# RESOURCES AT RISK: A FIRE-BASED HAZARD-RISK ASSESSMENT FOR THE BOISE NATIONAL FOREST

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## ABSTRACT

On the 2.6-million-acre (1.05-million-hectare) Boise National Forest (BNF) in southwestern Idaho, wildfires have burned nearly 50% of the ponderosa pine (*Pinus ponderosa*) forest over the last 9 years. Much of this forest has burned with catastrophic intensity. Ponderosa pine forests are now among the most endangered and threatened ecosystems in the U.S. The historic fire regime, one marked by nonlethal surface fires that removed dense understories of saplings or pole-sized trees and increased nutrient availability, has changed. The altered fire regime now results in severe, stand-replacing fires that kill large areas of forest and return them to grass- and shrub-dominated landscapes. Preliminary analysis shows the remaining ponderosa pine on the BNF could be fragmented within the next 20 years by severe, stand-replacing wildfire.

In partnership with the University of Idaho, the BNF has developed a Geographic Information System (GIS)-based "hazard-risk assessment" that estimates where the forest ecosystems are most at risk to severe, large wildfires burning in conditions outside the historical range of variability (HRV), and evaluates important resources at risk to these fires. The hazard-risk assessment links five submodels. When the submodels are linked, the assessment estimates where severe, large wildfires burning in conditions outside HRV would severely deplete late-successional habitat needed by old-growth-dependent and other wildlife species, accelerate naturally high levels of erosion and sedimentation, and increase the likelihood that identified fish populations will not persist.

The hazard-risk assessment is most appropriately used to approximate the relative size and extent of the fire-based ecosystem problem on the forest–the result of excluding fire from fire-adapted ponderosa pine ecosystems. From a landscape scale perspective, the system we describe here is intended to be between the large-scale analysis undertaken as part of the Upper Columbia River Basin assessment, and the site-specific evaluation performed for landscape- and project-level analyses.

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## INTRODUCTION

The Boise National Forest (BNF) has an especially acute focus on forest ecosystem health. Its ponderosa pine (*Pinus ponderosa*) forests are among the endangered and threatened ecosystems in the U.S. (Noss et al. 1995). Historically maintained by frequent, low-intensity fire, the 1.1-million acres (440,000 hectares) of ponderosa pine forests encompassed by the BNF have been altered by decades of fire suppression, grazing, and logging that removed fire-adapted species. In these and other areas throughout the Interior West, many ponderosa pine forests are now dominated by dense stands of small-diameter Douglas-fir (*Pseudotsuga menziesii)* and other fire-sensitive species (Noss et al. 1995).

When wildfires now occur in ponderosa pine forests with altered fire regimes, they are more intense, severe and larger than traditionally experienced. The historic, nonlethal surface fires that prevented dense understories of saplings or pole-sized trees and increased nutrient availability have been succeeded by stand-replacing fires that may return large areas of forest to grass and shrubland (Crane and Fischer 1986).

On the BNF, wildfires in ponderosa pine forest have been increasingly large and severe since 1986. Nearly 500,000 acres (201,860 hectares) of National Forest land (about 50% of the BNF's ponderosa pine forest, and almost 20% of the land managed by the forest) have burned. Many of these acres have burned with catastrophic intensity. Costs to suppress these fires and undertake emergency watershed rehabilitation have exceeded $100 million dollars. In many severely burned areas, soil productivity, aquatic resources, and wildlife and plant habitat have been critically damaged (USDA Forest Service, 1992, 1995).

Preliminary analysis shows the remaining mature ponderosa pine forest could be further fragmented, with only isolated pockets remaining, within the next 20 years (Neuenschwander 1995). To respond to this threat to the forest's ponderosa pine ecosystem, a forest interdisciplinary team, working in partnership with

the University of Idaho, has developed a GIS-based "hazard-risk assessment."

