Chapter 2: Postfire Restoration Framework

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Introduction

Land managers grapple with a variety of questions concerning the management of burned landscapes. All fires more than 500 ac (200 ha), and smaller fires if critical values are involved, trigger a Burned Area Emergency Response (BAER) program assessment that addresses emergency stabilization in the first year, with possible maintenance treatments for up to 3 years. After assessments for BAER and postfire reforestation have been completed, years of rehabilitation and restoration may be conducted, including planting trees, reestablishing native species, restoring habitats, and treating invasive plants. These actions are expected to be consistent with the directions in individual forest plans and to meet requirements under the National Forest Management Act, the National Environmental Policy Act (NEPA), and other statutory authorities (see app. 1). As part of planning for recovery of burned landscapes, land managers may consider many key questions:

- What are the long-term restoration goals and key objectives for the landscape where the burn occurred?
- What management actions will be needed to address long-term forest sustainability?
- Will natural regeneration meet forest management objectives, or will active reforestation efforts be needed, and if so, where?
- Do residual fuel loads require management activities to mitigate future wildfire risk?
- Is habitat connectivity for forest-dependent species impaired?
- Are there administrative, logistical, or other constraints for particular restoration activities?

Answering these questions may be facilitated by the use of a logical, intuitive framework that helps to provide appropriate context and focus to the management of burned landscapes. This chapter describes one such framework. Ideally, an interdisciplinary team would apply this framework within a timeframe that aligns with BAER activities and informs potential postfire treatments (e.g., salvage,

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reforestation) that may be proposed and evaluated under NEPA. Moreover, the framework may be applied to other contexts, including slower moving disturbances such as drought-induced tree mortality.

This chapter presents a series of steps that lead to the development of a postfire restoration portfolio. These include (1) assembling a team and identifying priority resources and desired conditions, (2) gathering and analyzing relevant spatial data (see chapter 3), (3) using a postfire flowchart to identify restoration opportunities, (4) developing and integrating a list of potential management actions that take advantage of these opportunities, and (5) building a portfolio of potential restoration actions and prioritizing these actions based on timing, feasibility, opportunity cost, and level of integration. The restoration portfolio provides a sequential plan for project implementation, including both long- and short-term actions. The restoration portfolio also documents management considerations that can be used to develop and refine additional restoration actions. This process is shown in figure 2-1; individual steps are described in more detail below.

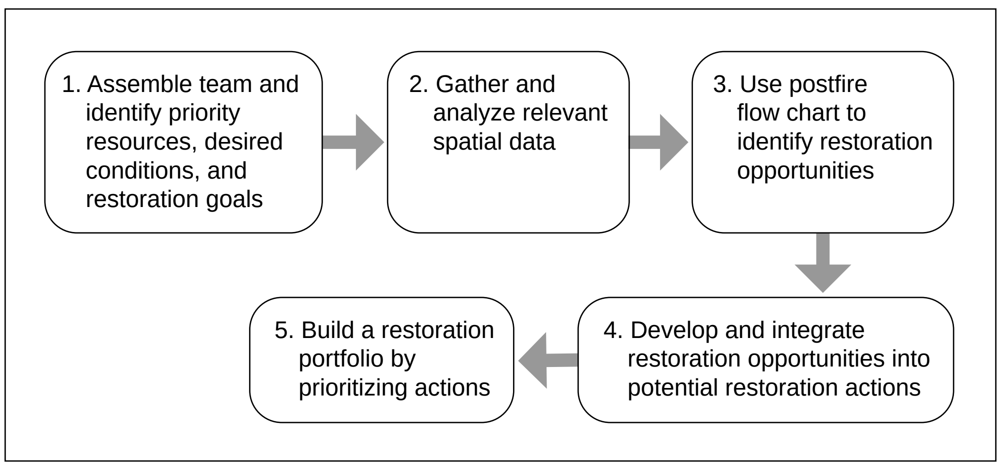

Figure 2.1—Process diagram of the postfire restoration framework.

