FIVE

ECOLOGICALLY SOUND PONDEROSA PINE RESTORATION IN JEFFERSON COUNTY: PROTECTING RESIDENTS WITHIN THE WILDLAND URBAN INTERFACE

David R. Schott

With large catastrophic wildfires ravaging the West and increasing resources devoted by federal, state and local fire services to suppressing these wildfires, many land managers have encouraged a proactive approach to forest and fire management in ponderosa pine (*Pinus ponderosa*) forests. By identifying a range of key evaluation criteria for safe and efficient wildfire mitigation interventions in the vulnerable area of Jefferson County, CO, this analysis provides Jefferson Country policy-makers with thorough, data-driven recommendations for protecting citizens, the built environment, and natural resources.

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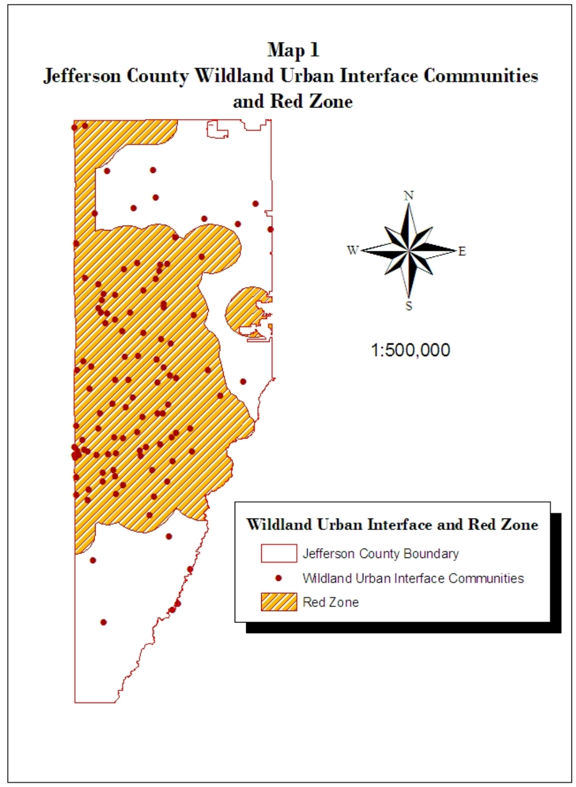
INTRODUCTION

With large catastrophic wildfires ravaging the West and increasing resources devoted by federal, state and local fire services to suppressing these wildfires, many land managers have encouraged a proactive approach to forest and fire management in ponderosa pine (*Pinus ponderosa*) forests. Ponderosa pine in the western United States poses unique opportunities to fire management agencies in that it is fire prone and has evolved with fire as part of its biology. The Front Range of Colorado[1], while only a short drive from major metropolitan areas, still provides a sense of remoteness and solitude valued by outdoors enthusiasts. Today, 80 percent of the Front Range of Colorado in Jefferson County is in the wildland-urban interface (WUI).[2]

In 2002, the Hayman Fire, the most destructive wildfire in Colorado's history, consumed 138,000 acres and destroyed 133 homes, one commercial building and 466 outbuildings. It cost $39 million to suppress (Wilderness Society 2003). Moreover, an additional $238 million of taxpayer dollars were spent in rehabilitation efforts. This analysis recommends options for increasing public safety, bridging the gap between planning of high-risk areas defined by the Community Wildfire Protection Plans (CWPPs) and implementating fuels reduction[3] and restoration[4] projects that protect the citizens of Jefferson County living in the WUI in the event of a catastrophic wildfire.

PROTECTING VALUES AT RISK

While the Hayman Fire certainly was destructive in many ways, the impact on residents in the Front Range was relatively minimal because the majority of the fire occurred south of Jefferson County in the Pike National Forest. Jefferson County has a population of 527,056 – 33 percent of whom live in the WUI (Steelman and Bell 2003: 1) (See Map 1).[5] Had the footprint of the Hayman Fire fallen north of Highway 285 in the heart of Jefferson County, public land managers would have had to protect the residents in coniferous areas against catastrophic wildfire.



Rocco Snart, Fire Management Officer for Jefferson County Emergency Management (JCEM), faces the daunting challenge of protecting the residents of Jefferson County. Furthermore, with over a quarter of a million acres of potential land to treat, JCEM must decide which areas to protect to best serve the public given the limited resources available. Protecting human life from catastrophic wildfire is priority number one. The protection of natural resources, the built environment, recreation values, national treasures and watersheds are supplementary but critical concerns, which are discussed in greater detail below.

Environmental Concerns

Wildfires such as the Hayman Fire are not naturally occurring events in forest ecology. Ponderosa pine forests were generally open[6] with frequent, light surface fires prior to European settlement of the West (Friederici 2003: 35). Large-scale wildfires with high intensity and high severity have a significant impact on the area's natural resources. These fires burn so hot they turn the soil hydrophobic[7] and destroy everything in their paths, creating a sterile environment. One species severely affected by the Hayman Fire is the Pawnee Montane Skipper Butterfly. In 1987, an estimated 116,000 butterflies were thought to be in the area prior to the Hayman Fire. As a function of habitat loss, there were only 5,000 individuals remaining (Curtain 2006) after the fire.

High intensity and high severity wildfires affect watersheds in the Front Range long after the fire because of increased siltation in local streams and reservoirs caused by erosion. The Denver Water Board faced this issue with the Buffalo Creek Fire in 1996, the Hi Meadow Fire in 2000 and the Hayman Fire in 2002. All of the affected areas suffered from significant rainfall after the fire that created massive flooding and erosion, which impacted the South Platte watershed. For example, 56 percent of the Hayman Fire footprint drains directly to Cheesman Reservoir, which supplies 15 percent of Denver-metro's water supply (The Pinchot Institute

2009). According to the Denver Water Board, sedimentation and erosion problems continue to exist (Denver Water 2009).

The Built Environment

Lives are destroyed when homes are lost due to wildfire. Insurance companies may cover the structures lost but people affected by wildfire can never replace family heirlooms or cherished memories left in the house, nor defray the major inconvenience of being displaced from their homes. Moreover, property values diminish as the landscape around the home is destroyed.

Wildfires can also affect critical infrastructure. For example, the Cerro Grande fire in New Mexico in 2000 threatened the Los Alamos National Laboratories, potentially affecting up to 10,000 jobs in addition to the safety and security provided by the facility's nuclear stockpile (Los Alamos National Laboratory 2010). This inferno, a prescribed fire[8] that escaped, consumed more than 46,000 acres and 235 homes" (Science News 2000).

Recreational Values and Local Economies

Many communities in the Front Range of Colorado and throughout the West depend on tourism as a significant part of their economic livelihood. When the forest is burned in a manner that devastates the landscape, tourism is negatively impacted. Outdoor enthusiasts, such as hikers, hunters, off-roaders, bicyclists and many other user groups go elsewhere to recreate. This can have devastating impacts to the local economies of small communities in the West. In 2002, Governor Bill Owens made the statement, "All of Colorado is burning today," which, according to Colorado State University professor Bob Aukerman, affected tourism by 20 percent or a $1.7 billion loss to the state's $8.5 billion annual tourism industry (Boston Globe 2003).

HISTORY

Fire is a natural occurrence in the West. Presettlement conditions (before the Euro-American arrival) consisted of natural wildfires of mixed severity. "Native Americans used fire for resource management, pest control, land clearing, fire-proofing villages, and even for malice and warfare" (Kaufmann et al. 2005, 7). The use of prescribed fire as an environmental management tool by the Native Americans improved forest health and created ecological diversity. Conversely, professional foresters in the early 1900s associated fire with destruction of natural resources and maintained a perspective that man must dominate the natural world.

