THE STRATEGIC TREATMENTS FOR FIRE USE ALTERNATIVE

Prepared by

THE CENTER FOR BIOLOGICAL DIVERSITY

For the benefit of

THE FOUR FOREST RESTORATION INITIATIVE
STAKEHOLDERS AND THE U.S. FOREST SERVICE

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EXECUTIVE SUMMARY

The U.S. Forest Service (USFS) is currently preparing an Environmental Impact Statement (EIS) for 'Rim Country' - the 2nd phase of NEPA planning under Arizona's Four Forest Restoration Initiative ("4FRI"), the largest forest restoration project yet undertaken in the U.S. and a centerpiece of the Collaborative Forest Landscape Restoration Program (CFLRP). As a foundational member of the 4FRI collaborative, the Center for Biological Diversity ("The Center") shares a deep commitment to accomplishing landscape-scale forest restoration. However, the Center is increasingly concerned that Rim Country planning is headed in the wrong direction, putting the entire effort at risk. Specifically, we feel that Rim Country has deviated from core tenets of 4FRI and the zone of agreement between USFS and 4FRI stakeholders, is overly reliant on mechanical thinning to meet restoration objectives, does not adequately reflect current policy guidance, and fails to incorporate the best available science. To address these concerns, on March 13, 2018, The Center submitted a formal request for a new, stand-alone *Strategic Treatments for Fire Use Alternative* to the Regional Forester and 4FRI Board. This follow-up document presents detailed background, justification, and design parameters for the requested alternative.

The current restoration paradigm underlying Rim Country is seriously flawed. It retains allegiance to the regulated-forest model, which requires regular mechanical intervention to attain and maintain "desired conditions" of forest composition and structure - an approach that is clearly at odds with natural disturbance regimes in these forests, by emphasizing fixed structural attributes rather than those shaped by spatially and temporally dynamic natural processes. USFS has also proposed aggressive mechanical treatments aka "Extended Duration Restoration" (EDR), which have uncertain ecological impacts and unknown ability to meet restoration objectives. From an operational perspective, Rim Country assumes that mechanical thinning can be applied at scale in a timely fashion, which has thus far proven unattainable across much of the first 4FRI EIS area. That unfortunate situation is unlikely to improve, and may in fact worsen, if new industry cannot be successfully established and a succession of new projects produce large volumes of biomass and other low-value material having few outlets. Simply put, USFS is attempting to impose a simplistic and arguably non-viable silvicultural solution on a complex ecological problem that is becoming ever more acute.

Given these circumstances and uncertainties, The Center asserts that expanded use of prescribed and resource benefit fire, coupled with strategic placement of mechanical treatments, is the best means to accomplish implementation of Rim Country in an ecologically sound manner and within reasonable time frames. The Rim Country landscape is ideally positioned for this, with current management direction strongly supportive of enhanced fire use. The *Strategic Treatments for Fire Use Alternative* is a principled, attainable, science-based approach to protect values-at-risk from undesirable fire effects, while allowing natural process-structure interactions to drive ecosystem restoration and improve resiliency.

The *Strategic Treatments for Fire Use Alternative* builds upon an extensive body of work by USFS and academic scientists, providing a spatially-explicit means to prioritize the Rim Country landscape and identify optimal treatment actions. The strategy incorporates the probability of an area to support fire of low, mixed, or high-severity, values-at-risk, existing planning/prioritization, a consensus-based suite of treatments, and key elements of the current proposed action for Rim Country. Under the *Strategic Treatments for Fire Use Alternative*, the planning area would be stratified into three management area tiers which provide for *Community Protection, Strategic Thinning Treatment,* and *Fire Use*. *Community Protection* areas (Tier 1) would be defined by existing plans and buffers around values-at-risk and represent the highest priority for mechanical treatment. *Strategic Thinning Treatment* areas (Tier 2) represent the next priority level for mechanical treatment and would be defined through optimization analysis. The proposed "Flexible Toolbox Approach" (FTA) could be applied within Tier 2, with addition of a "fire-only" option where stand conditions permit. *Fire Use Management Areas* (Tier 3) include all areas not included in Tiers 1 and 2, and would be treated using prescribed or resource benefit fire. We present recommendations for defining these management zones, with the expectation that they would be further refined through the collaborative process.

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I. 4FRI IS HEADED IN THE WRONG DIRECTION

The origin of the contemporary health crisis affecting Southwestern forests lies squarely on past attempts to bring order to wild, natural ecosystems. Fire suppression, old-growth liquidation, excessive livestock grazing, and application of silvicultural systems designed to maximize sawtimber production are primary factors that led to degraded forest health, diminished ecological integrity, and reduced resilience to climate change and other perturbations. Recognizing the need for comprehensive ecological restoration of degraded fire-adapted forests, watersheds, and endangered species habitats, a diverse group of stakeholders united in search of solutions, in what later became the Four Forest Restoration Initiative ("4FRI"). A seminal report by these stakeholders was the Statewide Strategy for Restoring Arizona's Forests ("Statewide Strategy"),[1] released in June 2007; two years before the Collaborative Forest Landscape Restoration Program (CFLRP) was authorized by Congress. Following passage of the CFLRP, stakeholders developed other foundational documents, including *The Path Forward* (March 2010), and the *Landscape Restoration Strategy for the First Analysis Area*[2] (October 2010), among other key collaborative products. These steps led to the 2011 Memorandum of Understanding (MOU[3]) between 4FRI stakeholders and the U.S. Forest Service (USFS), and ultimately to the Record of Decision that initiated implementation of the consensus-based plan analyzed in the first EIS (April 2015).

The Center believes that 4FRI planning is now moving in the wrong direction, with excessive emphasis on structural manipulation and insufficient attention to fire-driven ecological processes. In response, we have prepared the *Strategic Treatments for Fire Use Alternative* as a change of course to accomplish 4FRI's goals in a more effective and efficient manner. Fundamental to all guiding 4FRI documents is the need for strategically prioritizing and placing mechanical thinning treatments that facilitate safe application of prescribed and wildland fire. This need is consistent throughout the entire history of 4FRI. At the core of the *Strategic Treatments for Fire Use Alternative* is our position that the current direction in planning, analysis and implementation is overly reliant on meeting structural and compositional targets, representing what is in effect a non-viable silvicultural solution to a complex ecological problem. The quest to create the ideal vegetative state across every operable acre has marginalized the overriding importance of fire-driven ecological processes. Applying a new form of growth and density regulation, as articulated in GTR-310[4], cannot by itself accomplish restoration at meaningful landscape scale; only the additive effects of frequent fire can fully restore these ecosystems.

Strategically placed mechanical thinning has a critical role in Rim Country: to reduce the risk of uncharacteristic fire, and preparing for safe fire re-entry.[5] Currently, as much of the 4FRI landscape is densely stocked with dangerous surface fuel loads and ladder fuels, mechanical thinning is a viable tool

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[1] Governor's Forest Health Council, State of Arizona. June 2007. The Statewide Strategy for Restoring Arizona's Forests. Aumack, E., T. Sisk, and J. Palumbo, editors. Published by Arizona Public Service, Phoenix, AZ.

[2] Sesnie, S.E., J. Rundall, S. Hedwall, and V. Horncastle, technical editors. October 1, 2010. Landscape restoration strategy for the first analysis area: report from the Four Forests Restoration Initiative Stakeholder Group to the USFS Planning Team.

[3] Memorandum of Understanding between the 4 Forest Restoration Initiative (4FRI) Collaborative Stakeholder Group Representatives and the U.S. Forest Service, signed February 22, 2011.

[4] Reynolds *et al.* 2013. Restoring composition and structure in Southwestern frequent-fire forests: A science-based framework for improving ecosystem resiliency. RMRS-GTR-310.

[5] Stephens *et al.* 2016. U.S. federal fire and forest policy: emphasizing resilience in dry forests. *Ecosphere* 7(11): 1-19.

for preparing those areas for successful re-establishment of a predominantly low-intensity, frequent fire regime. However, if current implementation trends continue, that work cannot be accomplished at a pace commensurate with the scale of the ecological problem, and as such a course correction is needed. Because many acres identified for thinning may be poor candidates for economically-viable mechanical treatment but suitable for fire-based restoration, strategic placement of mechanical thinning is essential.

The 2011 MOU stated that "*The goal of landscape-scale restoration includes assessment of 2.4 million acres, identification of priority treatment areas, and aggressive implementation of restoration at an accelerated rate over the next 20-30 years.*" The four foundational underpinnings of this agreement (landscape assessment, NEPA analysis/planning, prioritization, and implementation) have not been fully realized. The first two elements have proven possible: the 4FRI collaborative and USFS successfully assessed and analyzed approximately half of the 4FRI landscape in the first EIS. However, the third and fourth elements have encountered significant challenges that call for an adaptive response:

1) The commitment to strategically place treatments was a foundational principle early in 4FRI's development; however, that direction was abandoned by USFS in favor of a new form of the regulated-forest model, albeit one that considers more than just timber production. The *Strategic Treatments for Fire Use* Alternative is centralized around advantages of returning to this strategic approach.

2) There was an expectation that issuing a landscape-scale, long term contract for harvest of wood fiber would facilitate expansion of industry needed to accomplish mechanical thinning objectives, particularly on the western portion of the 4FRI footprint. Unfortunately, this assumption has proven false, thanks to a series of missteps in contractor selection and their subsequent sub-standard performance.

These two facts, which are inextricably linked, support our call for strategic deployment of existing resources where they will yield the greatest restoration benefit. The degree to which 4FRI – the nation's largest CFLRP – does or does not achieve effective and timely ecological restoration will have effects beyond Arizona and the 4FRI National Forests; 4FRI has national significance and the potential to influence forest management nationwide. A successful outcome is crucially important, and as a founding Stakeholder and active party in every step in this process, the Center cannot let the current predicament go on without a return to the foundational principles and assumptions.

The Rim Country analysis will lead to a more effective outcome if it proceeds within existing consensus-based guidance developed from more than a decade of collaborative work. However, the extent of mechanical operations currently proposed under the USFS's proposed action (June 2016[6]) exceeds consensus-based determinations of the portion of 4FRI acres that should be mechanically thinned. The March 2010 document *The Path Forward* states that "*Landscape-scale restoration efforts should use elements of the consensus scenario developed in the Analysis of Small Diameter Wood Supply in Northern Arizona as sideboards for landscape scale restoration across the Four Forest Restoration area*," which includes the "*Percentage of landscape management areas to be mechanically thinned.*" The *Analysis of Small-Diameter Wood Supply in Northern Arizona* achieved consensus around mechanical thinning on appropriately 41% of the 2.4 million-acre 4FRI landscape[7]. In the first EIS, approximately 44% of the

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[6] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd506786.pdf

[7] Hampton *et al.* 2011. Estimating regional wood supply based on stakeholder consensus for forest restoration in northern Arizona. *Journal of Forestry* 109: 15-26.

analysis area was authorized for mechanical thinning – which equates to 72,000 acres beyond the consensus agreement – but because the Center is not unreasonable we did not object to this departure from the zone of agreement.