Step 1: Assemble a Team and Identify Priority Resources, Desired Conditions, and Restoration Goals

The first step is to assemble a knowledgeable team of specialists. Important team skills include familiarity with the local ecological setting (including unique and valued natural resources), understanding of vegetation succession and restoration, knowledge of forest priorities and constraints, and ability to analyze Geographic Information Systems (GIS). Assembling a team with diverse resource specializations (e.g., ecology, GIS, fuels, silviculture, wildlife, botany, soils, hydrology, aquatics, and others) would help to address the many dimensions of postfire environments, and ideally the team will include individuals familiar with BAER efforts for the fire. Collaboration, effective communication, and clear documentation of methods and decisions would help to explain the approach and facilitate future evaluations.

Once a team of specialists is assembled, priority resources and desired conditions can be identified, often with direction from line officers. Priority resources are high-value natural resources and assets located within the management area of interest, which may include one or more land management units such as ranger districts or national forests. Desired conditions are specific ecological characteristics or conditions that may be maintained or restored through management. Desired conditions, priority resources, and other important land management direction (e.g., standards, guidelines, potential management approaches) are provided in land and resource management plans (LRMPs), with supplementary information available in supporting planning documents such as forest or bioregional assessments, landscape or watershed assessments, environmental impact statements, fire management plans, natural range of variation (NRV) assessments, and science syntheses (e.g., Long et al. 2014, Safford and Stevens 2017). Reducing the list of priority resources and desired conditions to those most relevant for the landscape being evaluated will help focus the effort. Lastly, the identification of overarching ecological restoration goals and objectives (hereafter referred to collectively as "goals") is critical for a comprehensive vision for postfire management. These goals can be obtained from LRMP direction (e.g., forestwide desired conditions, goals, and objectives for terrestrial ecosystems) and other planning documents noted above and refined for the landscape of interest based on interdisciplinary team discussion. In later steps (step 3 or 4), restoration goals can be linked with specific restoration opportunities or more broadly applied across opportunities.

Identifying overarching ecological restoration goals and objectives is critical for a comprehensive vision for postfire management.

Step 2: Gather and Analyze Relevant Spatial Data

The process of gathering and analyzing relevant spatial data is described in chapter 3. Spatial data and other information are needed to identify restoration opportunities (step 3).

Step 3: Use the Postfire Flowchart to Identify Restoration Opportunities

The postfire flowchart (fig. 2.2) provides a rationale for developing a suite of restoration actions in response to the range of effects caused by the fire. Using the postfire flowchart will help the team identify specific spatial data outputs necessary