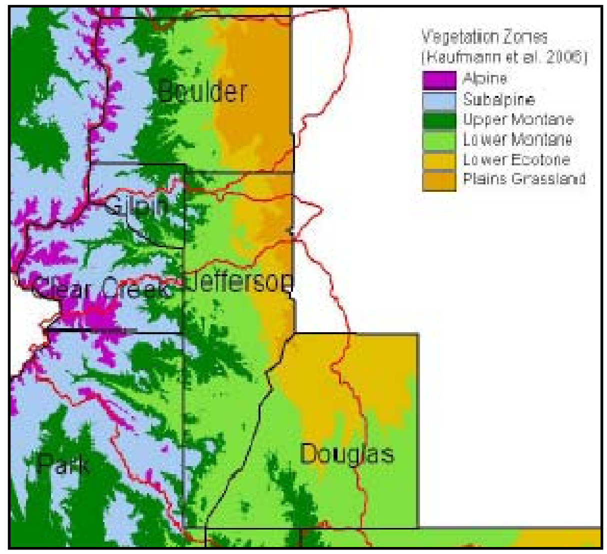


Exhibit 1: Lower Montane Region in Jefferson County.
Source: The Pinchot Institute 2009: 12

The United States Forest Service (USFS), established in 1905, soon became the lead agency in the fight against wildfires. In 1910, the "Big Blowup" – a complex of fires in Washington, Idaho and Montana – consumed three million acres of timber, which resulted in 80 fatalities (If Trees Could Talk: Essay). The USFS developed a policy for complete fire suppression to protect lives, economic values and aesthetics. The policy, implemented in 1935, became known as the "10 A.M. Policy" and stated that all fires would be controlled by ten o'clock the morning after a fire was reported (Dale 2009). This policy was developed because of pressure from ranchers, miners, loggers and the public outcry to fully suppress wildfires.

In 1944, the U.S. Forest Service created Smokey Bear. Ranking alongside Mickey Mouse and Santa Claus, this iconic symbol of the Forest Service soon became one of the most recognized fictional characters in America. Ninety-seven percent of adults were able to recall Smokey Bear's slogan, "Only You Can Prevent Wildfires" without prompting, according to an Ad Council tracking survey (National Association of State Foresters 2009). However, many believe this was a fatal blow for U.S. forests because the campaign depicted wildfire as destructive rather than an integral part of the natural ecosystem. The natural fire regimes, essential for the natural order of the forest, were virtually eliminated. Without this important component, forests became overgrown and prone to large scale insect and disease outbreaks. Lack of natural fires also helped create the conditions for catastrophic wildfire because of the increased fuel loading built up over time within the forest.

Beginning in the 1960s, the USFS moved into a management role to "get the cut out." Logging dominated the national forests as demand for wood products skyrocketed. In keeping with the utilitarian values of the USFS, the forest was managed to provide the greatest good for the greatest number of people. However, beginning in the 1990s, public lands managers realized that our forests were becoming unsustainable and unable to resist large-scale catastrophic wildfires. This began the restoration movement (Dale 2009).

Land managers now recognize that ponderosa pine forests were historically open with frequent light surface fires. Low intensity burns dominated the landscape, consuming fuel loads, conifers that encroach on meadow areas, and invasive Douglas-fir (*Pseudotsuga menziesii*) in ponderosa pine stands (Covington 1997; Dennis and Sturtevant 2008; Friederici 2003; Kaufmann 2006). High intensity, high severity fires and very thick ponderosa pine forests as seen today were rare or entirely absent in lower montane forests 100 years ago (See Exhibit 2). Natural fire is responsible for creating diversity in age and structure of the forest, which ultimately creates diversity in flora and fauna within the ecosystem. Ponderosa pine forests evolved with fire, creating a mosaic of unevenly aged vegetation community types, which support a healthy, sustainable forest.

Exhibit 2: Paired photographs showing forest condition along the South Platte River just below the Cheesman Lake dam in 1903 (left) and 1999 (right). The 1903 photograph is from archives of the Denver Water Department.
Source: Kaufmann et al 2001: 15

Fire management agencies and land managers emphasize three narrow components of managing severe wildfires: fuels, weather, and topography. Humans cannot control the weather or dictate the topography, but they can alter the fuels. Researchers, such as Dr. W. Wallace

Covington from Northern Arizona University; Dr. Merrill Kaufmann from the Rocky Mountain Research Station; and Frank C. Dennis and Bob Sturtevant from the Colorado State University (CSU) have begun to look at the forest – specifically ponderosa pine in the lower montane – from a fuels reduction standpoint and, more importantly, from a restoration standpoint[9].

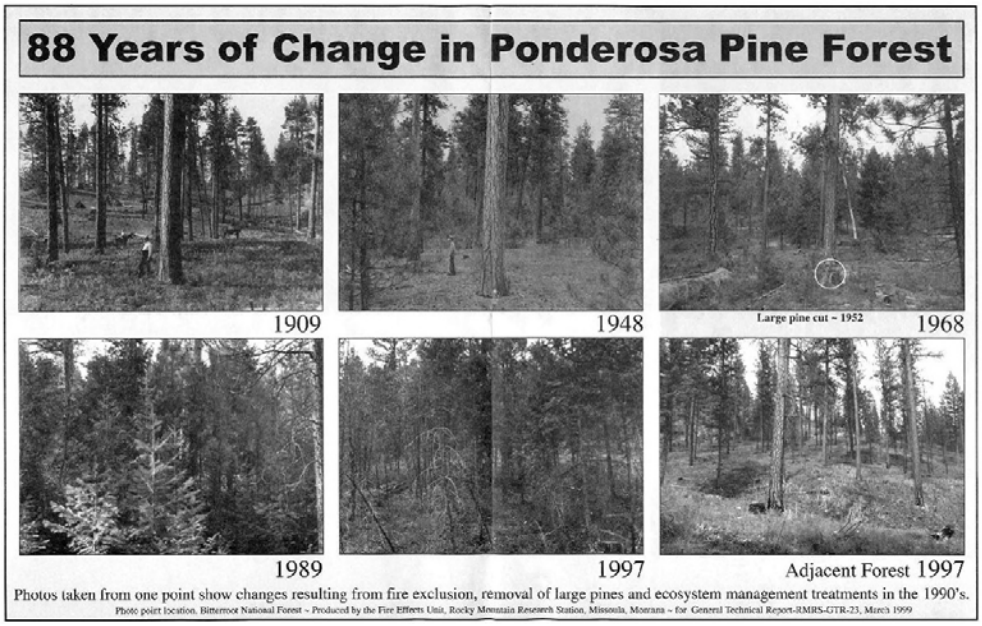
"The Flagstaff Model" – Northern Arizona University / Ecological Restoration Institute

Northern Arizona University (NAU) and the Ecological Restoration Institute (ERI) pioneered ponderosa pine restoration when they created the "Flagstaff Model" in the early 1990s. Researchers were able to determine reference conditions or presettlement conditions using dendrochronolgy, the study of tree rings.[10] Based on this finding, researchers concluded that modern day ponderosa pine stands had unhealthy characteristics including increases in tree density, forest floor depth, and fuel loading (Covington et al. 1997: 23). The study concluded that ecosystem restoration plans that combine thinning and prescribed burning reduce the potential for high intensity crown fires (known as Fuel Model 9) and promote low intensity surface fires, which are preferable (known as Fuel Model 2) (Covington et al. 1997: 28).[11] Fuel model 9 typically will produce a fire that has high intensity, high severity rather than fuel model 2, which will produce a fire that has lower intensity and severity. Therefore, managing the forest towards fuel model 2 will reduce the threat of high intensity, high severity catastrophic wildfire.