Now, the Rim Country proposed action makes up to 54% of the landscape available for mechanical thinning, approximately 161,000 acres beyond the consensus. Across both analyses, this departure equates to almost 192,000 acres. *The Strategic Treatments for Fire Use Alternative* provides a framework for reducing the total area projected for mechanical treatment to the zone of agreement shared by foundational 4FRI stakeholders. Additionally, this framework offers a pathway to return to 4FRI's original intent of prioritizing and strategically placing treatments, consistent with the most frequently cited principles for ecological restoration of southwestern ponderosa pine forests, which explicitly urge practitioners to "*Prioritize and strategically target treatment areas.*"[8]

Aggressive Structural Treatments Are Unproven and Unjustified

The USFS's current emphasis on aggressive structural manipulation to very low densities, as articulated in the Extended Duration Treatment (EDR) proposal for Rim Country, is an essentially unproven approach that lies outside the current zone of agreement among 4FRI stakeholders. As such, the EDR approach may be appropriate only in the Wildland Urban Interface, where infrastructure protection and fire suppression are primary management considerations. Treatments elsewhere on the Rim Country landscape should instead "*focus on creating conditions in which fire can occur without devastating consequences.*"[9] A 2013 Ecological Restoration Institute synopsis titled *Fuel Treatment Longevity*[10] identified 25 factors affecting fuel treatment longevity. Among those was "Treatment Intensity," which was only briefly mentioned as a bulleted point, and no evidence was provided supporting the notion that high intensity thinning to very low basal areas increased resilience or prolonged treatment effectiveness. In fact the opposite effect was depicted, as that synopsis cited a study from northern Arizona where "*higher-intensity treatments were found to have twice the number of ponderosa pine seedlings as low-intensity restoration treatments*,"[11] an example of where aggressive thinning may encourage dramatic increases in ladder fuels.

The Center rejects a framework which assumes that complex ecosystems can be wrangled into fixed proportions of tree ages and sizes that must be repeatedly tinkered with at 30-year rotations to maintain "desired conditions." In areas where strategically located mechanical intervention is implemented, fire alone can and should be the primary future maintenance tool.[12] Measuring the health of the forest on the basis of density-metrics represents a worn-out allegiance to a past industrial paradigm. This regulated-forest model defines successful restoration as growing large, defect-free trees as quickly as possible and ignores the complexity of process-centered ecosystem function. Restoring a forest is not an exercise in

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[8] p. 1424 in Allen *et al.* 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. *Ecological Applications* 12(5): 1418-1433.

[9] p. 1988 in Reinhardt *et al.* 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. *Forest Ecology and Management* 256: 1997-2006.

North *et al*. 2012. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. *Journal of Forestry* 110(7): 392-401.

[10] Yocum 2013. Fuel Treatment Longevity. Ecological Restoration Institute Working Paper No. 27.

[11] p. 5 in Yocum 2013

[12] North *et al.* 2012
Reinhardt *et al.* 2008

manipulating every quantifiable metric into a neat category, or alleviating any form of stress that might lead to unexpected mortality. Renowned fire ecologist Dr. Pete Fulé stated that "*The fire-related adaptations of pine forests are associated with fire's role as a selective force going far back in evolutionary time*,"[13] suggesting that restoration of fire adapted dry forests is inseparable from the influence of recurrent fire as a primary selective force.

The effect of mechanical thinning to very low density and basal area on drought resistance in ponderosa pine and mixed conifer forests has not been studied in long-term, replicated studies with broad geographic inference, and as such, is poorly understood.[14] Ecologists with USGS and USFS recently stated that "*the utility of basal area reduction for minimizing drought impacts in natural forests remains relatively unexplored, especially in dry forests like those of the Southwest US that may be particularly vulnerable to drought*."[15] There has been very little research to date assessing the effect of dramatic canopy reduction on soil heating and drying, which are significant concerns to forest managers. A study from the Fort Valley Experimental Forest found that stands thinned to basal areas of 30 to 100 ft^2/acre supported favorable microenvironments for early seedling establishment of ponderosa pine.[16] However, the study did not conclude that the 'low density' treatments (30 ft^2/acre) were any more effective than the 'moderate' density treatments (100 ft^2/acre) at providing conditions conducive to regeneration. Interestingly, the researchers found that basal area was negatively correlated to seedling survival. This finding suggests that excessively heavy thinning treatments will likely cause overly successful regeneration - a significant management challenge if prescribed or managed fire is not frequent enough to prevent development of dangerous ladder fuels, a phenomenon evident in many areas within the Rim Country footprint. Ongoing studies at the same site have not observed a clear correlation between lower basal area treatments and increased soil moisture during the critical pre-monsoon moisture deficit, and several years of additional data collection may be needed in order to identify any potential relationships.[17]

Complicating the translation of best available scientific information into management direction is the lack of consistency among key descriptors of forest density, especially as it relates to the effects of mechanical thinning on tree ecophysiology and soil-water/drought relationships. Such was the case with Petrie and colleagues research which suggests that 'intermediate' level thinning that minimizes soil surface temperatures will likely promote survival of ponderosa pine seedlings under climate change driven temperature rise.[18] While they do not provide any clarity on what 'intermediate' thinning constitutes, it is noteworthy that they did not suggest 'low' density thinning as a panacea for drought resistance. Another example can be found with Zou and colleagues, who studied soil water dynamics in 'low-density' and

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[13] p. 528 in Fulé 2008. Does it make sense to restore wildland fire in changing climate? *Restoration Ecology* 16(4): 526-531.

[14] D'Amato *et al.* 2013. Effects of thinning on drought vulnerability and climate response in north temperate forest ecosystems. *Ecological Applications* 23(8): 1735-1742

[15] p. 12 in Bradford and Bell. 2017. A window of opportunity for climate-change adaptation: easing tree mortality by reducing forest basal area. *Frontiers in Ecology and the Environment* 15(1): 11-17

[16] Flathers *et al.* 2016. Long-term thinning alters ponderosa pine reproduction in northern Arizona. *Forest Ecology and Management* 374: 154–165.

[17] Personal communication; J. Bradford and C. Andrews, U.S. Geological Survey, April 24, 2018.

[18] Petrie *et al.* 2017. Climate change may restrict dryland forest regeneration in the 21st century. *Ecology* 98(6): 1548-1559.

'high-density' ponderosa pine stands at 7,550 ft. on the Pajarito Plateau of New Mexico[19]. They found that over a 4-year period, the 'low-density' stand had an order of magnitude more water available on a per-tree basis than did the 'high-density' stand. It is important to note the condition of the two stands: the 'high-density' stand had 2710 trees/hectare (1120 trees/acre) while the low-density stand had 250 trees/hectare (103 trees/acre). These results suggest that thinning down to moderate densities at the upper end of the USFS's self-crafted "Desired Conditions"[20] is effective at increasing soil water significantly, and provide another example of how the scale of densities reported in research is not necessarily consistent with ranges debated within management dialogue or proposed within EDR.

Bradford and Bell studied the interactions between tree basal area and climate across 1,854 Forest Inventory and Analysis plots in Arizona, New Mexico, Utah, Colorado, and Wyoming[21]. They found strong evidence that tree mortality is positively related to 'high' stand basal area for ponderosa pine and Douglas-fir, and that managing to 'lower' basal areas may decrease future climate-induced mortality due to high temperatures and low moisture predictions. However, their study did not define 'high,' 'medium,' and 'low' basal areas, which essentially precludes managers from translating the results into actionable guidelines. Supplemental charts provided on-line by the researchers did not provide clarity, as there are no labels noting whether density was reported in metric or standard units. As another example, Kerhoulas and colleagues found that 'heavy thinning' of ponderosa pine stimulated growth, improved drought resistance, and provided greater climate change resilience[22]. Again, the definition of 'heavy' is not standardized, and in this case 'heavy thinning' equated to thinning down to approximately 70 ft^2/acre of basal area, while 'moderate thinning' was down to ~80 ft^2 /acre and 'light thinning' was down to ~98 ft^2. Their definition of 'heavy thinning' is near the upper level of basal area prescribed under current 4FRI and Regional direction. Overall, the effects of thinning to the low end of basal area range on soil surface temperatures, soil drying during pre-monsoon drought, and related variables has not been adequately studied. Until scientists can provide clear answers, caution is warranted.

Stand and tree-level growth modelling of EDR treatments by the USFS does not account for the effects of frequent prescribed or natural fires on density, spatial aggregations, fuel profiles, and other variables. In the process of returning fire to the landscape there will be situations where high rates of mortality will occur, even in thinned stands. Frequent fire will lead to formation of fire scars on an unknown proportion of trees which may have a long-lasting influence on mortality as scarred trees break, burn-through, or are otherwise weakened. Excessively heavy thinning to very low basal area, combined with incidental mortality resulting from initial entry fire and attendant soil heating and drying, may possibly promote conversion to non-forest vegetation types. Until appropriately scaled low-density thinning is implemented and studied in a statistically robust research design, it is premature to claim that heavy thinning to the low end of the range will promote climate resiliency or treatment durability any more than less intense treatments.

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[19] Zou *et al.* 2008. Soil water dynamics under low-versus high-ponderosa pine tree density: ecohydrological functioning and restoration implications. *Ecohydrology* 1: 309-315.

[20] The Rim Country proposed action (Table 2, page 6) gives a range of 11-124 trees per acre and basal area of 20-80 BAF as Desired Conditions for ponderosa pine forest types. These ranges match what was reported in GTR-310.

[21] Bradford and Bell 2017

[22] Kerhoulas *et al.* 2013. Managing climate change adaptation in forests: a case study from the U.S. Southwest. *Journal of Applied Ecology* 50: 1311–1320.

The cumulative effects of re-establishing frequent fires should not be understated and must be thoroughly assessed in the Rim Country effects analysis. Even with cool, low-severity burns, post-treatment mortality may range between 10% and 30% of the residual trees.[23] As an example, the photo below shows a portion of the GTR-310 Bluewater demonstration site on the Cibola National Forest, New Mexico. The 73-acre site was thinned to <32 ft^2/acre and ~25 trees/acre[24] in 2010. Despite the very low density of the remaining forest, a patch of more than 50 trees across 2 acres were killed by the first fire entry following thinning. This unexpected incident of torching led to the death of at least three old-growth trees and calls into question the efficacy of attempts to restore desired structure without consideration of the aggregate effects of re-establishing frequent fire.

A 2 acre patch of mortality at the GTR-310 Bluewater Demonstration site following initial prescribed fire re-entry, July 2017

In response to the shortcomings inherent in restoration projects which rely on extensive mechanical thinning, government and academic scientists have called for reconsideration of the strict adherence to historic structural attributes as the clearest pathway towards building resilience into dry fire-adapted forests. Williams and colleagues suggested that in the dynamic context of climate change threatening the sustainability of transitional environments, restoration "*must move beyond frameworks where historic structure and composition are fixed targets for recovery.*"[25] Similarly, Millar and colleagues stated that "*attempts to maintain or restore past conditions require increasingly greater inputs of energy from managers and could create forests that are ill adapted to current conditions and more susceptible to undesirable changes… Decisions that emphasize ecological process, rather than structure and composition, become critical.*"[26] The *Strategic Treatments for Fire Use Alternative* is consistent with that framework, and more in line with widely accepted principles for ponderosa pine forest restoration[27] than the approach currently codified in the Rim Country proposed action.

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[23] Fulé *et al*. 2005. Pine-oak forest dynamics five years after ecological restoration treatments. *Forest Ecology and Management* 218: 129–145; Fulé *et al*. 2007. Posttreatment tree mortality after forest ecological restoration, Arizona, United States. *Environmental Management* 40: 623-634

[24] July 2017 Center for Biological Diversity field inventory of 13 paired 1/10th-acre and 1-acre inventory plots.

[25] p. 21293 in Williams *et al.* 2010. Forest responses to increasing aridity and warmth in the southwestern United States. *Proceedings of the National Academy of Sciences* 107(50): 21289-21294.

[26] pp. 2145-2146 in Millar *et al.* 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications* 17(8): 2145-2151.

[27] See Allen *et al.* 2002

Impediments to Implementation Threaten Viability of 4FRI as Originally Envisioned

The *Strategic Treatments for Fire Use Alternative* seeks to achieve a realistic, attainable outcome where values-at-risk are protected from undesirable fire effects, while natural process-structure interactions drive ecosystem restoration and improve resiliency. This approach is badly needed in the Rim Country EIS. The status quo formula of effects analysis is fundamentally flawed, because it assumes that 100% of the potentially treatable area receives assigned prescriptions within the expected time line. Based on current trends, it is highly unlikely that such an outcome can be achieved. Therefore, it is reasonable and prudent to consider an intermediate approach, whereby a subset of strategically located treatments can be implemented in order to facilitate fire-based restoration across the broader landscape. Such an approach was the basis of the *Statewide Strategy to Restore Arizona's Forest*s and the *Landscape Restoration Strategy* for the first 4FRI analysis area.