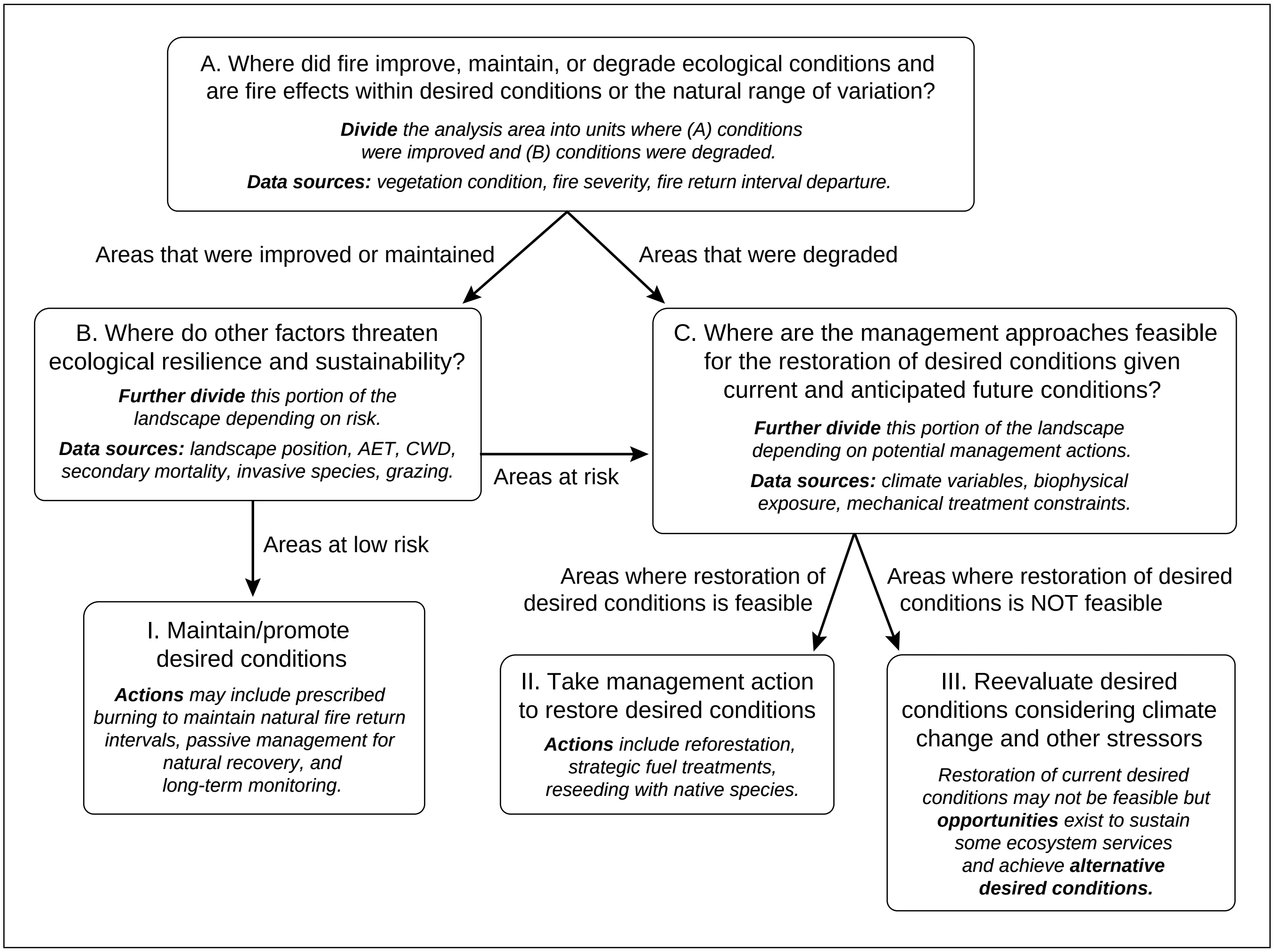

Figure 2.2—The postfire flowchart is based on three questions (A, B, and C) for the identification of management responses or "restoration opportunities" (1, 2, and 3) that support overarching restoration goals (e.g., promote or maintain native vegetation cover) in different portions of the postfire landscape. This framework represents the third step in the process diagram of figure 2.1.

to divide the postfire landscape into areas where fire improved or maintained ecological condition and areas where fire degraded ecological condition. Detailed methodologies for developing these outputs are described in chapter 3. Once the team has categorized the affected landscape according to fire effects, they can then consider restoration opportunities for these areas separately, allowing for the development of a diverse range of postfire restoration actions based on clearly articulated desired outcomes and restoration goals. Using the postfire flowchart will improve the quality of the decisionmaking process by analyzing ecologically similar areas separately while at the same time considering their role in the larger landscape.

Outputs from the data gathering and analysis step (chapter 3) that describe ecological conditions and stressors (i.e., current, future, and refined local conditions) are a primary data source for answering questions posed by the postfire flowchart. In addition to relying upon data products developed during the data gathering and analysis step (chapter 3), answering questions posed by the postfire flowchart will also require nonspatial data and local knowledge and expertise. In the following sections, we discuss each question posed by the postfire flowchart and provide examples of how these questions might be answered.

Question A: Where Did Fire Improve or Maintain Ecological Conditions, and Are Fire Effects Within Desired Conditions or the Natural Range of Variation?

The fundamental question posed by the postfire flowchart is "how did the fire affect ecological condition?" There are multiple answers to this question, depending on the resources identified in step 1, and by spatial variability in fire effects. Some parts of the landscape will have been negatively affected by the fire. Modern fires often degrade ecological conditions and move portions of the landscape away from desired conditions or outside the NRV. Common examples include large patches of high-severity fire in conifer forests (i.e., high proportion of overstory mortality) where desired levels of natural conifer regeneration are unlikely to occur over much of the area, areas where severe fire effects have homogenized vegetation and biodiversity, locations where soil erosion and stream sedimentation have drastically increased, or places where high fire frequency is overwhelming the ability of native species to regenerate successfully (e.g., in shrublands, vegetation dominated by serotinous species).

