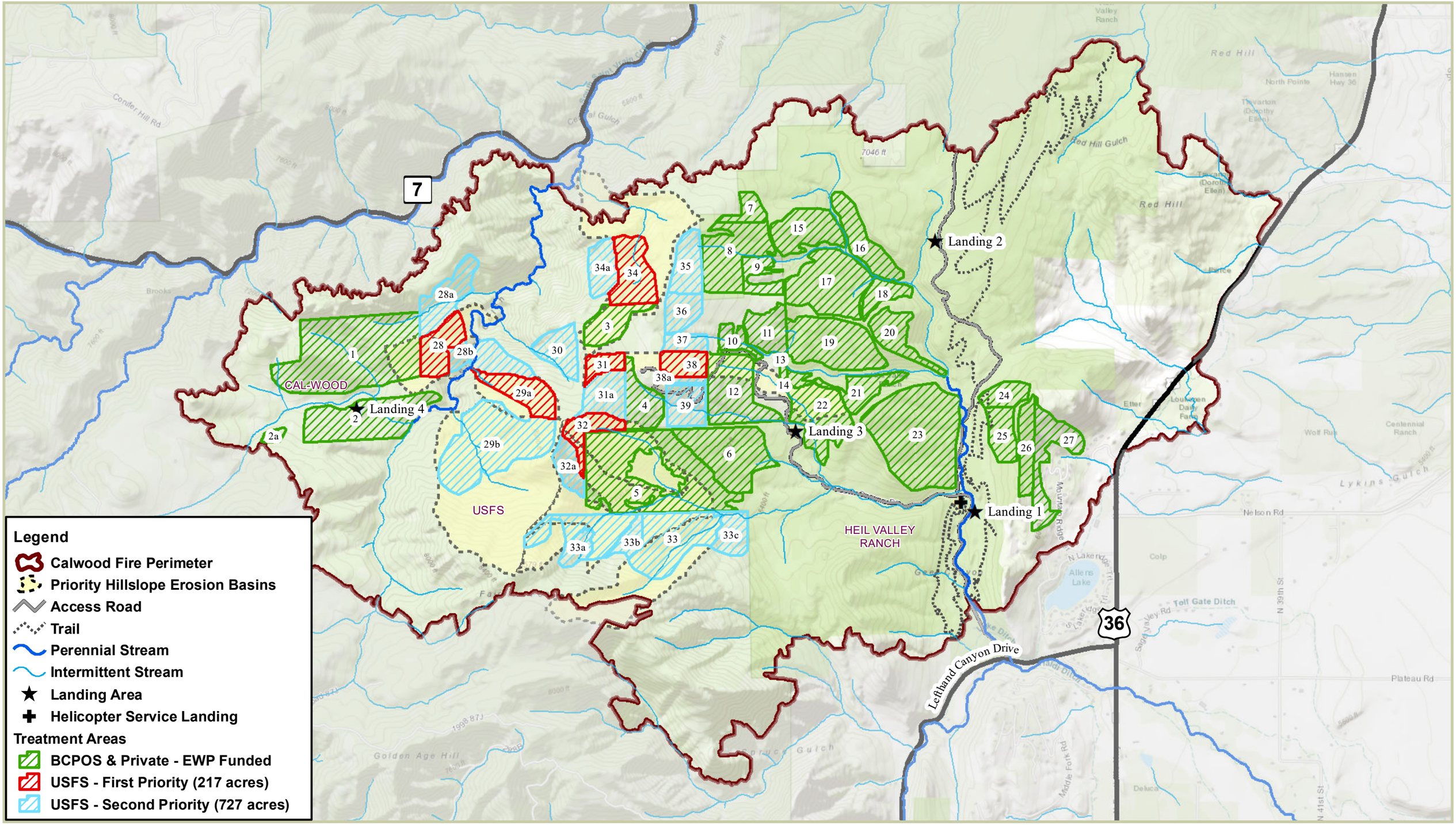

40°9'13"N -105°19'54"W
179° S
HVR_Calwood_Mulch_39_02
Jun 29, 2021 12:16:58 PM


N
W
E
S
40°9'12"N -105°19'48"W
0° N
HVR_Calwood_Mulch_39_03
Jun 29, 2021 11:50:58 AM