Leading fire scientists and managers have stated that nationwide "*The current priority and pace of fuels treatments outside the WUI is unlikely to significantly influence fire intensity and severity*."[28] Across the western United States, fuels reduction and forest restoration treatments are not keeping up with the historic fire return intervals for National Forest lands, including dry southwestern forests, resulting in a continued 'fire-deficit' where only about 50% of the required disturbance occurs on an annual basis.[29] The persistent disturbance deficit is a relic of failed past land management practices of commercial logging, fire suppression, grazing, and road building,[30] and continues to generate negative outcomes resulting from compensatory management responses, such as continued fire suppression.[31] Because of economic, legal, and logistical limitations which restrict effective large-scale implementation,[32] a full suite of techniques should be utilized to achieve restoration objectives, including dramatically increased use of prescribed fire and expanding the use of unplanned ignitions for resource benefit.[33]

Palpable, ongoing failures implementing timely and at scale mechanical treatments across much of the 4FRI footprint call into question the USFS's ability to accomplish accelerated landscape-scale restoration. These include: the loss of millions of dollars in just a few years by selected 4FRI contractors;[34] the inability of those contractors to complete more than a tiny fraction of contracted thinning;[35] USFS errors in basic record-keeping;[36] and soaring costs of implementation that exceed even the most well-crafted subsidy funding mechanisms.[37] Concerns surrounding the selection and capacity of the original and

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[28] p. 393 in North *et al.* 2012.

[29] Vaillant and Reinhardt 2017. An evaluation of the Forest Service hazardous fuels treatment program—are we treating enough to promote resiliency or reduce hazard? *Journal of Forestry* 115(4): 300-308.
Personal communication: Tessa Nicolet, USFS Region 3 Fire Ecologist, Sept. 23, 2017.

[30] Kauffman 2004. Death rides the forest: perceptions of fire, land use, and ecological restoration of western forests. *Conservation Biology* 18(4): 878-882.

[31] Calkin *et al.* 2015. Negative consequences of positive feedbacks in US wildfire management. *Forest Ecosystems* 2:9.

[32] Collins *et al.* 2010

[33] Stephens *et al.* 2009. Fire treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. *Ecological Applications* 19(2): 305-320.
North *et al.* 2015b.

[34] Arizona Republic, December 10, 2017: "Conservationists boost logging to restore national forests…"

[35] Arizona Daily Sun, January 31, 2018: "Flagstaff-area forest thinning falters"

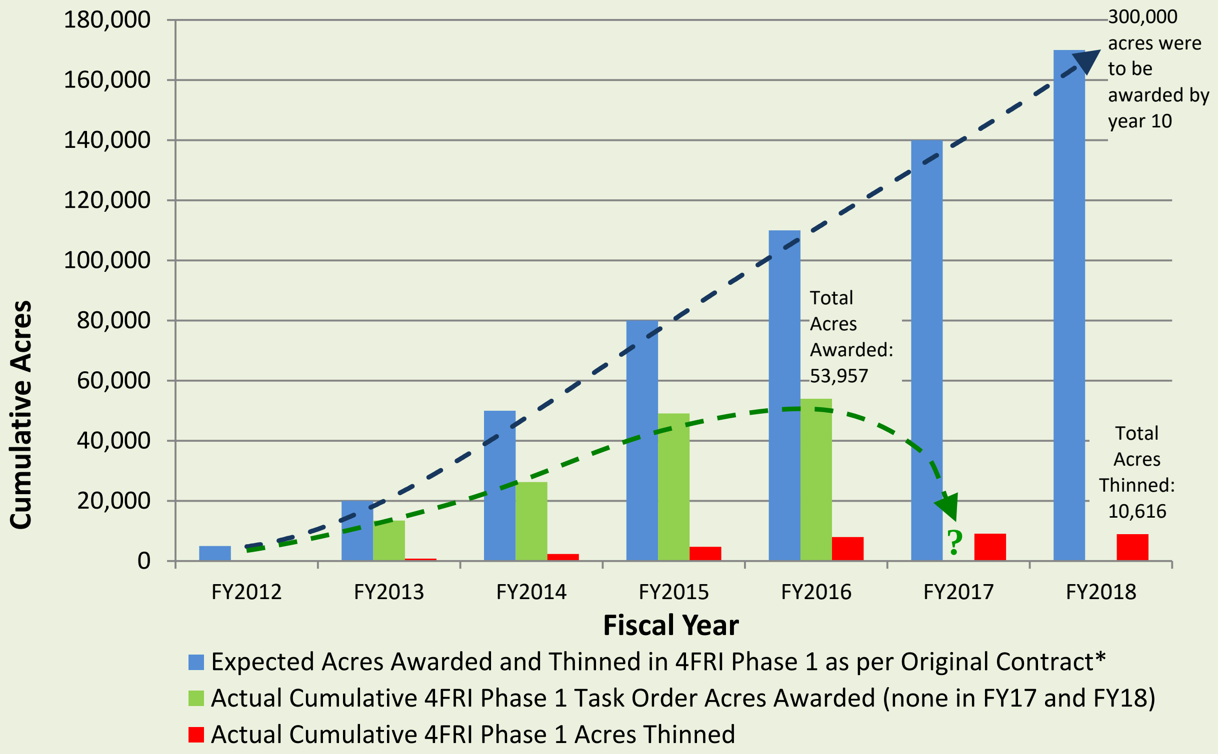
[36] Arizona Daily Sun, April 17, 2018: "Two steps forward, one step back at restored springs south of Flagstaff"

[37] Arizona Daily Sun, February 11, 2018: "City: $10 million bond not enough to cover Flagstaff forest thinning"

successive 4FRI contractors[38] and a marked lack of USFS progress making sufficient acreage available to attract new industry, have also contributed to the current cloud of uncertainty over who can and will complete the actual work of forest restoration.[39] The trend in implementing 4FRI supports our position that "*The backlog of areas in need of restoration combined with limited budgets requires that projects are implemented according to a prioritization system*."[40]

As illustrated in the figure below in red, since 2013, only 10,616 acres have been completed out of the 53,957 acres awarded to contractors for the first phase of 4FRI[41], an annual rate of around 2,000 acres per year. This amount equates to roughly 6% of the 170,000+ acres that would have been mechanically treated at this point in the original contract, had the original contractor not failed in meeting contractual obligations. These implementation rates do not meet expectations of 4FRI Stakeholders and more importantly, cannot meet the project purpose and need in a timeframe commensurate with the current forest health predicament.[42] This situation clearly undermines the validity of an effects analysis predicated on flawed assumptions of on the ground accomplishments.

Expectations Meet Reality: Acres Awarded and Thinned in the 4FRI Phase 1 Contract



* Expected acres data derived from USFS Contractor Selection Document which states: Contractor [Pioneer Forest Products] *"will begin implementation 7 to 8 months after the contract award. They proposed to begin with about 5,000 acres the first year and increase the rate of treatment to 30,000 by year 3."* Year 2 (FY2013) value of 15,000 acres is an estimate of "ramping up" from 5,000 to 30,000.

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[38] High Country News, September 1, 2014: "Lost in the woods: how the Forest Service is botching its…"

[39] Arizona Daily Sun, February 13, 2018: "Forest Service puts new 4FRI large-scale thinning contract on hold"

[40] p. 1 in Ager *et al.* 2013. Restoration of fire in managed forests: a model to prioritize landscapes and analyze tradeoffs. *Ecosphere* 4(2): 1-19.

[41] Table 3, 4FRI Monthly Update – Mechanical Thinning, Fire, and NEPA – March 2018

[42] It is important to note that significant acreage within the 4FRI footprint has been treated by White Mountains restoration businesses that preexisted 4FRI, utilizing projects authorized outside of the 4FRI EIS project area.

II. A PATHWAY TO RETURN TO FOUNDATIONAL 4FRI PRINCIPLES

The Rim Country proposed action does not include language enabling treatment prioritization or strategic placement across the 1,240,000 acre analysis area. This is in spite of the clear fact that such an approach has been a consensus element of 4FRI since its inception more than a decade ago. Prominent fire scientists and managers are increasingly calling for strategically placed treatments on portions of the landscape in order to safely facilitate the use of prescribed and managed wildfire to achieve restoration of frequent fire adapted ecosystem processes, composition, and structure. USFS researchers have established that any science-based planning should ask "*Which locations provide the greatest strategic opportunity for fuel treatments that would facilitate attainment of desired conditions*?"[43] The *Strategic Treatments for Fire Use Alternative* asks this important question. One of the Nation's foremost forest restorationists has stated that "*restoration of surface fire in most sites and thinning in strategic sites will increase resistance to severe wildfire at the stand and landscape scales, insect pathogens, and invasive non-native species.*"[44] The Center agrees with that assertion and believes that 4FRI should approach the Rim Country analysis within such a framework. We therefore request the USFS to analyze the *Strategic Treatments for Fire Use Alternative* as a standalone alternative in the 4FRI Rim Country analysis.

By integrating the fire behavior modelling methodologies used in the first 4FRI EIS with treatment optimization simulations, the *Strategic Treatments for Fire Use Alternative* builds upon the work already underway by the USFS and eliminates any perceived need to "reinvent the wheel." The *Strategic Treatments for Fire Use Alternative* also provides appropriate opportunities for implementing the Extended Duration Treatments modification and the Flexible Toolbox Approach in ways that do not compromise consensus-based decision making and the existing 4FRI social contract. The additional analytical overlays that define the *Strategic Treatments for Fire Use Alternative* would prioritize treatment areas following a treatment optimization technique developed by scientists at the Earth Systems Ecology Lab at the University of New Mexico (the Hurteau Lab). Their research[45] has developed "*prioritization strategies for implementing fuel treatments… with the goal to maximize treatment efficacy using optimal placement and prescription options under typical and extreme fire weather conditions*." [46] We propose a tiered implementation structure that combines existing treatment direction, optimized treatment locations, and fundamental 4FRI principles to define three zones with distinct management approaches. This approach could inform landscape-scale restoration planning nationwide, as "*Testing of strategic placement of treatments by resource managers will add data in the years ahead and provide information that can be shared and applied in other locations*."[47] A full description of the *Strategic Treatments for Fire Use Alternative* framework is provided in Section V of this document.

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[43] Peterson and Johnson 2007. Science-based strategic planning for hazardous fuel treatments. *Fire Management Today* 67(3): 13-18.

[44] p. 529 in Fulé 2008

[45] Krofcheck *et al*. 2017a. Prioritizing forest fuels treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. *Global Change Biology DOI: 10.1111/gcb.13913.*
Krofcheck *et al*. 2017b. Restoring surface fire stabilizes forest carbon under extreme fire weather in the Sierra Nevada. *Ecosphere* 8(1): 1-18.