On the other hand, some parts of the landscape may have benefitted from fire. Although many people associate fire and other ecological disturbances with negative outcomes, many California ecosystems evolved with and depend on such processes (Keeley and Safford 2016). Despite the alteration of fire regimes across most ecosystems, the occurrence of wildfire can often have positive (or at least neutral) effects on ecological conditions, depending on factors such as weather, fuels, topography, and the ecosystem (and its condition) in question. For example, in areas with a long history of fire suppression, the occurrence of a single fire may move the landscape closer to the NRV for fire return interval, structural diversity, and the abundance of early-successional habitats and species. Because fires tend to have highly heterogeneous effects, even those that were catastrophic in their effects on human infrastructure may result in ecological benefits in some part of their footprint. By dividing the postfire landscape into areas that were negatively affected and those that were positively affected or not changed, the postfire flowchart permits customization of restoration and management opportunities for different portions of the landscape.

The question, "where did fire improve or maintain ecological conditions and are fire effects within desired conditions or the natural range of variation?" may be answered by reviewing the current vegetation condition, fire severity, and other data outputs described in chapter 3. These outputs can then be compared to desired conditions or NRV information as identified in step 1 above. The team clearly identifies what components of the ecosystem were affected by the fire, including consideration of factors for such priority resources:

- Is there a lack of essential structural components (e.g., sufficient tree or shrub cover, large trees, snags) to meet desired conditions?
- Are vegetation patch sizes, spatial heterogeneity, and habitat connectivity for forest-dependent wildlife species radically departed from NRV or desired conditions?
- Were current and expected future species compositions fundamentally altered? This includes evaluating not only the current suite of species present, but also factors that allow these species to persist, such as reproductive pathways (e.g., obligate seeding species) and key ecosystem components (e.g., specialized habitat features).

By separating the landscape into different units based on fire effects, the team can begin to identify where different restoration opportunities exist on the postfire landscape.

Question B: Where Do Other Factors Threaten Long-Term Ecological Resilience and Sustainability?

For areas where the fire improved or maintained ecological condition, the postfire flowchart asks whether other conditions, not directly related to the fire, may ultimately jeopardize the potential success of restoration efforts. To answer this question, the team considers factors that could affect restoration outcomes, recognizing that these factors may have different impacts depending on the time scale. Important factors that can influence restoration outcomes over the long term are current and probable future climatic conditions, and secondary mortality resulting from insect and disease outbreaks. Other factors that might be considered include the following:

- Fuel development—could be initially low, but depending on inputs such as snag and coarse woody debris production, could increase high-severity reburn potential and affect mid- to longer term forest sustainability (Stephens et al. 2018).
- Anthropogenic ignitions—could result in repeated fires at unnaturally short intervals or at inappropriate times of year when species are most vulnerable.

- Grazing regimes—could affect native plant species recovery or facilitate nonnative plant invasion, alter herbaceous fuel loads, and help to reduce nonnative species cover and thatch in annual grasslands.
- Invasive species—could displace native species, modify habitat, and result in fairly rapid development and connectivity of fuel, allowing for unnaturally frequent fire.

Identifying and analyzing data relevant to these questions are described in chapter 3.

Question C: Where Are Management Approaches Feasible for the Restoration of Desired Conditions Given Current and Anticipated Future Conditions?

This branch of the postfire flowchart addresses two areas on the postfire landscape: (1) areas where fire effects did not improve ecological condition and (2) areas where fire effects were positive, but where other factors jeopardize the probability of successful restoration (see questions A and B above). This question asks whether desired conditions can be restored through management actions, but it also invites the team to consider other factors (current and anticipated future conditions) that may affect the effectiveness of management. The data gathering and analysis step (chapter 3) includes an evaluation of some of these factors, such as biophysical exposure and changing climatic conditions. For example, fencing may be a feasible management approach to protect regenerating aspen (*Populus tremuloides* Michx.) from browsing until they can mature. However, in areas with high climatic risk where future climate projections suggest that aspen are unlikely to persist over the long term, the team will want to consider how this might alter the prioritization of these stands for fencing.