Appendix B: Large Format Maps

Figure 1. Calwood Fire - Priority USFS Sub-basins and Mulching Units

Boulder County Parks & Open Space



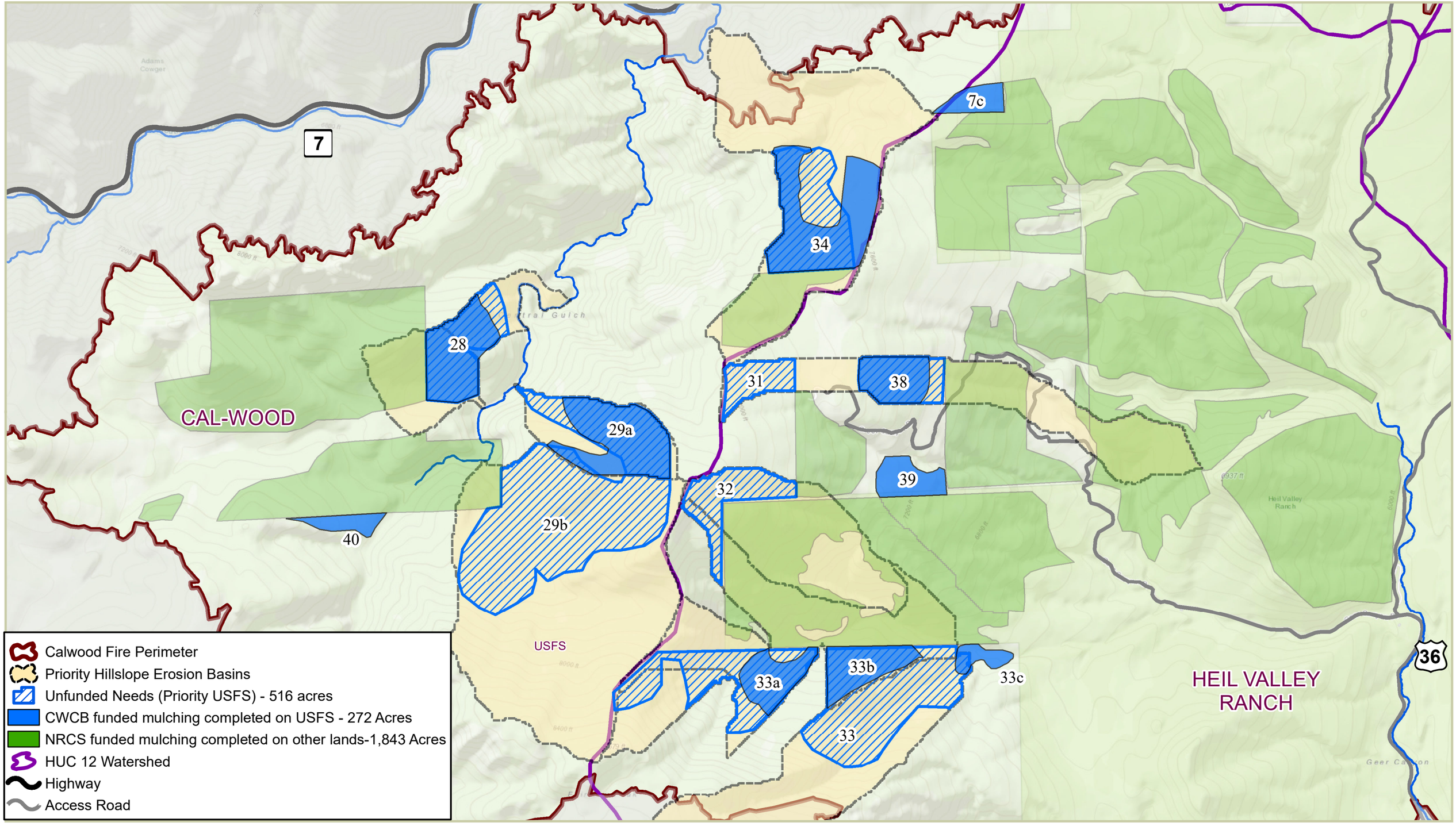
2021

0 0.5 1 Miles

N

Figure 12. Calwood Fire - Completed USFS Mulching Units

Parks & Open Space



2021

0 0.5 1 Miles

50

N

FILE: \\gis\pcshare\gispa\plants\Staff\Brad\Calwood_Fire\2021-08-26_Calwood Fire_USFS_Proposed_and_Completed_Mulching_Units.mxd