[46] http://www.hurteaulab.org/

[47] p. 15 in Peterson and Johnson 2007

Current Policy and Guidance Calls For Strategic Treatment Implementation

In addition to failing to apply the best available scientific information, 4FRI is also failing to address both national fire management policy and foundational principles of the 4FRI charter. The allocation of treatments in the proposed action is overly reliant on mechanical thinning to restore structural attributes to within the historical range of variability. Mechanical restoration treatments, while proven effective to emulate historical structural and compositional attributes,[48] are not the only valid approach to enhancing resiliency, diversity, and function in fire-adapted forests. A range of treatments that can be realistically implemented is required. In a sweeping review of federal fire policy, Stephens and others recommended that the number one improvement that could be made in planning and implementing forest and fire management is to "*mandate evaluation of opportunities for ecologically beneficial fire in land management planning*."[49] The Rim Country analysis would benefit from relaxing the focus on strict structural parameters and utilizing cost-effective means that emphasize fire-based ecological process to establish landscape mosaics and maintain ecological integrity.[50]

The dramatic deficit of annual acreage burned in frequent-fire adapted forests has led senior USFS scientists to call for increasing the scale and rate of fuels treatments following three key strategies:[51] 1) Increasing the extent of fuel treatments if resources permit; 2) Designing treatments to create conditions conducive to naturally ignited fires burning under desired conditions while fulfilling an ecological role; and 3) Placing treatments to reduce hazard while providing options for firefighting when highly valued resources and assets are present. These strategies are becoming widely accepted by fire scientists and managers, but intransigence remains firmly rooted in certain elements of USFS culture.[52]

The *Strategic Treatments for Fire Use Alternative* is rooted in these strategies and demonstrative of the approach promoted in the *National Cohesive Wildland Fire Management Strategy* ("National Strategy").

The National Strategy identifies this general guidance for Vegetation and Fuels Management:[53]

i. **Design and prioritize fuel treatments.** Where wildfires are unwanted or threaten communities and homes, design and prioritize fuel treatments to reduce fire intensity, structure ignition, and wildfire extent.

ii. **Strategically place fuel treatments.** Where feasible, implement strategically placed fuel treatments to interrupt fire spread across landscapes.

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[48] Fulé *et al.* 2012. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine dominated forests help restore natural fire behavior? *Forest Ecology and Management* 269: 68-81.

[49] p. 4 in Stephens *et al.* 2016

[50] Millar *et al.* 2007; Reinhardt *et al.* 2008

[51] p. 301in Vaillant and Reinhardt 2017. An evaluation of the Forest Service hazardous fuels treatment program—are we treating enough to promote resiliency or reduce hazard? *Journal of Forestry* 115(4): 300-308.

[52] Doane *et al.* 2006. Barriers to wildland fire use a preliminary problem analysis. *International Journal of Wilderness* 12(1): 36-38.
North *et al.* 2015b. Reform forest fire management – agency incentives undermine policy effectiveness. *Science* 349(6254): 1280–1281.
Stephens *et al.* 2009. Fire treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. *Ecological Applications* 19(2): 305-320.

[53] pp. 1 and 58 in National Strategy 2014: https://www.forestsandrangelands.gov/strategy/thestrategy.shtml

iii. **Increase the use of wildland fire for meeting resource objectives.** Where allowed and feasible, manage wildfire for resource objectives and ecological purposes to restore and maintain fire-adapted ecosystems and achieve fire-resilient landscapes.

iv. **Continuing and expanding the use of all methods to improve forest and range resiliency.** Continue and expand the use of prescribed fire to meet landscape objectives, improve ecological conditions, and reduce the potential for high-intensity wildfires. Use and expand fuel treatments involving mechanical, biological, or chemical methods where economically feasible and sustainable, and where they align with landowner objectives.

Unlike the current direction of the Rim Country analysis, the *Strategic Treatments for Fire Use Alternative* puts equal emphasis on these four courses of action. These guidelines are mirrored in *The Statewide Strategy for Restoring Arizona's Forests*[54], a seminal document that established the 4FRI framework for landscape-scale forest restoration in Arizona:

"*To meaningfully address restoration, fire, and community protection simultaneously, we must identify strategies for maximizing the effectiveness and efficiency of limited forest management resources. Here we offer four promising management approaches worth serious consideration*:"

i. Strategically prioritize restoration, fire management, and community protection activities at the landscape-level

ii. Strategically place treatments to reduce the threat of landscape-scale fire events

iii. Employ prescribed fire and Wildland Fire Use as restoration and fire management tools

iv. Employ adaptive management to continually refine management approaches and increase strategic efficiency

The *Strategic Treatments for Fire Use Alternative* would bring additional focus on the first three approaches – consistent with the National Strategy – which have thus far been not been given adequate attention in formulation of the Rim Country EIS. By focusing limited resources on specific key locations, expanded wildland fire use for resource benefit can be utilized to achieve fuels reduction and ecological restoration objectives. The National Strategy clearly asserts that "*Prescribed fire and managing wildfire for resource objectives have the greatest potential for treating large areas at lower cost than mechanical treatments.*"[55] Researchers have long asserted that "*Prioritizing restoration efforts is essential because resources are limited. An initial focus on areas most likely to provide benefits and that present a low risk of degradation of ecological values will build experience and credibility.*"[56] Prominent fire scientists have recently affirmed that "*Strategically placing fuel treatments to create conditions where wildland fire can occur without negative consequences and leveraging low-risk opportunities to manage wildland fire will remain critical factors to successful implementation of the* [National] *Strategy.*"[57] The *Strategic Treatments for Fire Use Alternative* considers these fundamental principles, and prioritizes mechanical

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[54] pp. 10-12 in Statewide Strategy 2007

[55] p. 58 in National Strategy 2014

[56] Brown *et al*. 2004. Forest restoration and fire: principles in the context of place. *Conservation Biology* 18(4): 903-912.

[57] p. 8 in Barnett *et al.* 2016. Beyond fuel treatment effectiveness: characterizing interactions between fire and treatments in the US. *Forests* 7(237): 1-12.

thinning where it would be most effective to ensure community protection, preserve recreational opportunities, and restore predominantly low-intensity fire regimes.

This approach is further called for in the 2012 Mexican Spotted Owl Recovery Plan, which suggests that restoration projects "*Conduct a landscape-level risk assessment to strategically locate and prioritize mechanical treatment units to mitigate the risk of large wildland fires while minimizing impact to PACs*."[58] Additionally, the *Strategic Treatments for Fire Use Alternative* builds on the 2010 *Landscape Restoration Strategy,* which utilized (1) an assessment of current forest conditions, (2) mapping of Firescapes, and (3) fire behavior modeling; resulting in a document that provided "*a proof-of-concept for using a systematic approach to stratify a large analysis area into strategic areas for treatment area identification*" at "*three scales at which landscape-level forest restoration planning should be conducted.*" [59] The *Landscape Restoration Strategy* began when "*the USFS requested information regarding…identification and prioritization of treatment areas,*"[60] and it successfully identified areas that 4FRI Stakeholders considered the highest-priority for treatment. A similar process – consistent with ecological restoration principles – is needed in the Rim Country analysis. These are essential components of landscape scale restoration that have not been given adequate attention in 4FRI but are foundational in the National Strategy, long-standing 4FRI guiding documents, the Mexican Spotted Owl Recovery Plan, and the latest advances in science-based landscape scale planning.

III. SUCCESSFUL IMPLEMENTATION OF RIM COUNTRY REQUIRES EXPANDING THE USE OF FIRE

Abundant evidence points to the success of fuels reduction treatments including thinning, burning, and combinations of the two at restoring natural fire behavior,[61] even though restoration treatments may not produce significant changes in mean diameter, canopy base height, surface fuels, spatial aggregation, or vertical heterogeneity.[62] Despite the benefits accrued from thinning treatments, restoration of fire-adapted natural and human communities in the Rim Country landscape will require a substantial increase in the area burned annually. Fortunately, the Rim Country landscape is ideally positioned to accomplish this, as current management direction is strongly supportive of enhanced fire use. Three examples illustrate how the Rim Country landscape is moving towards wider deployment of fire:

1) Barnett and colleagues assessed nearly 4,000 wildland fires, more than 136,000 individual fuel treatments, and their interactions across ecoregions of the continental United States[63]. While less than 7% of fuels treatments nationwide were later encountered by a wildfire, the rate rose to more than 30% for the Mogollon Rim Ecoregion where there were >720 instances across >21,000 hectares where a wildfire encountered an area treated by thinning, burning, or combination thereof.

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[58] p. 262 in USFWS 2012 Mexican Spotted Owl Recovery Plan, First Revision (*Strix occidentalis lucida*). Southwest Region U.S. Fish and Wildlife Service Albuquerque, New Mexico.

[59] p. 5 in Landscape Restoration Strategy 2010

[60] p. 4 in Landscape Restoration Strategy 2010

[61] Fulé *et al.* 2012

[62] Ziegler *et al.* 2017. Spatially explicit measurements of forest structure and fire behavior following restoration treatments in dry forests. *Forest Ecology and Management* 386: 1-12.

[63] Barnett *et al.* 2016

2) Among USFS Regions, Vaillant and Reinhardt found that the Southwest (Region 3) is far ahead of the rest of the country in returning fire to the landscape[64]. Their analysis showed that Region 3, compared to the 6 other western Regions, has proportionally the most acres burned by characteristic severity wildfire, the smallest deficit of land area needing treatment to match historical acreage-burned, and the least amount of area being mechanically treated

3) The March 2018 4FRI Monthly Update of Mechanical Thinning, Fire, and NEPA projects lists 442,952 acres of Prescribed Fire and Wildfire with Beneficial Effects occurring between 2010 and 2017 across the four 4FRI National Forests, compared with 185,899 acres of mechanical thinning.

These robust macro-scale analyses and real data confirm that the Southwest Region - and the 4FRI Forests in particular - are ahead of the rest of the nation in returning fire to the landscape, often with beneficial outcomes as determined by proportion of the area burning at characteristic historic fire-severity. The *Strategic Treatments for Fire Use Alternative* would position 4FRI to build upon this trend.

Resource benefit fires tend to cover far more acres than do thinning and prescribed fire treatments.[65] Large treatments can be more effective at moderating fire behavior relative to smaller treatments because they contain more interior area and less edge and are more likely to be encountered by a wildfire.[66] Large fire footprints are more effective at modifying future fire activity than small fires and generally reduce the size of subsequent overlapping burns that occur within ten years of the initial fire, which increases manageability and benefits of subsequent fires.[67] Strategically placed treatments that facilitate the management of wildfire for resource benefit can lead to the required increases in annual wildfire acres burned.[68] Breaking the typical cycle of management reaction and suppression response by increasing the scale and frequency of large prescribed and resource benefit fire use will support sustainable feedback mechanisms whereby future suppression efforts, even in severe fire-weather events, become less necessary.[69] Because the Southwest has entered an era of longer, hotter, drier, and unpredictable fire seasons, it is critical that fire use is accelerated in order to reduce fuels, restore ecosystem process, create landscape heterogeneity, and reduce the impact and severity of the next big blaze beyond the horizon.

Evidence of Mixed Fire Severities in Southwestern Frequent-Fire Forests

Multiple lines of evidence support the occasional occurrence of fire effects outside the traditionally accepted notion that low-severity fire was characteristic of southwestern middle elevation forest types. This section discusses this growing body of evidence and is specifically focused on southwestern ponderosa pine and ponderosa pine dominated dry mixed-conifer ecosystems. Because the occurrence of mixed-severity fire is now recognized as within the historical range of variability for these forests, and there are noteworthy advantages of such effects (discussed in Section IV), there is valid scientific support

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[64] Vaillant and Reinhardt 2017

[65] Hunter *et al.* 2011. Short- and long-term effects on fuels, forest structure, and wildfire potential from prescribed fire and resource benefit fire in southwestern forests, USA. *Fire Ecology* 7(3): 108-121.

[66] Barnett *et al.* 2016

[67] Teske *et al.* 2012. Characterizing fire-on-fire interactions in three large wilderness areas. *Fire Ecology* 8(2): 82-106.