It is important to identify areas where the fire improved ecological conditions, areas where restoration of desired conditions is important and feasible, and areas where desired conditions may need to be reconsidered.

Restoration opportunity 1: maintain or promote desired conditions—An important step in planning restoration is to identify areas where the fire improved ecological conditions. For example, a fire may have promoted a more natural fire regime and desirable ecological heterogeneity. Conventionally, we concentrate our efforts on highly degraded areas, when instead our greatest restoration opportunities may be in places where ecological conditions improved or remained unaltered. It may be more effective to maintain or enhance an area in good condition than it is to restore one that has been heavily degraded (Hobbs et al. 2009). In addition to providing an opportunity to capitalize on positive effects where they occurred, these areas also present an opportunity to develop and implement a robust monitoring plan to evaluate fire effects and ecosystem function over the long term. For example, as part of an adaptive management framework, ecological monitoring could examine vegetation successional trajectories following fire (i.e., are existing conditions trending toward or away from desired conditions) or evaluate the effectiveness of pre- or postfire management actions.

Restoration opportunity 2: take management actions to restore desired conditions—
In areas where management approaches are feasible, especially where future anticipated conditions are auspicious, the team will likely have the greatest suite of opportunities for postfire restoration. Most teams will have a large and robust set of tools to apply in this situation. However, even in areas where anticipated future conditions may put restoration at risk, management actions may be able to address that risk, for example, by considering climate-smart reforestation (Nagel et al. 2017), strategic fuel treatments, or other approaches that address predicted future conditions (Millar et al. 2007a, Peterson et al. 1998, Swanston et al. 2016), including experimental approaches where outcomes are uncertain (box 2A).

Box 2A:
Experimental Approaches

There is considerable uncertainty in postfire ecosystem trajectories with and without management intervention. Experimentation using the following types of approaches can address this uncertainty and provide major insights into the management of postfire landscapes:

- Develop and test new and innovative approaches.
- Provide a logical framework for testing hypotheses, examining foundational assumptions, and addressing applied ecological questions.
- Encourage creativity, teamwork, and collaboration with researchers through science-management partnerships.
- Support the development of bet-hedging strategies that spread management risk and reduce overall impacts from large disturbances.

Experimental approaches frequently require active partnerships to integrate research and boundary-spanning science organizations for effective translation and integration of science information in postfire management activities. Yet, experimentation can fill critical information gaps and provide robust evaluations of restoration techniques and approaches before they are applied across larger project areas. These approaches can be embedded within a larger project, and are contingent on sufficient time, funding, and other resources to accomplish. For example, partnerships between researchers and managers on the Eldorado National Forest within the 2004 Power Fire (fig. 2.3)

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Restoration opportunity 3: reevaluate desired conditions considering climate change and other stressors—

In some areas, restoration of desired conditions may not be feasible, or alternatively, desired conditions may need to be reconsidered. For example, areas that burned at high severity with large patch sizes in lower elevation forests with low site potential or higher climatic water deficit may be at high risk of conifer-regeneration failure and type-conversion, especially under continued climate warming. In this case, restoring desired conditions for coniferous forest vegetation may not be feasible. However, many ecosystem services may continue to be provided by these landscapes if they can be realigned (sensu Millar et al. 2007b) with a trajectory that is more stable under developing conditions. For example, conversion of conifer- to hardwood-dominated vegetation often may maintain (or even improve) some specific ecosystem services, such as wildlife habitat, soil nutrient status, regional biodiversity, and watershed or landscape integrity, despite major changes

will compare trends with and without postfire treatments, including prescribed burning and thinning of resprouts on multistemmed black oaks (*Quercus kelloggii* Newberry). It is important to understand results from this experiment, such as, among other things, the impacts of reburns on forest vegetation under more moderate conditions associated with prescribed burning. Additional experimental interventions could be designed to elucidate patterns such as vegetation trajectories in riparian areas, the effectiveness of cluster planting for reforestation, and the impacts of climate change on postfire restoration efforts.