The Rocky Mountain Research Station / United States Forest Service

While there are similarities between the ponderosa pine forests in Arizona and the Front Range of Colorado, there are significant differences as well. The key similarity between the lowest elevation ponderosa pine zone of the Colorado Front Range and the ponderosa pine forests of the Southwest is that during the 20th century both areas experienced substantial increases in tree density (Kaufmann et al. 2006: 7)(See Exhibit 3).

Exhibit 3: Typical ponderosa pine forest succession with fire exclusion.
Source: Rocky Mountain Research Station 1999.



Conversely, Southwestern forests are different in two distinct ways. First, they are dominated by ponderosa pine stands. The Front Range of Colorado has ponderosa pine stands and mixed stands consisting of ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*) Second, fire-scar evidence suggests that fires in low-elevation ponderosa pine were substantially less frequent in Colorado than those reported for Arizona and New Mexico. Whereas ponderosa pine forests near Flagstaff may have experienced fire every three to ten years, Boulder County experienced fire only every ten to thirty years (Kaufmann et al. 2006: 6-7).

Front Range Ponderosa Pine Restoration Guidelines

The Colorado State Forest Service (CSFS) and Colorado State University (CSU) have developed guidelines for forest restoration in ponderosa pine forests. Ponderosa pine forests in the Front Range of Colorado have become dense and unhealthy, and thinning and prescribed fire are needed to reduce the fire danger. According to Dennis and Sturtevant (2008: 1):

> Fuels reduction in ponderosa pine is only altering the structure of the forest for the short term. Restoration on the other hand, alters the forests function for the long term. A combination of thinning and prescribed fire within ponderosa pine has the effect of reducing the fire danger and restores the forest by improving forest health. Moreover, in the long term, restoration treatments are likely to be a far more cost effective and ecologically sustainable solution to the current wildfire problem than fuels treatments alone.

Therefore, restoration of ponderosa pine forests in the Front Range reduces fuel loading while restoring the forest to a healthy condition, which will enable it to withstand catastrophic wildfire (See Exhibit 4).

Front Range Fuels Treatment Partnership

Following the worst fire season in Colorado's history in 2002, which included the Hayman Fire, ten Front Range counties formed the Front Range Fuels Treatment Partnership (FRFTP), an entity that is charged with:

> … the development of a long-term vision and roadmap for achieving comprehensive forest restoration and fire risk mitigation goals within the Front Range and to engage local communities in the effort. The goals were to reduce wildfire risks through fuels treatment projects that are economically feasible, socially acceptable, and ecologically sustainable; to protect communities from wildland fire; and restore fire-adapted ecosystems (FRFTP 2006: 4).

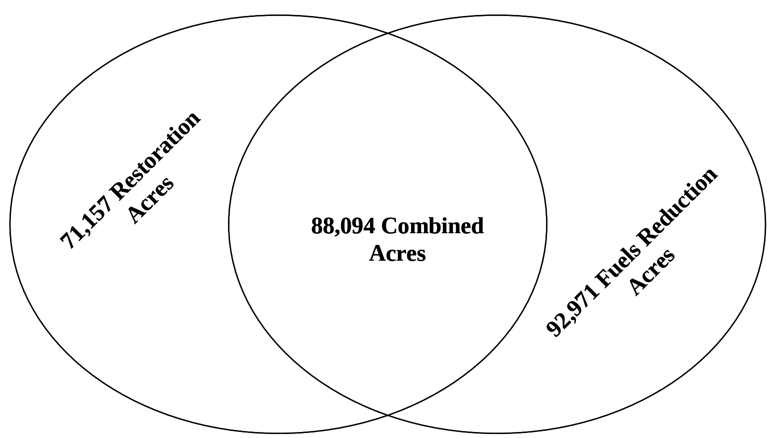
The FRFTP identified 1.5 million acres along the Front Range available for treatment to protect communities or restore forest health. Of the 1.5 million acres, Jefferson County has 71,157 acres available for restoration, 92,971 acres available for fuels mitigation and 88,094 acres that need fuels reduction and restoration. In total, Jefferson County has 252,222 acres that need treatment; 73 percent of this acreage is on private land (See Table 1).

Table 1

Front Range forests requiring forest treatment by county (acres)

	Restoration only	Fire risk mitigation only	Both restoration and fire risk mitigation	Total restoration and/or fire risk mitigation	Private land (percent of total)
Boulder	35,978	77,212	51,021	164,211	58%
Clear Creek	833	58,595	7,356	66,784	59%
Douglas	90,807	61,143	40,529	192,479	42%
El Paso	31,169	41,891	57,107	130,167	62%
Gilpin	2,177	42,365	472	45,014	63%
Grand	1,838	94,321	390	96,549	65%
Jefferson	71,157	92,971	88,094	252,222	73%
Larimer	98,856	130,956	42,350	272,162	60%
Park	27,463	122,808	31,377	181,648	57%
Teller	27,211	86,848	23,168	137,227	61%
Total Front Range	387,489	809,110	341,864	1,538,463	60%

Jefferson County: 252,222 Total Acres for Treatment



Source: Living with Fire: Protecting Communities and Restoring Forests: Findings and Recommendations of the Front Range Fuels Treatment Partnership Roundtable, May 2006: 8.

Based on extensive research and community input, the FRFTP released ten initiatives with suggestions on how to implement the plan. One of these initiatives is pertinent to this study: promote the development of Community Wildfire Protection Plans for Front Range communities that are at risk.

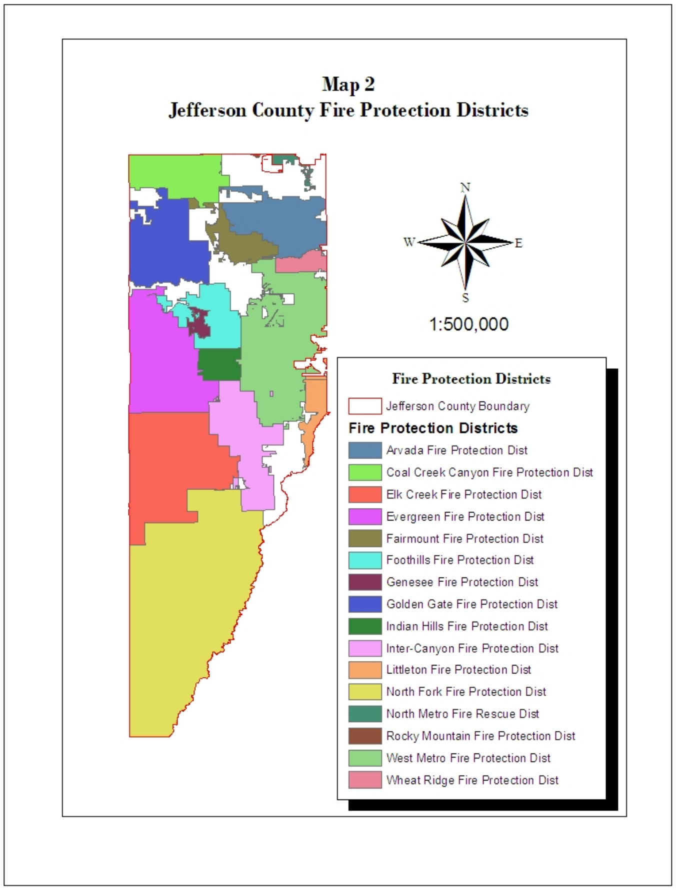
Community Wildfire Protection Plans

Community Wildfire Protection Plans (CWPPs) are strategic plans developed for all the fire districts in Jefferson County (except North Fork Fire Protection District). The CWPPs identify wildland issues facing communities and prioritize the treatment of those wildland fire issues. Created in response to the severe wildfire threat that manifested itself in the 2002 wildfire season, the CWPPs are legally reinforced by Title I of the Healthy Forests Restoration Act (HFRA), signed into law in 2003. The CWPP, as described in HFRA,

> …brings together diverse local interests to discuss their mutual concerns for public safety, community sustainability and natural resources. It offers a positive, solution-oriented environment in which to address challenges such as local firefighting capability, the need for defensible space around homes and subdivisions, and where and how to prioritize land management – on both federal and non-federal land (CSFS 2007: 3).