[68] Vaillant and Reinhardt 2017

[69] Calkin *et al.* 2015. Negative consequences of positive feedbacks in US wildfire management. *Forest Ecosystems* 2:9.
North *et al.* 2015b

for utilizing it as a restoration tool *where appropriate and feasible in a manner that does not put communities, infrastructure, and other key values at risk.*

The historical phenomenon of stand-replacing fire and attendant debris flows in ponderosa pine dominated mixed-conifer forests have been recorded at Kendrick Mountain on the Kaibab National Forest, Missionary Ridge in the San Juan Mountains of Colorado, The Jemez Mountains of New Mexico, at Rio Puerco in northern New Mexico, the Sacramento Mountains of New Mexico, and elsewhere throughout the West.[70] While the methods used to age severe fire events cannot suggest the size of such events, these studies uniformly conclude that fire behavior is highly sensitive to relatively modest climatic change and that it is important to include mixed-severity fire at centennial to millennial scales as a component of the natural range of variability. Roos and Swetnam reported that the combined effects of a century long fire-free period (1360 to 1455) punctuated by two unusually wet periods and followed by a hemispheric mega-drought may have led to conditions that supported widespread crown fires in southwestern ponderosa pine forests. They also suggested that similar periods of reduced fire frequency in the eighth, ninth, and sixteenth centuries may have "*led to altered forest structures that were more vulnerable to increased fire severity.*"[71]

Fire history research has provided additional support for mixed fire severities in more recent centuries. Hunter and colleagues reported that high-severity burn patches within moderate severity burn matrixes in ponderosa pine and pinyon-juniper ecosystems on the Gila National Forest were generally smaller than, but up to, 120 hectares.[72] Those findings corroborate Abolt's determinations that historical stand-replacing patches in the Mogollon Mountains ranged from 6 to 103 hectares along an elevational gradient, based off of aged aspen stands.[73] In a fire history study in the Black Mesa Ranger District of the Apache-Sitgreaves National Forest, Huffman and colleagues determined that their 1,300 hectare study site (7,600-7,900 ft.) was dominated by frequent, low-severity fires that maintained a ponderosa pine-dominated mixed conifer plant community. However, they did suggest that fire-induced even-aged regeneration events up to 25 hectares in size did occur historically, based off of spatial patterns of large trees and stumps.[74] Williams and Baker concluded that around 30% of trees survived high-severity fires along the

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[70] Jenkins *et al.* 2011. Late Holocene geomorphic record of fire in ponderosa pine and mixed-conifer forests, Kendrick Mountain, northern Arizona, USA. *International Journal of Wildland Fire* 20: 125-14

Bigio *et al.* 2010. A comparison and integration of tree-ring and alluvial records of fire history at the Missionary Ridge Fire, Durango, Colorado, USA. *The Holocene* 20(7): 1047-1061.

Fitch 2013. Holocene fire-related alluvial chronology and geomorphic implications in the Jemez Mountains, New Mexico. M.S Thesis, University of New Mexico, Albuquerque, NM.

Meyer and Frechette 2010. The Holocene record of fire and erosion in the southern Sacramento Mountains and its relation to climate. *New Mexico Geology* 32(1): 19-21.

French *et al.* 2009. Holocene alluvial sequences, cumulic soils and fire signatures in the middle Rio Puerco basin at Guadalupe Ruin, New Mexico. *Geoarchaeology* 24(5): 638-676.

Pierce and Meyer 2008. Late Holocene records of fire in alluvial fan sediments: fire-climate relationships and implications for management of Rocky Mountain forests. *International Journal of Wildland Fire* 17*:* 84-95.

[71] p. 288 in Roos and Swetnam 2011. A 1416-year reconstruction of annual, multidecadal, and centennial variability in area burned for ponderosa pine forests of the southern Colorado Plateau region, Southwest USA. *The Holocene* 22(3): 281-291.

[72] Hunter *et al.* 2011

[73] Abolt 1997. Fire histories of upper elevation forests in the Gila Wilderness, New Mexico via fire scar and age structure analysis. MS Thesis, University of Arizona, Tucson, AZ.

[74] Huffman *et al.* 2015. Fire history of a mixed conifer forest on the Mogollon Rim, northern Arizona, USA. *International Journal of Wildland Fire http://dx.doi.org/10.1071/WF14005*

Mogollon Rim,[75] which was not refuted by Fule and Colleagues, although it led to a robust discussion of what the definition of 'high-severity' really is.[76]

Studies at Grand Canyon, the Mogollon Rim, and the Gila Wilderness are also consistent with research coming from the Sierra Nevada of California. For example, a study at Illilouette Creek Basin in Yosemite National Park (4,600-9,900 ft.) determined that in Jeffrey pine and mixed conifer forests that have seen a return to near-normal fire regimes, high-severity patch sizes made up 15% of burned areas, and were typically less than 4 hectares, with occasional patches up to 60 hectares.[77]

The restoration of functional natural fire processes in the future is likely to regulate ecosystem structure and composition[78] and re-establish a new dynamic equilibrium that tracks climate effects on vegetation and landscape pattern in real time.[79] Cutting-edge research has concluded that these small patches of near or total mortality contribute to spatial heterogeneity, and may be consistent with historical spatial patterns.[80] After observing the effects of numerous resource benefit fires in the Gila Wilderness, Holden and colleagues concluded that fire-caused openings ranged in size from 0.25 to 20 hectares and that "*most of the risks, in terms of mortality to medium- and large-diameter trees are associated with the first fire after long periods of fire exclusion.*"[81]

Traditionally, the extensive body of literature surrounding restoration of ponderosa pine and dry mixed-conifer ecosystems has supported the notion that fires burned almost exclusively at low-severities. In a seminal paper on the subject, Moore and colleagues stated that "*low-frequency, high intensity stand replacement fires were very rare or nonexistent.*"[82] However, a growing body of research during intervening years, described here, suggests that a mix of severities have historically occurred across landscapes similar to or including the Rim Country area. For example, Owen and colleagues stated frankly that "*ponderosa pines evolved under fire regimes dominated by low- to moderate-severity wildfire*"[83] which is a substantial philosophical departure from Moore and colleagues' statement.

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[75] Williams and Baker 2012. Spatially extensive reconstructions show variable severity fire and heterogeneous structure in historical western United States dry forests. *Global Ecology and Biogeography* 21(10): 1042-1052.

[76] Fulé *et al.* 2014. Unsupported inferences of high-severity fire in historical dry forests of the western United States: response to Williams and Baker. *Global Ecology and Biogeography* 23: 825-830.

[77] Collins and Stephens 2010. Stand-replacing patches within a 'mixed-severity' fire regime: quantitative characterization using recent fires in a long-established natural fire area. *Landscape Ecology* 25: 927-939.

[78] Parks *et al.* 2015. Wildland fire as a self-regulating mechanism: the role of previous burns and weather in limiting fire progression. *Ecological Applications* 25(6): 1478-1492.

[79] Falk 2006. Process-centered restoration in a fire-adapted ponderosa pine forest. *Journal for Nature Conservation* 14: 140-151.

[80] Iniguez *et al.* 2009. Spatially and temporally variable fire regime on Rincon Peak, Arizona, USA. *Fire Ecology* 5: 3-21.

Margolis and Balmat 2009. Fire history and fire-climate relationships along a fire regime gradient in the Santa Fe Municipal Watershed, NM, USA. *Forest Ecology and Management* 258: 2416-2430.

Sensibaugh and Huffman 2014. Managing naturally ignited wildland fire to meet fuel reduction and restoration goals in frequent-fire forests. Ecological Restoration Institute Fact Sheet.

[81] p. 28 in Holden *et al.* 2007. Effects of multiple wildland fires on ponderosa pine structure in two southwestern wilderness areas, USA. *Fire Ecology* 3(2): 18-33.

[82] p. 1269 in Moore *et al.* 1999. Reference conditions and ecological restoration: a southwestern ponderosa pine perspective. *Ecological Applications* 9(4): 1266-1277.

[83] p. 134 in Owen *et al.* 2017. Spatial patterns of ponderosa pine regeneration in high-severity burn patches. *Forest Ecology and Management* 405: 134-149.

Additionally, Fulé and colleagues, in their noteworthy response to Williams and Bakers[84] claims of widespread high-severity fires in northern Arizona's forests, stated that "*historical fires in relatively dry forests dominated by ponderosa pine included a range of fire severities*."[85]

Increased frequency, extent, and severity of wildland fires may attend climate warming and increasing drought.[86] Numerous research approaches using a range of modelling techniques suggest that widespread conifer mortality, diminished recruitment opportunities, and high-severity fire feedbacks will reduce the range and sustainability of southwestern forested ecosystems.[87] Ponderosa pine forests have survived past mega-droughts and protracted mortality events, however,[88] suggesting that resilience-to and recovery-from extreme perturbations may be driven by complex multidirectional relationships between disturbance and abiotic and biotic factors.[89] Extreme droughts driving widespread mortality events can be followed by profoundly wet periods where fire frequency declines and tree recruitment increases.[90] Extensive bark beetle outbreaks, such as those which repeatedly occurred on the Kaibab Plateau up to the period of fire-suppression initiation,[91] can create large openings within the forest canopy, which may have increased fire severity at the patch scale as downed logs were consumed.

This evolution of our understanding of drought, insects and diseases, and occasional mixed-severity fire occurring at limited scales within the natural range of variability, as well as the utility of such fires in restoring forest structure, provides needed justification for concerns that arise from expanding the use of fire to achieve beneficial outcomes. Based on these studies, prescribed and resource benefit fires could mimic historical fire behavior by accepting higher levels of mortality in patches of up to 100 hectares in ponderosa pine, and perhaps up to several hundred or more in mixed-conifer forests during the initial fire entry*, and only in areas where such fires can be managed to protect communities, infrastructure, and other key values*.

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[84] Williams and Baker 2012

[85] p. 827-828 in Fulé *et al.* 2014

[86] Seager and Vecchi 2010. Greenhouse warming and the 21st century hydroclimate of southwestern North America. *Proceedings of the National Academy of Sciences* 107(50): 21277-21282.
Williams *et al.* 2010

[87] Savage *et al.* 2013. Double whammy: high-severity fire and drought in ponderosa pine forests of the southwest. *Canadian Journal of Forest Research* 43: 570-583.
McDowell *et al.* 2015. Multi-scale predictions of massive conifer mortality due to chronic temperature rise. *Nature Climate Change*
Petrie *et al.* 2017
Williams *et al.* 2010

[88] Brown and Wu 2005. Climate and disturbance forcing of episodic tree recruitment in a southwestern ponderosa pine landscape. *Ecology* 86(11): 3030-3038.

[89] Puhlick *et al.* 2012. Factors influencing ponderosa pine regeneration in the southwestern USA. *Forest Ecology and Management* 264: 10-19.

[90] Brown and Wu 2005

[91] Lang and Stewart 1910. Reconnaissance of the Kaibab National Forest. Available on-line at www.nau.edu/library/speccoll/manuscript/kaibab_recon.
Craighead 1924. The black hills beetle practicing forestry on the Kaibab. *Forest Worker*, November, 1924: 74.
Craighead 1925. The *Dendroctonus* problem. *Journal of Forestry* 23: 340-354.

Benefits of Mixed-Severity Fires in Southwestern Frequent-Fire Forests

Implementing a strategic approach to facilitate the expanded use of prescribed and resource benefit wildfire includes a greater acceptance of mixed-severity fire across all vegetation types in the Rim Country landscape. In this section, we review the state of our understanding of how mixed-severity fire can be a useful tool to achieve beneficial ecological outcomes. As described in the next section, sufficient evidence exists to support the occurrence of a range of fire effects in the evolutionary environment at multiple temporal scales. The diversity of fire effects is driven by factors that are common on the Rim Country landscape, such as topographic variation, disturbance history, vegetation characteristics, and proximity to values-at-risk. Because wildland fire use has been increasingly used throughout the west, research on its ecological and practical benefits has multiplied. An extensive body of science now points towards a wide range of fire intensities and severities as a critical driver of ecological restoration and fuels reduction success.

Reducing fuels and restoring historic structure.