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Figure 2.3—Experimental prescribed burn in an area burned 14 years earlier by the Power Fire on the Eldorado National Forest.

in vegetation composition and structure (Millar and Stephenson 2015). Alternately, lost values associated with highly degraded ecosystems may potentially be restored elsewhere on the landscape, within the fire perimeter or outside it. Once a new suite of desired conditions have been developed for these portions of the landscape (often based on forest plan direction to help guide modification of desired conditions), the postfire flowchart can be reevaluated to identify restoration options for these newly defined conditions. The reevaluation of desired conditions may require adaptive management to guide plan shifts, and ultimately plan amendments if necessary.

Step 4: Develop and Integrate Restoration Opportunities Into Potential Restoration Actions

This step ideally begins with team brainstorming, literature reviews by individual resource specialists, and consultation with researchers and other experts. Encouraging open and creative thinking, including both known and experimental approaches, may be particularly important at this step to avoid prematurely discounting options based upon feasibility and logistics. This step is intended to generate an extensive list of potential actions that can take advantage of the restoration opportunities that address restoration goals identified in earlier steps. In some cases, a restoration opportunity exists only by targeting a specific place on the landscape, while in other cases, there may be multiple options for restoration and several pathways to success. Identifying multiple actions for each restoration opportunity and associated restoration goal will help identify avenues for project integration and allow for the development of a comprehensive restoration portfolio.

Potential restoration actions can be integrated in a number of ways, including grouping actions together according to geographic location, type of resource, or type of action. Organizing actions according to common restoration goals provides another foundation for integration. For example, actions with a similar goal of reducing the risk of future high-severity fire, such as reducing fuels in high-severity stands and reintroducing fire into areas that burned at low or moderate severity, could be logically integrated into a single potential action. The integration step is also a chance to identify when management actions proposed to address one goal may be counterproductive vis-à-vis another goal. For example, reducing fuels in high-severity stands (action) could reduce the risk of future high-severity fire (goal), but may not maintain habitat features for snag-dependent wildlife species (goal) unless the two goals are explicitly linked. In these cases, the team can revise and refine its list of management actions to develop a cohesive, integrated list.

Step 5: Build a Restoration Portfolio by Prioritizing Actions

The number of potential restoration actions that can be implemented will be limited by a number of factors, including staff capacity and financial and logistical constraints. These actions can be evaluated and prioritized according to their costs and benefits. A restoration portfolio is a way to identify and prioritize among potential restoration actions in order to develop a cohesive, integrated restoration strategic plan with a high probability of success (table 2.1). The section below provides some examples of the types of information that may be considered in the restoration portfolio, but is not meant to be comprehensive. Factors such as timing, feasibility, opportunity cost, and level of integration may vary considerably among ecoregions and vegetation types and will be dependent on the capacity of individual management units.

A restoration portfolio should identify and prioritize actions that can accelerate the scale, pace, and impact of restoration.

Timing

There is a specific timeframe within which a given restoration action is likely to be effective. It is particularly important to identify opportunities where immediate action is required before an area or resource crosses a threshold such that potential restoration actions may no longer be feasible or effective, whether it be from ecological, socioeconomic, or political viewpoints. Many restoration projects will require multiple, sequential steps (initial, intermediate, and longer term) to succeed, and if the incipient steps are delayed, longer term goals may not be met. Although some projects are best implemented soon after the fire, others may need to be implemented years after the fire (and may depend on earlier steps having been accomplished). Project plans will be more useful if they specify the timing of restoration actions and the timeframe within which a project and its steps would be implemented.

Feasibility

Consideration of policies, logistics, capacity, access, operability, land allocation, public support, and cost are all critical components to consider when prioritizing restoration opportunities. Are there regulations that make the project infeasible or ineffective? Are there external factors outside of the control of the manager that may threaten the success of the project? What level of planning is required? Does the project have measurable outcomes that can be used to build support? Does it have public or collaborative backing?