Once the CWPP is adopted in each fire district, it is the responsibility of the community to implement the plan. Moreover, it is the responsibility of the community to plan at the project level, acquire funds, and gather support from the community (Walsh 2007: 2).

BRIDGING THE GAP BETWEEN PLANNING AND IMPLEMENTATION: PROVIDING SAFE AND ECOLOGICALLY SOUND PONDEROSA PINE RESTORATION IN COLORADO



While the CWPPs along the Front Range of Jefferson County outline communities that are at extreme, high, moderate and low risk of wildfire in all 16 fire protection districts (See Map 2), they do not outline where treatments are feasible and ecologically sound. JCEM is now in the process of bridging this gap between the planning and implementation stages of sound fire management intervention. To do so, JCEM uses GIS mapping technology to consolidate all extreme and high-risk communities in a single category (or GIS map layer) in order to analyze potential opportunities for fuels reduction and restoration projects. By utilizing the GIS data, this study defines areas where JCEM crews should target their limited resources in order to have the greatest impact on wildfire mitigation through ecologically sound restoration projects in Jefferson County.

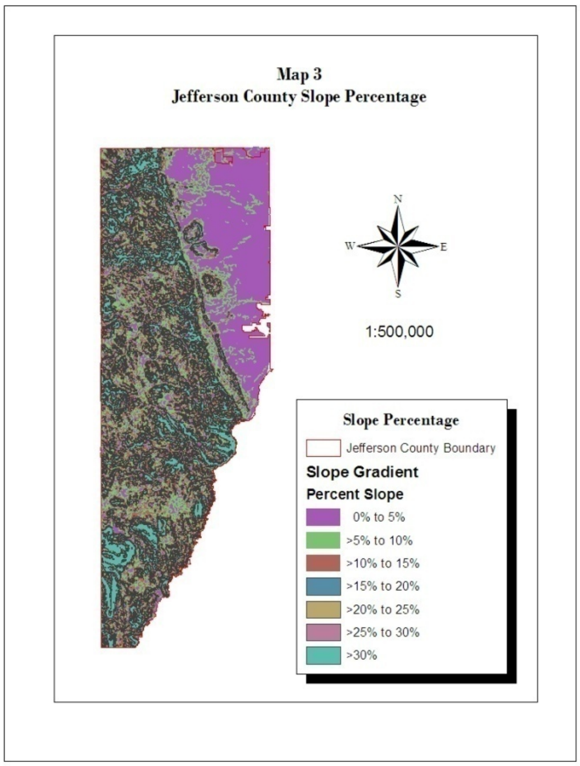
Methodology

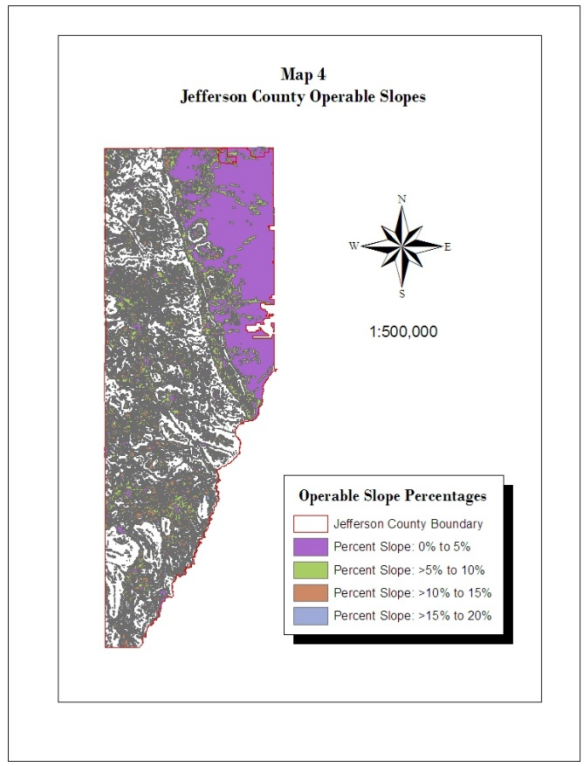
This study determines targeted operable acres throughout Jefferson County and, specifically, targeted operable acres identified by the CWPPs as extreme, high, moderate, and low (See Table 2; Appendix A) using GIS data based on the criteria of: slope, vegetation community types, public and private property, and roads. Once these critical priority target operable acres have been identified within Jefferson County, JCEM mitigation crews can implement fuels reduction and restoration projects based on the best ecological science available and operability measures that ensure the safety of crews and equipment.

GIS Criteria

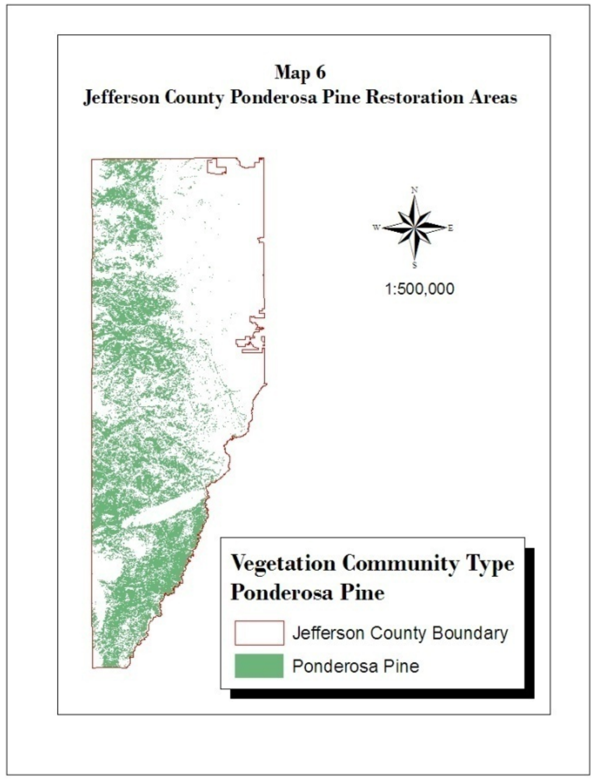
The criteria for the GIS analysis are as follows:

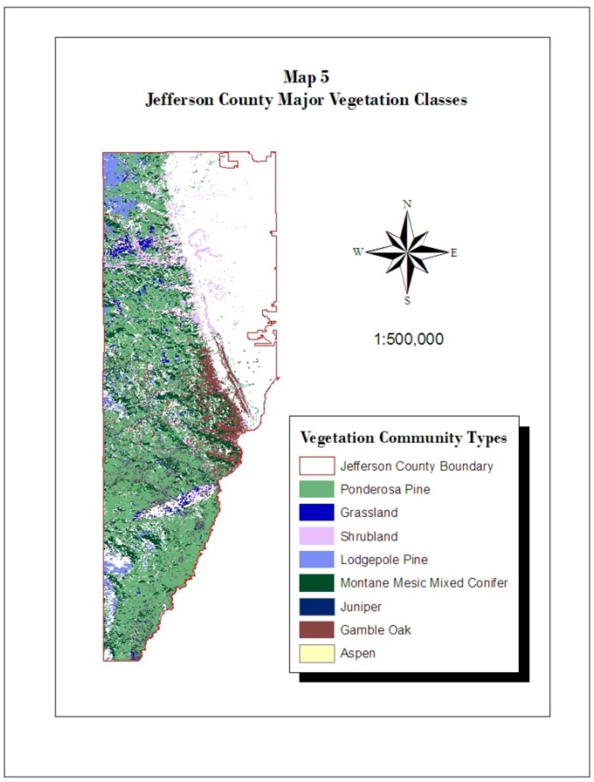
Slope: The slope percentage within Jefferson County is an integral part of this analysis. Slope has a direct correlation between the rate of spread of a wildfire and the effectiveness of forest management in the area. Jefferson County's GIS warehouse provided the slope data. Slopes typically range from zero percent to 200 percent in Jefferson County. For safety and cost effectiveness for the JCEM crews, a standard slope of operability for wheeled machines is used. "In western logging operations skidders are usually limited to maximum ground slopes between 35-45% on favorable slopes and half on adverse slopes given the same load" (Jaffe and O'Brien 2009: 30). A common piece of equipment to implement forest and fire management along the Front Range is a rubber tired skidder. Therefore, this is the basis for the slope standard. However, some agencies have more durable equipment than others, allowing them to accommodate more extreme slopes. Because of this, an average of 20% has been determined as the slope criteria for the GIS analysis.[12] Map 3 describes all slope ranges within Jefferson County, while Map 4 describes all the operable slopes within Jefferson County (slopes under 20 percent). Slope percentages between zero and 20 percent were combined as a union feature[13] class in ArcGIS – the mapping software used by JCEM.





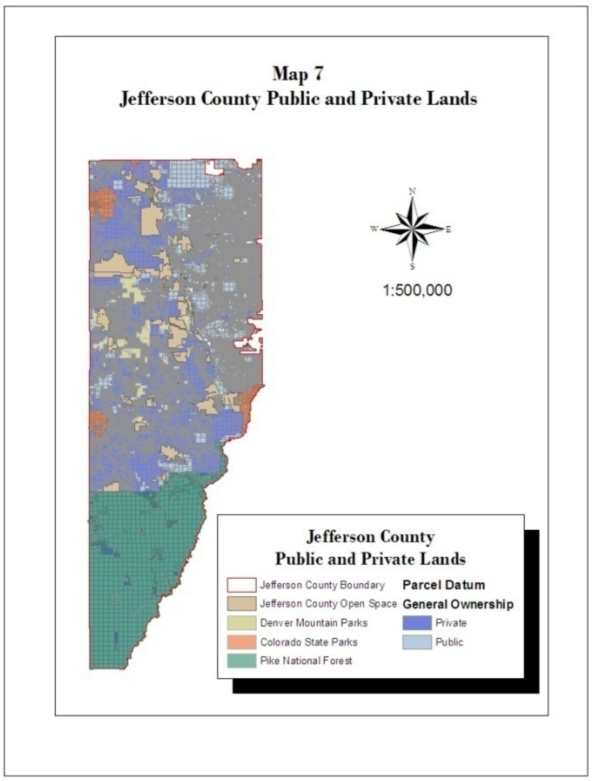
Vegetation Community Types: The United States Geological Service (USGS) provided vegetation community types. This dataset generated vegetation community types throughout Jefferson County, specifically ponderosa pine stands (USGS GAPServe 2001). Map 5 shows the major vegetation community types within Jefferson County, while map 6 shows ponderosa pine stands.

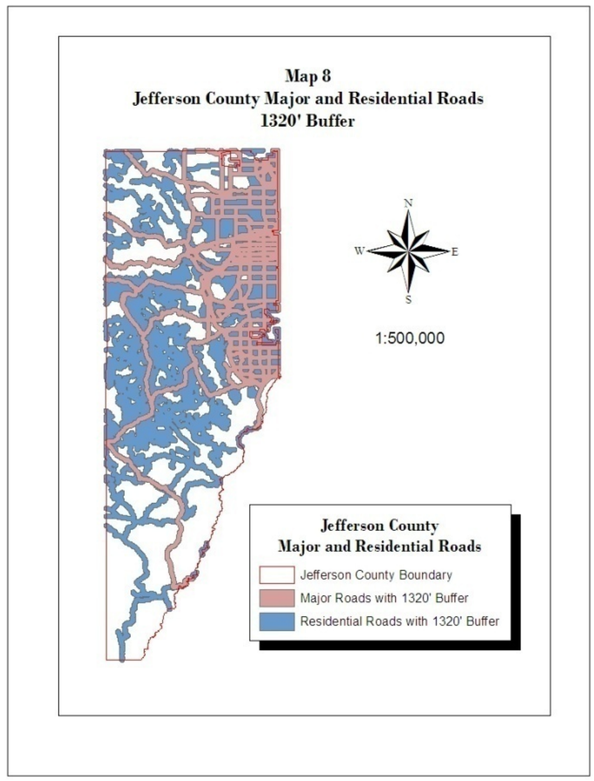




Public and Private Lands: The parcel data in Jefferson County's GIS warehouse define ownership of land throughout Jefferson County (See Map 7). This is important because an extreme fire risk community may not fit the criteria for the GIS analysis but an adjacent public property may fit the criteria. Therefore, forest and prescribed fire management may have the effect of protecting that community indirectly.

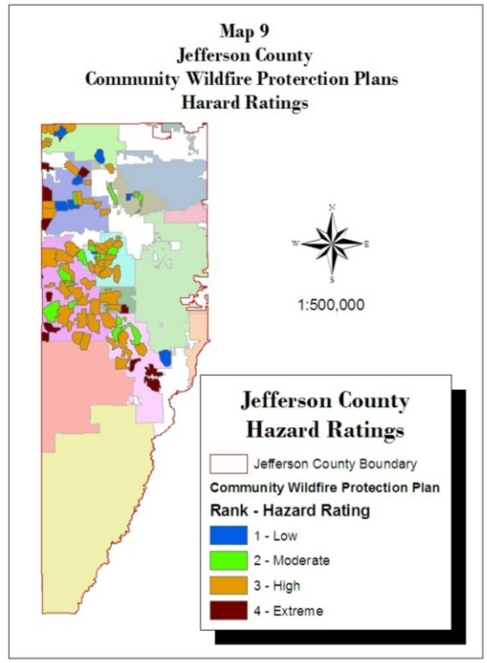
Roads: The roads throughout Jefferson County are also part of the county's GIS warehouse. Forest management requires a road system to bring in the appropriate equipment and remove forest product. Furthermore, prescribed fire management and suppressing wildland fires also take advantage of the road system for ingress and egress from an area. For this analysis, areas





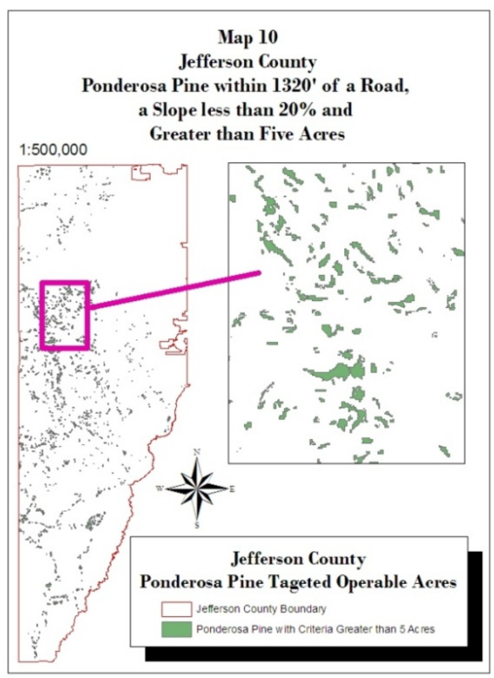
will be within 1,320 feet or ¼ mile of a road because this standard allows access by the necessary equipment to accomplish the implementation of forest restoration. (See Map 8).