Agee and Skinner suggested that prescribed fire is generally effective at reducing surface fuels and raising canopy base height, but because of undesirable “severity thresholds” reductions in crown density were less easy to achieve.[92] Implementing the *Strategic Treatments for Fire Use Alternative* requires reconsideration of acceptable severity thresholds. A growing body of research from dry, frequent-fire adapted forests supports the use of moderate-severity prescribed and/or natural-ignition fire in a mosaic of severities to achieve fuels reduction objectives, as well as restoring historic structure and pattern. Patchy-mosaics resulting from mixed-severity fire provide timely opportunities to conduct additional prescribed burns while fuel continuity and density have been reduced.[93] Often, subsequent fires burn at lower severity and result in fewer changes to the forest.[94]

Low severity prescribed fire alone may not always reduce canopy density sufficient to meet fuels reduction or ecological restoration objectives.[95] On the Gila National Forest (outside of the Gila Wilderness) moderate-severity resource benefit fire more effectively reduced basal area, tree density, seedling density, crown bulk density, canopy base height, and surface fuel loads than did low-severity prescribed or resource benefit fires in ponderosa pine and pinyon-juniper ecosystems.[96] Because of reductions in crown bulk density and crown base height, moderate-severity resource benefit fires in ponderosa pine and pinyon-juniper ecosystem can be more effective at reducing predicted crown fire potential than low-severity prescribed fires, even under very severe fire weather conditions.[97]

Studying the effects of a mixed-severity fire in ponderosa pine and dry mixed-conifer forest on Kendrick Peak, Kaibab National Forest, Stevens-Rumann and colleagues observed that areas of moderate-severity burn effects with mortality rates generally ranging between 40%-80% had met target basal area thresholds the highest amount of ponderosa pine regeneration, optimum coarse woody debris loadings, adequate fine

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[92] Agee and Skinner 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211(1): 83-96.
[93] Williams *et al.* 2010
[94] Holden *et al.* 2007
[95] Stephens *et al.* 2009
[96] Hunter *et al.* 2011
[97] Hunter *et al.* 2011

woody debris to carry a surface fire, and met minimum requirements for snags. The authors concluded that areas where 40-80% tree mortality occurred should be managed with reintroduction of frequent low-severity surface fires to maintain stand structure, and pointed out that these moderate-severity burned areas would be more resilient to future disturbance and would be easier to maintain than thinning overly dense ponderosa pine forests. [98] Similarly, Huffman and colleagues found that across ten single-entry resource benefit fires in northern Arizona, most structural and fuels targets were only met when fire-induced mortality exceeded 31%.[99] Hunter and colleagues compared prescribed and resource benefit fires on the Gila National Forest and their "*results show that a single fire of moderate severity alone can result in stand densities that more closely resemble pre-settlement conditions.*"[100]

Pulses of dead trees resulting from patches of high-severity fire have led to speculation increased fuel loadings may lead to amplified reburn severity. In the Southwest, patches of fire-killed trees can be expected to have fallen and substantially decomposed within one decade,[101] and even in areas of very high mortality coarse woody debris is unlikely to exceed management recommendations for fuel loadings.[102] Studies from the dry forests of the Pacific Northwest have shown that standing dead and dead/down woody debris actually experienced lower severity subsequent fires than salvage logged and replanted sites.[103] Similarly, Meigs and colleagues discovered after analyzing several hundred fires in the Pacific Northwest that burn severity was generally lower in forests with higher cumulative bark beetle damage, and that burn severity continued to decrease with time.[104]

A number of studies have reported inadequate post-fire ponderosa pine regeneration and type-conversion to shrub or grassland habitats with decades-long legacy effects.[105] However, this is not a universal phenomenon. Despite the size of high-severity burn patches in the Rodeo-Chediski fire, ponderosa pine appears to be regenerating in abundance, spatial pattern, and uneven-agedness along a trajectory that is similar to historical structural characteristics, albeit with a higher abundance of sprouting oak and juniper

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[98] Stevens-Rumann *et al.* 2012. Ten years after wildfires: How does varying tree mortality impact fire hazard and forest resiliency? *Forest Ecology and Management* 267: 199-208.

[99] Huffman *et al.* 2017a. Efficacy of resource objective wildfires for restoration of ponderosa pine (*Pinus ponderosa*) forests in northern Arizona. *Forest Ecology and Management* 389: 395-403.

[100] p. 117 in Hunter *et al.* 2011

[101] Roccaforte *et al.* 2012. Woody debris and tree regeneration dynamics following severe wildfires in Arizona ponderosa pine forests. *Canadian Journal of Forest Research* 42: 593-604.
Passovoy and Fulé 2006. Snag and woody debris dynamics following severe wildfires in northern Arizona ponderosa pine forests. *Forest Ecology and Management* 223: 237–246.
Savage and Mast 2005. How resilient are southwestern ponderosa pine forests after crown fire? *Canadian Journal of Forest Research* 35: 967-977.

[102] Stevens-Rumann *et al.* 2013. Pre-wildfire fuel reduction treatments result in more resilient forest structure a decade after wildfire. *International Journal of Wildland Fire* 22: 1108-1117.

[103] Thompson *et al.* 2007. Reburn severity in managed and unmanaged vegetation in a large wildfire. *Proceedings of the National Academy of Sciences* 104(25): 10743-10748.

[104] Meigs *et al.* 2016. Do insect outbreaks reduce the severity of subsequent forest fires? *Environmental Research Letters* 11.

[105] Haire and McGarigal 2008. Inhabitants of landscape scars: succession of woody plants after large, severe forest fires in Arizona and New Mexico. *The Southwestern Naturalist* 53(2): 146-161
Savage and Mast 2005

species. [106] Also on the Rodeo-Chediski Fire, Shive and colleagues reported significantly more ponderosa pine regeneration in high severity burn patches than in low-severity patches.[107]

In spite of the tremendous size of the Rodeo-Chediski Fire – which the Center agrees is dramatically beyond the scale of characteristic fire behavior in the southwestern ponderosa pine forest – the situation today is not as grim as it appeared in the fires immediate aftermath. Leveraging the reduced fuels across the Rodeo-Chediski fire area to return low-intensity prescribed fire would be useful for limiting the degree to which sprouting woody species dominate the post-fire community, breaking up fuel continuity in future fires, and restoring natural frequent fire processes.

Increasing spatial and temporal heterogeneity.

Fire and forest structure interact such that the variability in stand structures present within a landscape influences the distribution of fire behaviors and severities, which in turn influence successional trajectories of post-fire environments.[108] The patchy mosaic patterns attributed to historic forest ecosystems were influenced by a range of fires and other disturbances through time and space – including patches of high-severity fire – that "*create coarse-grained, high-contrast heterogeneity…*[and]… *a complex mosaic of seral stages at the landscape and local scales*."[109] Fine scale, site-specific factors can produce dissimilar spatial patterns between sites in close proximity[110] in response to site characteristics, disturbance, successional pathways, and management history.[111]

Fire can create heterogeneity in ways that mechanical approaches simply cannot. A study of eleven mixed-severity Arizona fires across a sixteen year chronosequence described dramatic variability between fires in residual structure, regeneration response, snag and coarse woody debris dynamics, and future trajectories.[112] On the Rodeo-Chediski Fire in Arizona, Shive and colleagues observed that pre-fire treatments combined with mixed fire-severities to produce landscape heterogeneity that defied simple classification by burn severity.[113] On the same fire Owen and colleagues observed unexpected and paradoxical regeneration characteristics that included the highest documented rates of ponderosa pine regeneration occurring intermixed with the highest density of re-sprouting species in a plot far from the nearest pine seed-source.[114] These types of complex spatial arrangements of vegetative successional stages with variations in patch size and shape enhance biological diversity and influence future fire spread

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[106] Owen *et al.* 2017

[107] Shive *et al.* 2013. Pre-wildfire management treatments interact with fire severity to have lasting effects on post-wildfire vegetation response. *Forest Ecology and Management* 297: 75-83.

[108] Ziegler *et al.* 2017

[109] p. 310 in DellaSala *et al*. 2014. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? *Natural Areas Journal* 34(3): 310-324.

[110] Rodman *et al.* 2016. Reference conditions and historical fine-scale spatial dynamics in a dry mixed-conifer forest, Arizona, USA. *Forest Science* 62: 268–280.

[111] Hessburg *et al.* 2015. Restoring fire-prone Inland Pacific landscapes: seven core principles. *Landscape Ecology* 30: 1805-1835.

[112] Roccaforte *et al.* 2012

[113] Shive *et al.* 2013

[114] Owen *et al.* 2017

and behavior.[115] Diverse understory communities across a spectrum of disturbance histories and successional trajectories may provide additional resilience to future climate-induced changes.[116]

High-severity burn patches in the Rodeo-Chediski Fire on the White Mountain Apache Reservation in Arizona have been found to have significantly higher forb species richness, total understory plant cover, and ponderosa pine regeneration compared to low-severity areas.[117] A high-intensity escaped prescribed fire in a ponderosa pine dominated mixed-conifer forest at Grand Canyon National Park led to a dramatic increase in understory native plant cover, species richness, and composition.[118] Naturally recovering high-severity burn patches within mixed-severity mosaics have increased plant diversity and may be more resilient to future climate stress.[119]

The contemporary fire crisis is not so much predicated on high-severity fire being inherently "bad," but that the scale of patches exceeds what would have historically occurred. Determining the appropriate scale and frequency of fire-induced patch disturbance is an important step towards harnessing the efficacy of fire to achieve restoration objectives.

Promoting complex early-successional ecosystems

Early-successional forest ecosystems possess high structural complexity, spatio-temporal heterogeneity, and biological/foodweb diversity resulting from variability in disturbance severity, environmental conditions, and surviving trees.[120] Patches of moderate to high-severity fire can produce highly spatially variable forest structures as a response to uneven burn effects and patchy mortality dynamics.[121] Tree regeneration patterns in early-successional habitats reflect favorable environmental conditions[122] and variable thinning by fire and other disturbance.[123] These areas of localized disturbances create valuable wildlife habitat[124] and provide opportunities to apply additional fire treatments which promote further spatial diversity.[125]

The common attributes of complex early seral forests include:[126]

- Abundant and widely distributed large trees, snags and downed logs

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[115] Teske *et al.* 2012

[116] Halofsky *et al.* 2011. Mixed- severity fire regimes: lessons and hypotheses from Klamath-Siskiyou Ecoregion. *Ecosphere* 2(4): art40.
Hurteau *et al.* 2014. Climate change, fire management, and ecological services in the southwestern US. *Forest Ecology and Management* 327: 280-289.

[117] Shive *et al.* 2013

[118] Huisinga *et al.* 2005. Effects of an intense prescribed fire on understory vegetation in a mixed conifer forest. *Journal of the Torrey Botanical Society* 32(4): 590-601.

[119] Hunter *et al.* 2011; Owen *et al.* 2017

[120] Swanson *et al.* 2011. The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and the Environment* 9(2): 117-125.

[121] Fulé *et al.* 2004. Effects of an intense prescribed forest fire: is it ecological restoration? *Restoration Ecology* 12(2): 220–230.

[122] Savage *et al.* 1996. The role of climate in a pine forest regeneration pulse in the southwestern United States. *Ecoscience* 3(3): 310-318.