Table 2.1— Simplified example of a restoration portfolio, a suite of potential actions developed using the postfire flowchart (fig. 2.2) as indicated by letters and roman numerals corresponding to figures

Restoration opportunity	Restoration goal	Potential restoration actions	Target areas	Postfire flowchart Path	Timing	Feasibility	Cost of inaction	Level of integration
Maintain/ promote desired conditions (I)	Keep fire return intervals within natural range of variation	Prescribe burning at low to moderate severity, use of wildland fire	Where fire return interval, severity, and patch sizes are now within natural range of variation; biophysical and future climatic risk low	B→I	Variable depending on natural range of variation fire return interval	Low to moderate	Moderate to High	Meets desired outcomes for forest health, fuel reduction, wildlife, and rare plants
Take management actions to restore desired conditions (II)	Reduce the risk of future high-severity fire	Reduce fuels via mechanical removal and grapple piling	High-severity patches with low biophysical exposure	C →II	Mid term (5 to 10 year)	Low to moderate	Moderate	Meets desired outcomes for fuel reduction; needs specific design criteria to meet wildlife desired outcomes
	Reduce browsing in regenerating aspen stands	Fence aspen for 3 to 5 years	Aspen stand where fire promoted suckering, browsing pressure is high, and future climatic risk is low to moderate	B→C→II	Short term (3 to 5 years)	Moderate	High	Meets desired outcomes for forest health and wildlife
Reevaluate desired conditions considering interacting stressors	Maintain diverse shrub communities, nutrient cycling, soil stability	Long-term monitoring	Large, high-severity patches where future climatic risk is high, reforestation unlikely	C→III	Long-term (>10 years)	High	Low	Meets some wildlife habitat and watershed desired outcomes

Cost of Inaction and Opportunity Costs

When evaluating the need for potential restoration actions in postfire landscapes, it is important to consider the cost of inaction. To answer this, the team could evaluate the need for restoration in a broader context. For example, a small portion of the landscape degraded by the fire may be a low priority for restoration based on vegetation conditions alone (low cost of inaction). However, when evaluated in the context of habitat connectivity for a rare species, restoration of such an area may be considered important to avert local extirpation (high cost of inaction). In addition, because there are usually finite resources available for restoration, any choice made is at the expense of alternative choices. The magnitude of these opportunity costs can be minimized when projects serve multiple purposes and are linked to longer term desired outcomes (see next section).

Level of Integration

Potential restoration actions aim to achieve multiple goals, serve long-term purposes when possible, and reconcile competing goals. For example, reintroducing fire into areas that burned at low or moderate severity could, among other things, reduce fuels and the risk of future high-severity fire, safeguard large trees that store carbon and provide wildlife habitat, increase the probability of successful germination of fire-tolerant trees, promote broadleaf species such as oak or aspen, release important nutrients such as nitrogen, and increase understory biodiversity. Reintroducing fire would therefore be considered highly integrated because it achieves multiple goals. Documenting decisionmaking during the integration process will be important to communicate the level of integration to other stakeholders. Other questions to consider include the following: Does this action address multiple resource concerns? Does it consider other projects that have already occurred or are being planned in the area? Does it support the goals of one or more species conservation strategies? In most cases, an interdisciplinary and collaborative approach can accelerate the scale, pace, and impact of restoration.

Potential restoration actions aim to achieve multiple goals, serve long-term purposes, and reconcile competing goals.

Conclusions

The postfire restoration framework includes five steps that leads to the development of a postfire restoration portfolio. These steps include (1) assembling a team and identifying priority resources and desired conditions, (2) gathering and analyzing relevant spatial data, (3) using a postfire flowchart to identify restoration opportunities, (4) developing and integrating a list of potential management actions that take advantage of these opportunities, and (5) building a portfolio of potential restoration actions and prioritizing these actions based on several considerations. The restoration portfolio identifies three types of restoration opportunities for postfire landscapes (maintain or promote desired conditions, take management actions to restore desired conditions, and reevaluate desired conditions considering interacting stressors). This framework provides the basic building blocks for creating a postfire restoration strategy. The next chapter will cover the second step in this process (i.e., gathering and analyzing relevant spatial data) in greater detail.

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