Community Wildfire Protection Plans: The CWPPs gathered from each of the fire protection districts identify critical areas for management. Hazard ratings[14] identify extreme (4), high (3), moderate (2) and low (1) for wildfire risk in communities in the WUI (See Map 9). A merge[15] tool combined the wildfire risk hazard ratings into one layer within ArcGIS within Jefferson County.

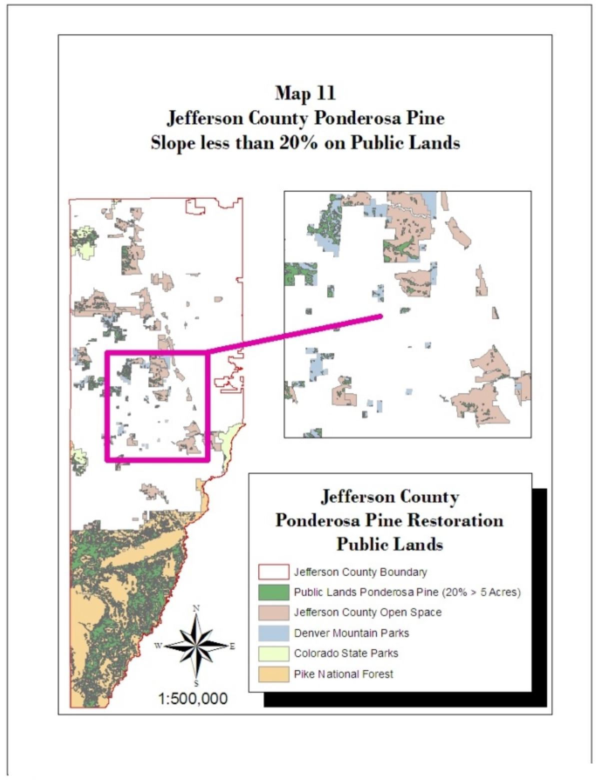


RESULTS

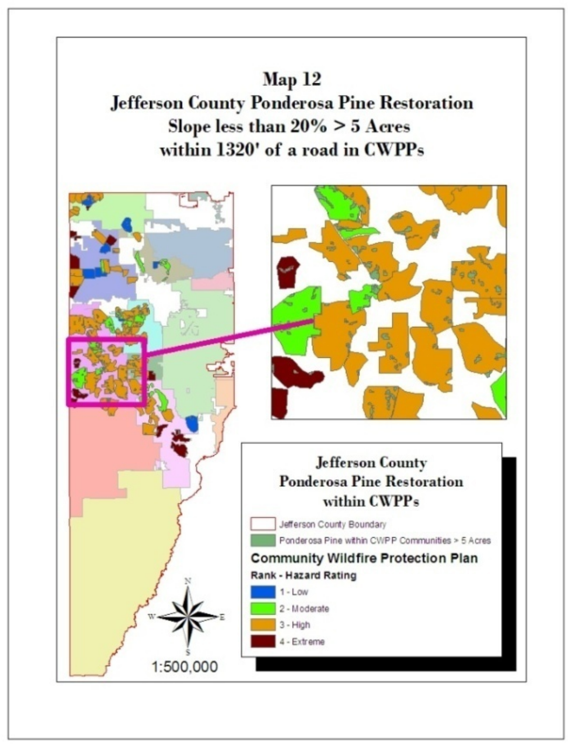
The final criterion in the analysis was a five-acre or larger parcel of land for implementation (See Map 10). Based on the criteria, there are 7,077 targeted operable acres of ponderosa pine available for restoration throughout Jefferson County.



Because Jefferson County has both public and private ownership throughout the county, the analysis projected targeted operable acres on both private and public land. Public lands were refined further to major public landholders: Jefferson County Open Space, Denver Mountain Parks, Colorado State Parks and the Pike National Forest. Because of the lack of roads within these public properties, modifications of the GIS analysis tool to accommodate areas of treatment that meet all criteria except the road criteria were developed. Much of the public lands throughout the Front Range do not have federal, state, or county roads; however, these public lands do have service roads and trails. Therefore, areas of treatment minus the road criteria were examined for the potential to indirectly protect WUI communities. (See Map 11).



Map 12 shows the areas within the WUI identified as extreme, high, moderate and low wildfire risk by the CWPPs. There are 2,181 acres of potential ponderosa pine restoration with a minimum acreage of 5 acres and a maximum acreage of 81 based on the criteria for ecologically



sound restoration. There are 119 acres of extreme wildfire risk, 1,475 acres of high wildfire risk, 491 acres of moderate wildfire risk and 82 acres of low wildfire risk available for ecologically sound ponderosa pine

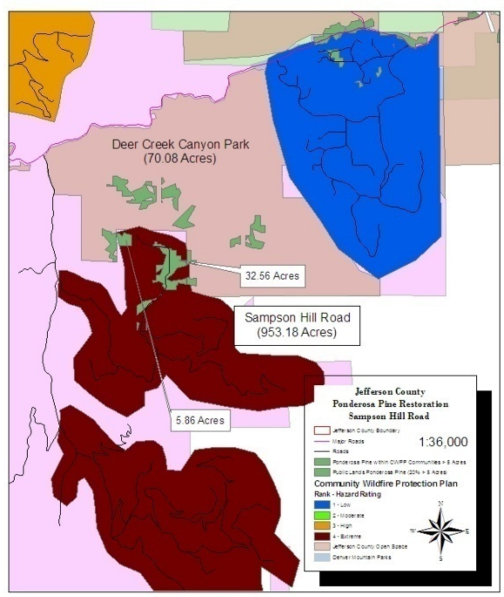
restoration (See Table 3).

Table 3

Community Wildfire Protection Plans 2181.12 Acres	
Extreme (4)	118.93 Acres
High (3)	1475.27 Acres
Moderate (2)	491.49 Acres
Low (1)	82.21 Acres

The Sampson Road community in the Inter-Canyon Fire Protection District has a wildfire risk assessment of extreme. The Sampson Hill Road community is 953 acres. Within this community, there are thirty-eight acres that fit the criteria for ecologically sound ponderosa pine restoration. Furthermore, Deer Creek Canyon Park, adjacent to the community, has seventy acres of potential ponderosa pine restoration without the road buffer criteria. Therefore, there are 109 acres within the areas that are potential areas for treatment to reduce the threat of catastrophic wildfire to the Sampson Hill Road community (See Map 13).