[123] Holden *et al.* 2007

[124] Halofsky *et al.* 2011; Hunter *et al.* 2011

[125] Williams *et al.* 2010

[126] p. 314 in DellaSala *et al.* 2014

•Varied and rich understory flora
•Varied and rich floral invertebrate, avian and mammalian species composition
•Highly complex structural complexity with many biological legacies
•Complex and functional below-ground biological processes
•Complex and varied genetic diversity
•Rich ecosystem processes including pollination and predation
•Low susceptibility to invasive species
•Varied and complex disturbance frequency
•High landscape integrity with shifting mosaics and disturbance dynamics
•High resilience and resistance to climate change due to varied and complex genomes

Haire and McGarigal studied high-severity burn patches at Saddle Mountain (Kaibab Plateau, Arizona; burned in 1960) and La Mesa (Pajarito Plateau, New Mexico; burned in 1977), both of which share similar soils, topography, and vegetative communities as the Rim Country landscape. The purpose of their research was to "*better understand plant succession after severe fire events in the southwestern United States, given the possibility that these landscapes occupy an important place in long-term variability of ecosystems.*"[127] Fifty-two species of native trees and shrubs, arranged along dynamic spatially and temporally influenced gradients, were documented at the two sites. Distance from edge-of-burn was strongly correlated to prevalence of resprouting species (generally shrubs, including oaks) over off-site seeders (generally coniferous trees), and was influenced by conditions in the pre-fire landscape. However, evidence of continued tree establishment and succession was evident decades post-fire as environmental conditions permitted tree establishment.

The early-successional habitats encountered by Haire and McGarigal led to their conclusion that:

"Areas burned in severe fire at Saddle Mountain and La Mesa included communities that might diversify function of landscapes through creation of early successional habitats for wildlife. In addition, woody species at the study sites have a wide range of traditional and current uses; basketry and other building material important food sources, a plethora of medicinal remedies, and ceremonial uses in contrast to studies that emphasize undesirable effects when forests transition to openings and alternative habitats, our research elucidates the need for further consideration of both young forest communities, and the persistent species and communities described as landscape scars, in conservation plans for forest systems of the southwestern United States."[128]

Recent work by Owen and colleagues at the Rodeo-Chediski and Pumpkin Fires confirmed ponderosa pine establishment > 300m from nearest seed source in spatial arrangements that were indistinguishable from forest-edge locations regardless of presence of sprouting woody species, suggesting forest recovery was in fact occurring.[129] Unfortunately, complex early seral forests are poorly understood in southwestern dry forests as reference site studies and stand reconstructions characteristically cannot account for small diameter trees and other small vegetation. In order to maintain biodiversity and support landscape heterogeneity it is imperative that scientists initiate more research on these ephemeral habitats in dry

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[127] p. 147 in Haire and McGarigal 2008
[128] p. 159 in Haire and McGarigal 2008
[129] Owen *et al.* 2017

southwestern forests in order to account for their contribution in ecosystem management.[130] Meaningfully increasing the use of prescribed and wildland fire for ecological restoration requires recognition of the benefits of mixed fire severities in shrub, woodland and forested ecosystems. Based on the information presented above, small patches of high-severity fire effects interspersed within a matrix of low and moderate-severity can meet restoration objectives, create important ephemeral habitats, and reduce the risk of uncharacteristic reburn potential.

Repeated Fire Application in Prescribed and Managed Wildfire Settings is Needed and Reflects the Best Available Science

The objective of ecological restoration in southwestern fire-adapted forests is to restore resilience to the inevitable future fires that will come, regardless of climate, environmental or human influences.[131] A number of fires have occurred across the Rim Country landscape that can be leveraged for additional gains in fuels reduction and ecosystem restoration. It's a lost opportunity to not follow recent prescribed, resource benefit, and uncontrolled wildfires with additional fire, knowing that past fires act as fuel breaks and that effect diminishes with time.[132] It is critical to remember that "*historical ponderosa pine forest structure was a product of not one but of a series of fires over time.*"[133] The compounding effect of recurring fire through centuries was selection for functional traits that incur ecophysiological adaptive benefits for drought and fire tolerance.[134] Overlapping fire mosaics promote development of differential tree recruitment, increase structural diversity and successional pathways, and break up fuel beds, facilitating more beneficial fires in the future.[135]

Holden and colleagues, in an analysis of thirteen fires in the Gila and Aldo Leopold Wilderness areas found evidence that initial wildfire severity slightly influenced severity of subsequent fires. In that study, which did not provide information for the size or distribution of burn patches, initial high-severity burns frequently reburned at high-severities, but most often in moist, high-elevation sites. The authors ultimately concluded that satellite imagery must be interpreted carefully and that field verification of their sites was needed.[136] Later work provided a contrasting conclusion, that previous wildfires do in fact moderate the severity of subsequent fires and lead to proportionally more area burned at low-severity.[137]

Returning frequent fire to the landscape will continue to alter forest structure and composition in ways that are not yet fully known, especially for wildlife that utilize snags and coarse woody debris.[138] Consistently, however, research from throughout the western United States alludes to the efficacy of

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[130] Swanson *et al.* 2011

[131] Allen *et al.* 2002
Schoennagel *et al.* 2017. Adapt to more wildfire in western North American as climate changes. *PNAS* doi/10.1073/pnas.1617464114.

[132] Parks *et al.* 2015

[133] p. 118 in Hunter *et al.* 2011

[134] Strahan *et al*. 2016. Shifts in community-level traits and functional diversity in a mixed conifer forest: a legacy of land-use change. *Journal of Applied Ecology,* doi: 10.1111/1365-2664.12737.

[135] Teske *et al.* 2012

[136] Holden *et al*. 2010. Burn severity of areas reburned by wildfires in the Gila National Forest, USA. *Fire Ecology* 6(3): 77-85.

[137] Parks *et al*. 2014. Previous fires moderate burn severity of subsequent wildland fires in two large western US wilderness areas. *Ecosystems* 17: 29-42.

[138] Holden *et al*. 2006. Ponderosa pine snag densities following multiple fires in the Gila Wilderness, New Mexico. *Forest Ecology and Management* 221: 140–146.

returning fire in a mixed-severity approach, and following up with repeated low-severity burning for restoring historical structure, pattern, and process.[139] Modelling by Shive and colleagues showed that under milder climate scenarios, prescribed fire combined with climate-induced growth reductions resulted in ponderosa pine basal areas within the HRV[140], consistent with field observations of fire-based restoration at Grand Canyon and the Gila Wilderness, described below.

Repeated summer wildfires since 1946 at in the Gila and Saguaro Wilderness areas have successfully reduced density of small-diameter trees while not affecting large tree density, effectively shifting towards a larger tree distribution while reducing risk of crown fire, increasing resilience, and creating desired structural heterogeneity.[141] Similar effects have been documented on the Hualapai Indian Reservation, where more than fifty years of frequent prescribed fires have increased resilience to crown fire and climate change near the lower elevational limit of ponderosa pine.[142]

Repeated mixed-severity prescribed and natural-ignition fires in ponderosa pine dominated forests at Grand Canyon National Park have been shown to limit large tree mortality, reduce density of conifer seedlings and shade tolerant understory saplings, and reduce surface fuels consistent with restoration objectives and managing for climate resilience.[143] Initial mortality pulses resulting from initial fire entry create numerous snags, but many are consumed upon fire reentry as snag recruitment and persistence reaches a possible equilibrium.[144]

Studying the effects of prescribed fires on burn severity in the Rodeo-Chediski Fire, Finney and colleagues found that areas which were repeatedly burned significantly reduced subsequent burn severity, but the beneficial effects diminished with time since fire. Their observations of fire progression, captured via satellite, provided evidence "*consistent with model predictions that suggest wildland fire size and severity can be mitigated by strategic placement of treatments*."[145] Researchers observed the same effect studying fires in New Mexico and Idaho, where the "*severity of reburns increases with time since the previous fire, likely due to biomass accumulation associated with longer fire-free intervals.*"[146] Although their data showed that previous fires did have an effect up to 22 years later, further study concluded that initial fires ability to act as a fuel break was as little as 6 years in warm/dry climates such as southwestern ponderosa pine forests.[147]

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[139] Hunter *et al.* 2011

[140] Shive *et al*. 2014. Managing burned landscapes: evaluating future management strategies for resilient forests under a warming climate. *International Journal of Wildland Fire* 23: 915–928

[141] Holden *et al.* 2007

[142] Stan *et al*. 2014. Modern fire regime resembles historical fire regime in a ponderosa pine forest on Native American lands. *International Journal of Wildland Fire* 23: 686-697.

[143] Fulé *et al*. 2002. Natural variability in forests of the Grand Canyon, USA. *Journal of Biogeography* 29: 31-47.
Fulé and Laughlin 2007. Wildland fire effects on forest structure over an altitudinal gradient, Grand Canyon National Park, USA. *Journal of Applied Ecology* 44: 136-146.
Laughlin *et al*. 2011. Effects of a second-entry prescribed fire in a mixed conifer forest. *Western North American Naturalist* 71(4): 557-562; and Fulé *et al.* 2004

[144] Holden *et al.* 2006; Laughlin *et al.* 2011

[145] p. 1714 in Finney *et al*. 2005. Stand- and landscape-level effects of prescribed burning on two Arizona wildfires. *Canadian Journal of Forest Research* 35: 1714-1722.

[146] p. 38 in Parks *et al.* 2014

[147] Parks *et al.* 2015

Repeated resource objective fires on the Kaibab National Forest were recently reported to be more effective at restoring desired structure when they burned at moderate-severity under active fire-weather conditions.[148] Collins and Stephens found that in two Sierra Nevada wilderness areas where fire use policies were adopted, contemporary low-severity fires had allowed forests to become more resistant to insects, drought, and disease despite not having been thinned to historical densities. They concluded that "*what may be more important than restoring structure is restoring the process of fire*…[which] *could be important in allowing these forests to cope with projected changes in climate*."[149]

Collins and colleagues studied mixed conifer forests in Yosemite National Park (4,800 - 7,000 ft.) where up to seven management and lightning started fires burned between 1983 and 2009, following an approximately 80-year fire-free period. They found that recent low severity fires reduced surface fuels and understory trees but did not kill enough intermediate sized trees to move towards desired structural characteristics. Their findings indicated "*no significant differences between current forest structure in areas that burned recently with moderate severity and forest structure in 1911*"[150] which was the year that historical inventory data was available for, and that only moderate fire-severity could substantially alter the ratio of fir to pine trees.

Taylor reported that two late twentieth century fires in an old growth ponderosa pine-Kellogg oak forest in California's Ishi Wilderness were effective at restoring pre-fire-exclusion structural characteristics, including composition, density, basal area and spatial pattern.[151] Similar effects were reported by Larson and colleagues, where reintroduction of natural-ignition fire in the Bob Marshall Wilderness of Montana has restored low-density mixed conifer forest dominated by large, old ponderosa pine by consuming surface fuels and thinning shade-tolerant species from the forest understory and mid-canopy.[152]

These studies support the concept that repeated fires will move ponderosa pine and dry mixed-conifer systems towards predominantly low-severity fire equilibrium, consistent with the body of work focused on frequent fire systems achieving a self-regulating state.[153] The consistent theme is that a mixed-severity initial fire entry creates conditions conducive to repeat burning at low and moderate severities within the historical fire regime.[154] By allowing for moderate sized patches of high mortality that do not generally exceed 100 to 200 hectares (where determined appropriate by optimization analysis), there is relatively little risk of high-severity re-burning, inadequate regeneration, excessive coarse woody debris loadings, or transition to non-forest types.

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[148] Huffman *et al*. 2017b. Restoration benefits of re-entry with resource objective wildfire on a ponderosa pine landscape in northern Arizona, USA. *Forest Ecology and Management* 408: 16-24.

[149] pp. 526-527 in Collins and Stephens 2007. Managing natural wildfires in Sierra Nevada wilderness areas. *Frontiers in Ecology and the Environment* 5(10): 523–527.

[150] p. 10 in Collins *et al*. 2011. Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. *Ecosphere* 2(4): 1-14.

[151] Taylor 2010. Fire disturbance and forest structure in an old-growth Pinus ponderosa forest, southern Cascades, USA. *Journal of Vegetation Science* 21: 561-570.

[152] Larson *et al*. 2013. Latent resilience in ponderosa pine forest: effects of resumed frequent fire. *Ecological Applications* 23(6): 1243–1249.