Map 13
SampsonHill Road Ponderosa Pine Restoration
Slope less than 20% > 5 Acres
within 1320' of a road in CWPPs



Limitations and Future Research

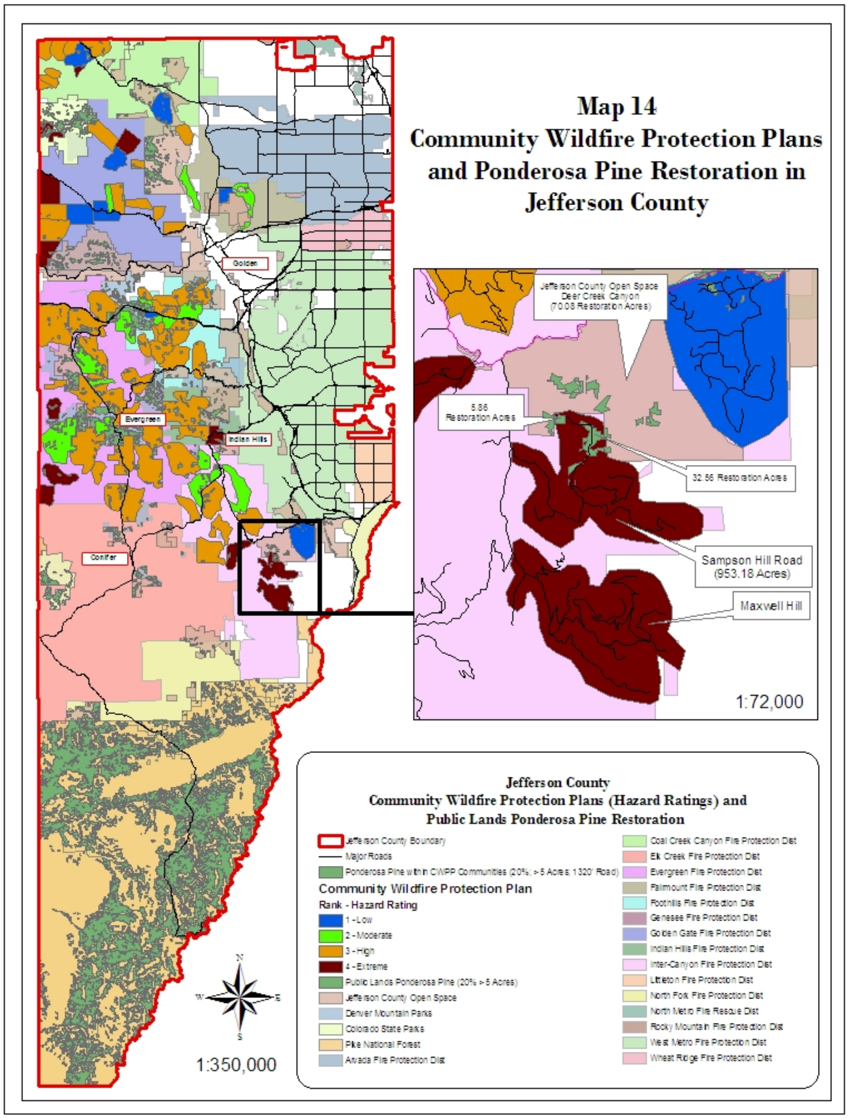
The data and the software used to manipulate the data pose the greatest limitations to this analysis. The Gap Analysis Program (GAP) data provided by the USGS is a vegetation community type model from 2001. Moreover, there are missing data from Elk Creek Fire Protection District, West Metro Fire Protection District, and North Fork Fire Protection District, which does not have a CWPP.

Areas projected as targeted operable acres for JCEM crews to implement management or contract out services require verification by ground truthing[16] by staff. This process ensures that management will be safe, have the desired ecological effect through restoration, and meet the goals for fuels reduction to protect the residents in the WUI. Further development of the GIS analysis tool by creating a ModelBuilder[17] feature within ArcMap will prove useful in altering GIS criteria.

With targeted operable acres established to protect residents in the WUI, future research projects must identify staffing and funding sources for JCEM to accomplish their mission. Funding sources and staffing are and will continue to be a challenge for land management agencies. Currently, the JCEM fuels crew is based on grant monies, which limit staffing and funding for forest and prescribed fire management in Jefferson County. A more stable funding source, such as an operating budget, similar to Jefferson County Open Space, would aid JCEM in implementing targeted operable acres throughout the county.

Policy Recommendations

The FRFTP identified and recommended 252,222 acres in Jefferson County for treatment. Of this, 71,157 acres were classified as restoration acres, 92,971 were classified as fuels reduction acres and 88,094 acres were classified as combined acres for restoration and fuels reduction. To bridge the gap between planning and on-the-ground implementation, this project concludes that JCEM crews concentrate on the 7,077 acres identified as targeted operable acres countywide. Moreover, it is recommended that of the 2,181 total acres of targeted operable acres identified within the CWPPs, the areas classified as extreme and high wildfire risk communities, 119, and 1,475 acres respectively, should be addressed as priority



number one. These areas provide the greatest potential gains for protecting residents in the WUI and have been determined to be ecologically sound (See Map 14). As JCEM plans for the future, it is important to evaluate and monitor treatment areas for effectiveness in both protecting the residents in the WUI and providing sound ecological restoration of our Front Range forests.

With limited resources, funding and staffing, JCEM must concentrate on areas that will do the greatest good with the greatest cost efficiency. By concentrating on targeted operable acres, JCEM can have an impact on wildfire protection within the WUI along the Front Range of Colorado, protecting residents and forests. Moreover, targeted operable acres provide a strong foundation for the justification of implementation on lands both public and private. With targeted operable acres identified, JCEM can coordinate with landowners to treat these critical acres. With adequate staffing and funding, JCEM can ensure residents of Jefferson County that their efforts toward meeting the goals and objectives set forth in JCEM's mission are being met.

CONCLUSION

Because the GIS analysis tool was built within ArcGIS, JCEM staff can now alter the parameters: slope, road buffers and vegetation community types, to expand targeted operable acres for the future. For example, if JCEM staff determined that their crew safety would not be jeopardized by an increase in the slope standard from 20 percent or less to 30 percent or less, they would be able to increase the targeted operable acres with the new GIS analysis tool, created for this project, assuming all other criteria remains the same. This may have a higher cost due to the increased complexity of the operation, but the benefits may warrant such actions.

Agencies throughout the Western United States, the Southeastern United States and the world can also develop GIS tools to determine targeted operable acres to target specific management areas based on their own criteria. Determining these critical areas is vital to treat acres effectively and cost efficiently. Ecologically sound ponderosa pine restoration with effective placement in the landscape can protect communities from catastrophic wildfire and return our forests to a healthy, self-sustaining ecosystem resistant to large, destructive fire events.

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Appendix A: This table shows the different fire protection districts within Jefferson County and the extreme and high fire risk communities that each is responsible for.

Table 2: Community Wildfire Protection Plans Matrix

Fire Protection District	Extreme	High
Coal Creek Canyon	Burke, Wondervu	Nadm, Chute Road, Lyttle Dowdle, Camp Eden, Coal Creek Height, Stanton, Crescent Park, Copperdale, Miramonte, Vonnie Claire
Golden Gate	Bear Paw, Geneva Glen, Douglas Mountain-South	Douglas Mountain-North, Horseradish Gulch, Thea Gulch, Window Rock, Drew Hill, The Grange Area, Robinson Hill-West, Bear Road/Lower Canyon, North Ranch
Fairmount Fire		Indian Head
Foothills		Ski Hill, Rainbow Hill, Moss Rock, Mount Vernon Club Place, Cody Park, Hess, Zephyr, Krestview, Lininger, Idledale, Mount Vernon, Lookout Mountain: Columbine, Cedar Lake, Grandview, Buffalo Bill Historic Site
Genesse		Ski Hill (FFPD), Tamarac, Montane West, Genesee Vista, The Preserve, Montane East, Grapevine (shared with FFPD)
West Metro		Willow Brook, Willow Spring South, Red Rocks
Indian Hills	285 Area	Upper Indian Hills, Lower Indian Hills
Evergreen	Echo Hills, Brook Forest Estates, Upper Cub Creek, Rosedale Acres, Segar Acres, Beaver Brook Canyon, Highland Hills, Chase Subdivision, Elmgreen Acres, Pleasant Lane, Homestead Hideaway, Buffalo Park Estates, Evergreen Hills	Evergreen West, Greystone Estates, Independent Heights, Forest Hill, Mountain Park Homes, Bear Mountain Vista, Stanley Park, French Springs, Cub Creek Ranch, Evergreen Highlands, North Marshner, South Marshner, Soda Creek, Fox Ridge, Circle K, Bendemeer Valley, Golden Willow, Greystone Lazy Acres, Bear Creek Estates, Diamond Park, Wilderness Point, Beaver Brook, Beaver Brook Lodge Estates, Hoffer Heights, Pine Valley Estates, Evergreen Meadows East, Estates of Blue Creek, Blue Creek Road, Hiwan Hills, Hidden Village at Hiwan, Douglas Park, Hiwan Homestead Museum, Pine Valley Estates, Hillcrest Village, Peaceful Hills, Herzman Mesa, Wonderview, Pine Crest Park, Sunset Heights, High Prairie, Far View Acres, Craigmont Estates, Marshdale Park, Marshdale, Tanoa, Overlook, Palo Verde, Troutdale Estates, Glen Eyrie, Bear Creek, The Ridge at Hiwan, Evergreen Park Estates, Evergreen Heights, Evergreen Golf Course, Evergreen Valley Estates, Columbine Road, El Pinal Acres, Kittredge, Quartz Mountain, Pine Valley Acres, Mountain Meadow Heights, Evergreen Meadows West, Timbers Estates, Hidden Valley, Ruby Ranch, Nob Hill, Avery Acres, El Rancho
Inter-Canyon	McKinney Ranch, Sampson Rd, Maxwell Hill	Homestead East, Tiny Town, Double Header, Murphy Gulch, Hilldale, Jennings Road

Appendix B: The data analysis section describes the reasoning for the GIS criteria selected for this project and how these criteria shape targeted operable acres within Jefferson County for on the ground implementation.

Data Analysis

To attain the targeted operable acres for restoration efforts within Jefferson County, the GIS analysis combines the criteria by acreage. A union function within ArcGIS creates one feature class for the roads, vegetation community types and slope percentages, which was combined by common attributes through an intersect[18] function that created a feature class of areas that shared an area that had a slope less than 20 percent, within 1,320 feet of either side of a road and a vegetation type of ponderosa pine. Moreover, these criteria must fall within the CWPP identified extreme and high wildfire risk communities. Finally, only areas that have all the criteria and exceed five acres will be considered for restoration efforts based on the assumption that the desired effects will have a significant impact on-the-ground.

Because of the large scale of Jefferson County, this study concludes with a case example of an extreme fire risk community within Jefferson County using the GIS criteria. This case study provides an example of this project's intention to identify areas that fit defined criteria for targeted operable acres. The community on Sampson Hill Road, in the Inter-Canyon Fire Protection District, provides an example of an extreme wildfire risk community that has both public and private land within and around the community. Public lands near Sampson Hill Road are evaluated with all the criteria except the 1,320 feet from road criteria for possible management to indirectly protect the Sampson Hill Road community.

ENDNOTES

[1] The Front Range of Colorado is a geographic region in Colorado that extends north and south from Pueblo, Colorado to Cheyenne, Wyoming and east and west from the eastern plains to the continental divide.

[2] Wildland Urban Interface (WUI): Defined as the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels (CSFS 2002: 15).

[3] Fuels reduction, defined by the Colorado State Forest Service, are forest management prescriptions that focus on lowering the fire risk by removing ladder fuels and reducing crown connectivity through mechanical fuels treatments or prescribed fire (Dennis and Sturtevant 2008:1).

[4] Restoration is forest management prescriptions that alter both the forest structure and function and lower fire danger, while increasing biological diversity, producing a long term, healthy, self-sustaining forest ecosystem through mechanical thinning and prescribed fire (Dennis and Sturtevant 2008:1).

[5] The Red Zone is where present fuels, topography and high value areas intersect. There are 2.4 million acres of the Red Zone in the Front Range and 6.3 million acres statewide (Lynch and Mackes 2002; Colorado Mountain Estates CWPP 2007).

[6] Historically, ponderosa pine stands were open, meaning they have an open canopy. Conversely, ponderosa pine stands today are typically closed canopy, having no gaps in the over story.

[7] Hydrophobic soils are produced by very high temperature wildfires that are high severity and high intensity. This creates a layer in the soil that cannot absorb water. Therefore, when there is a rain event after the fire there is massive flooding and erosion.

[8] Prescribed Fire: "The planned and/or permitted use of fire to accomplish specific land management objectives" (CSFS 2002: 14).

[9] These are different forest management prescriptions to accomplish different management goals. Fuels reduction standpoint is to reduce fuel regardless of being ecologically sound. Conversely, restoration is returning the forest to an ecologically sound condition that is resistant to catastrophic wildfire.

[10] Researchers use dendrochronolgy to determine what ponderosa pine forests looked like prior to European settlement. Reference conditions are defined as conditions that existed prior to European settlement of the West. Determining reference conditions is vital because it is a historical record of what a healthy, self-sustaining forest looked like. However, according to the Colorado State Forest Service, reference conditions are not necessarily the same as restoration goals. Factors, such as, social, economic, or other management considerations may make it impossible or undesirable to fully recreate reference conditions (Friederici 2003; Dennis and Sturtevant 2008).

[11] Fuel models, as defined by the United States Forest Service, describe fuels in four groups; grasses, brush, timber, and slash. These groups are broken into subgroups that are related to the fuel loading and fuels size classes to predict fire behavior in a specific area (Anderson 1982).
[12] This study defines slope as a percentage. However, slope notation can also be expressed as slope angle or degrees. Slope percentage is (vertical distance / horizontal distance) * 100. Slope angle or degree is the Arctan (vertical distance / horizontal distance) (Menashe 2004). Therefore, a 100 percent slope equals a 45 degree slope.
[13] In GIS, a union is defined as the vertical combination of two spatial data layers, typically over the combined extents of the data layers, and preserving data from both layers. A feature is an object in the landscape, a digital representation of the object. (Bolstad 2008: 559, 567).
[14] Hazard rankings provide quantifiable guidance to determinate priorities among mitigation treatment projects (Walsh 2008:27).
[15] Merge is a GIS tool that combines any selected polygons, regardless of their attribute values (Ormsby et al. 2004: 416).
[16] Ground truthing refers to staff visiting the site on-the-ground to verify results produced by computer hardware and software.
[17] ModelBuilder is a graphic design tool for diagramming solutions to spatial analysis problems. It is an interconnected set of processes, each consisting of input data, a tool, and the resulting output data (Ormsby 2001: 517-518).
[18] In GIS an intersection is the vertical combination of two data layers, typically restricted to the extent of one data layer but preserving the data contained in both data layers for that extent (Bolstad 2008: 560).