[153] Miller and Aplet 2015. Progress in Wilderness Fire Science: Embracing Complexity. *Journal of Forestry* 113: 1-11; and Parks *et al.* 2014; Parks *et al.* 2015

[154] Laughlin and Fule 2006. Meeting forest ecosystem objectives with wildland fire use. *Fire Management Today* 66(4): 21-24.

IV. THE STRATEGIC TREATMENTS FOR FIRE USE ALTERNATIVE FRAMEWORK

USFS research scientists have long worked to develop decision support, risk management, and prioritization tools for use in applications like 4FRI. Their work has been fundamental in establishing the science of optimization that is increasingly being explored and implemented in the western United States. Important considerations for utilizing wildland fire use have been identified by fire management professionals[155] and agency-developed risk management and decision support systems, such as Fire Effects Planning Framework,[156] provide systematic geospatial techniques for managing fire for resource benefit.

Ager and colleagues stated in a 2013 article that "*Meeting the long-term goals of dry forest restoration will require dramatic increases in prescribed and managed fire that burn under conditions that pose minimal ecological and social risk. Optimization models can facilitate the attainment of these goals by prioritizing management activities and identifying investment tradeoffs.*"[157] That 2013 work, located in ponderosa pine forests on the Deschutes National Forest in Oregon, studied an optimization model "…*to locate project areas to most efficiently reduce potential wildfire loss of fire resilient old growth ponderosa pine while creating contiguous areas within which prescribed and managed fire can be effectively used...*"[158] The complex modelling and algorithms used by the researchers ultimately identified locations where strategically deployed mechanical treatments would reduce flame length and thus save old growth ponderosa pine.

One common fundamental similarity between all optimization models is that they seek to reduce fire-severity or minimize wildfire risk, balancing tradeoffs between the size of treatment units, the placement of treatments, and the proportion of the landscape treated.[159] Collins and colleagues[160] also reviewed fuel treatment strategies, including much of Finney and Ager's work, and arrived at some basic parameters for optimizing fuel reduction treatments at the landscape scale that provide some guidance for those evaluating tradeoffs and can be used as guidelines in the *Strategic Treatments for Fire Use Alternative*:

> • Treating 10% of the landscape provides notable reductions in modeled fire size, flame length, and spread rate across the landscape relative to untreated scenarios, but treating 20% provides the most consistent reductions in modeled fire size and behavior across multiple landscapes and scenarios.
>
> • Increasing the proportion of area treated generally resulted in further reduction in fire size and behavior, however, the rate of reduction diminishes more rapidly beyond 20% of the landscape treated.

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[155] Black *et al.* 2008. Wildland Fire Use Barriers and Facilitators. *Fire Management Today* 68(1): 10-14.
Doane *et al.* 2006

[156] Black and Opperman 2005. Fire Effects Planning Framework: a user's guide. RMRS-GTR-163.

[157] p. 11 in Ager *et al.* 2013

[158] p. 3 in Ager *et al.* 2013

[159] Collins *et al.* 2010. Challenges and approaches in planning fuel treatments across fire-excluded forested landscapes. *Journal of Forestry* Jan/Feb 2010: 24-31
Chung 2015. Optimizing fuel treatments to reduce wildland fire risk. *Current Forestry Reports* 1: 44-51.
Krofcheck *et al*. 2017a

[160] Collins *et al.* 2010

> • Random placement of treatments requires substantially greater proportions of the landscape treated compared with optimized or regular treatment placement.
>
> • The improvements offered by optimized treatments are reduced when 40-50% of the landscape is unavailable for treatment due to land management constraints.
>
> • Treatment rates beyond 2% of the landscape per year yield little added benefit.

Considering the fire modeling already underway by the USFS, and the key takeaways reviewed here, the Center believes that a modified version of the methodology developed by the Hurteau lab and used by Krofcheck and colleagues[161] is most appropriate for the Rim Country analysis. Their optimization model, which mechanically treats only the operable areas with a high probability of mixed- and high-severity fire, was shown in multiple fire simulations to be as effective as thinning all operable acres at reducing wildfire burn severity and facilitating landscape scale low-severity fire restoration. The authors summarize their methods here:

> "*We developed three scenarios: no-management, naive placement, and optimized placement. Both management scenarios employed combinations of mechanical thinning and prescribed burning. The naive placement scenario aimed to simulate mechanical thinning from below and prescribed fire to all forest types that have experienced a fuels load departure from their historic condition due to fire exclusion. Within each forest type that received mechanical thinning, thinning was constrained based on operational limits (slope>30%, which totaled 22,436 ha available for mechanical thinning). The optimized placement scenario further constrained the area that received mechanical thinning by limiting thinning to areas that also had a high probability of mixed- and high-severity wildfire…In both treatment scenarios, stands identified for mechanical treatment were thinned from below, removing roughly one-third of the live tree biomass over the first decade of the simulation. Stands selected for mechanical thinning were only thinned once in the simulations, and all thinning was completed within the first decade*."[162]

Their results suggested that thinning the most optimum 33% of the operable acres could achieve the same effect as thinning all operable acres. The study was simulated in the Sierra Nevada of California, but the authors asserted that their approach was *"broadly applicable to historically frequent-fire ecosystems, or systems which have transitioned away from a low severity and fuel limited fire regime to one characterized by high-severity fires*."[163] The authors have recently completed similar optimization simulations in the Santa Fe Fireshed, which is likely to provide additional direction for utilizing such an approach in Southwestern ponderosa pine and mixed conifer forests (findings are to be published in summer, 2018).[164] We believe that it is possible and beneficial to integrate the existing 4FRI fire behavior and risk assessment modelling into an optimization simulation based on that work. We recommend that the Hurteau Lab is contacted immediately to begin dialogue with 4FRI Stakeholders as to how an optimization process can take existing fire modelling to the next level of strategic utility, while

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[161] Krofcheck *et al*. 2017a; Krofcheck *et al*. 2017b
[162] p. 2 in Krofcheck *et al*. 2017a
[163] p. 6 in Krofcheck *et al*. 2017a
[164] Personal communication: Matt Hurteau, University of New Mexico, March 29, 2018

maintaining the viability of existing consensus agreements for treatments in SPLYT stands, old and large tree retention, Mexican spotted owl and northern goshawk habitat, and aquatic ecosystems.

Three-tier Management Area Strategy

Reflecting advances in landscape level planning, the *Strategic Treatments for Fire Use Alternative* proposes a three-tier strategy, basing management area decisions on optimized treatment locations rather than just arbitrary distances from values-at-risk. Past management zone strategies have been proposed by fire ecologists to facilitate resource benefit fire in Wilderness areas, and were based on distance from the wildland-urban interface.[165] Later, those approaches were extended to non-Wilderness public lands beyond a 5 ½ mile buffer around private land.[166] Both of those distance-dependent approaches resulted in identification of community protection zones, restoration management zones, and fire use zones. More recently, USFS and academic scientists called for a similar three-zone approach to be incorporated into National Forest Land and Resource Management Plans, with no specification of zone distances from the wildland-urban interface.[167] Conversely, the *Strategic Treatments for Fire Use Alternative* proposes that thinning treatments be prioritized in the Wildland Urban Interface, around critical infrastructure, and in areas having the highest probability of active crown fire, irrespective of proximity to human values-at-risk. Placement of such treatments would reflect existing 4FRI protections (SPLYT, MSO, etc) as well as economic costs/benefits of implementation. The three tiers of the Alternative are as follows:

Tier 1) Community Protection. These areas should be highest priorities for mechanical treatment, where feasible. Identification of the Community Protection Areas follows the consensus-based criteria established in the first 4FRI EIS of ½ mile around homes and critical infrastructure. Consistent with the agreements forged in the *Analysis of Small-Diameter Wood Supply in Northern Arizona* and memorialized in the first EIS, management objectives for the Community Protection Areas take precedence wherever they overlap with another management area. Extended Duration Restoration treatments, as proposed in the modified Alternative 2, may be appropriate for experimental implementation in this zone within a research framework. Additional areas that demand special attention may be addressed through the collaborative stakeholder process.

Tier 2) Strategic Thinning Treatment. These areas should be the next level of priority for mechanical treatment, implementing consensus-based treatments already agreed-upon by the USFS and the 4FRI Stakeholders. The Flexible Toolbox Approach, once agreement is reached on its parameters and constraints, could be utilized in these areas with the additional option of treating with fire-only if stand conditions permit, if mechanical treatment is not economically viable, and/or if on the ground conditions differ from expectations. *Strategic Thinning Treatment* areas would be identified through optimization analysis. An additional, secondary prioritization could be developed collaboratively to identify those stands which are the foremost priority for accelerated mechanical treatment within this zone. This analysis should include all "other projects" within the Rim Country footprint, because "*Understanding where past fuel treatments and wildfires have occurred is important for prioritizing future fuel*

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[165] Wilmer and Aplet 2005. Managing the Landscape for Fire: A Three-Zone, Landscape-Scale Fire Management Strategy. The Wilderness Society, Washington, DC.

[166] Aplet and Wilmer 2010. The potential for restoring fire-adapted ecosystems: exploring opportunities to expand the use of wildfire as a natural change agent. *Fire Management Today* 70(10): 35-39.

[167] North *et al.* 2015b

treatment."[168] Based on the 2010 synopsis competed by Collins and colleagues, a reasonable starting point may be that approximately 20% of the operable landscape could be targeted for strategically placed treatments, which would equate to approximately 250,000 acres of the Rim Country footprint. Krofcheck and colleagues optimization simulations from the Sierra Nevada resulted in approximately 8.5% of the landscape being identified for mechanical treatment. It will be important to let the process speak for itself, but if the optimization successfully locates thinning treatment priorities within those ranges, that amount of available acreage would provide 15-20 years of contracts to local industry, especially considering the challenges to implementation discussed earlier in this document. These acres may be in addition to those within the *Community Protection* areas and would be determined through the optimization analysis.

Tier 3) Fire Use. Areas located outside Tier 1 and 2 are not prioritized for mechanical treatment. Instead, management prioritizes prescribed and resource benefit fire at frequencies appropriate to local fire regimes. Because progressively warmer and drier winters may be conducive to year-long prescribed fire,[169] we recommend that increased resources are made available for burning, including the use of Prescribed Fire Training Exchanges (TREX), Wildland Fire Modules, forming prescribed fire councils, and a dedicated 4FRI prescribed fire implementation team.[170]

V. CONCLUSION

Optimizing spatial prioritization of mechanical treatments reflects an evolution of fire management, placing emphasis on restoring fire as a natural process, rather than simply disrupting fire spread and protecting areas from burning.[171] The result of a strategic approach is to move away from managing for short-term outcomes and towards achievement of long-term restoration goals and objectives, consistent with calls from the scientific community to increase the use of prescribed and managed wildfires for resource benefit.[172] In a review of optimization strategies, Collins and colleagues stated that "*The basic idea is that an informed deployment of treatment areas, a deployment that covers only part of the landscape, can modify fire behavior for the entire landscape.*"[173] As an example, researchers have observed that thinned stands within the Rodeo-Chediski Fire affected fire behavior in neighboring untreated stands, leading to more complex heterogeneity, reduced fire severity, and increased ponderosa pine regeneration following the fire.[174] The Center believes that an *informed deployment* of the mechanical and fire treatments can more effectively and efficiently restore ponderosa pine and mixed conifer forests of the Rim Country landscape than the current 4FRI direction, and the *Strategic Treatments for Fire Use Alternative* is the way to get there.

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[168] p. 301 in Vaillant and Reinhardt 2017

[169] Seager *et al.* 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316:1181.

[170] Stephens *et al.* 2016

[171] Ager *et al.* 2013

[172] Stephens *et al.* 2016

[173] p. 25 in Collins *et al.* 2010

[174] Shive *et al.* 2013