The assessment estimates on a relative, forestwide basis where forest ecosystems are most at risk to catastrophic wildfires, and identifies important resources at risk to these fires. The hazard-risk assessment links five submodels: forested vegetation outside HRV, fire ignition, wildlife habitat persistence, watershed hazard (erosion and sedimentation potential) and fisheries condition. When linked, these submodels estimate where severe, large wildfires would alter the composition, structure and function of an ecosystem by: 1) severely depleting late-successional habitat needed by old-growth-dependent and other wildlife species, 2) accelerating naturally high levels of erosion and sedimentation, and 3) increasing the likelihood that fish populations will be impacted negatively.

## METHODOLOGY

In developing the hazard-risk assessment, the team used GIS tools, state-of-the-art computer software designed to process and analyze spatial information. The assessment was written using ARC/INFO Version 7.03 and uses automated machine language (AML) to process data in the GRID, ARCPLOT, ARCEDIT and TABLES modules. Most of the analysis was performed using rasterized data in the GRID module, ARCPLOT for graphic output, and TABLES for reports. Data were analyzed and displayed on a system that included an IBM RISC-6000 "390" server and AIX 3.2.5 operating system on a Thinwire Ethernet local area network (LAN).

The assessment was formulated through the following steps:

1. Five GIS submodels were first created to evaluate hazards for specific resources. These submodels included forested vegetation outside HRV, fire ignition, wildlife habitat persistence, watershed hazard (erosion and sedimentation potential), and fisheries condition.
2. For each of the five submodels, a relative hazard rating, ranging from 1 (lowest) to 5 (highest), was assigned to each subwatershed. (The 378 subwatersheds on the BNF are drainages averaging 6,000 acres [2422 hectares] in size.)

The submodels and sample hazard ratings include:

### Forested Vegetation Outside HRV

This submodel locates areas where ponderosa pine is or once was climax or a major seral species, and examines the density of the forested vegetation in these areas (based on June, 1992 LANDSAT satellite imagery classification). Hazard ratings were assigned to subwatersheds based on the number of acres in satellite imagery cover types that represent forest vegetation outside HRV, relative to the total number of acres in that subwatershed. In assigning hazard ratings, historical structure information from the Boise Basin (Sloan *this volume*), analysis from the Deadwood Landscape Assessment (USDA 1994), and documentation of research in similar habitat types in Montana (Arno et al. 1995) was used. Professional judgement as validated through proportional analysis indicates that areas with moderate to high hazard (3 or higher on the 1–5 scale) for forested vegetation outside HRV are those where 25% or more of the subwatershed consists of moderate or dense areas of mixed Douglas-fir, ponderosa pine and grand fir (*Abies grandis*), mixed Douglas-fir and ponderosa pine, homogeneous Douglas-fir, or homogeneous ponderosa pine.

### Fire Ignition

The fire ignition submodel evaluates where fires, both lightning- and human-caused, have historically started, based on BNF fire records from 1956–1994. This submodel assumes fire starts will continue to occur where they have historically. The forest's fire ignition database was first sorted by section (640 acres [258 hectares]) to determine the number of total ignitions in each section. The total number of ignitions varied from 0 to 14. The number of ignitions per section was overlain with a map of subwatersheds, and a fire ignition score was then assigned to each subwatershed based on the highest number of ignitions in any one section of the subwatershed. Using professional judgement validated with proportional analysis, hazard ratings were then assigned to fire ignition scores. Subwatersheds with moderate to high risk (rated 3 or more on the 1–5 scale) are those where $> 4$ fire starts have occurred in any one section (640 acres) throughout the 39-year fire history.

### Wildlife Habitat Persistence

The wildlife habitat persistence submodel is based, in part, on the assumption that extensive, contiguous, stand-replacing fires are the primary threat to wildlife persistence (Erickson and Toweill 1994). This submodel first assesses the amount and distribution of mid- and late-seral wildlife habitat in a subwatershed, and then determines the amount and distribution of this habitat considered outside HRV, and therefore considered at risk to large, catastrophic fire. First, satellite imagery forest cover types were combined with Digital Elevation Model (DEM) information such as elevation, slope, and aspect to develop a map of habitat types. (Habitat types reflect potential natural vegetation and indicate the successional pathway following a disturbance.) Habitat types with similar successional pathways and disturbance regimes were combined into habitat type groups. "Habitat at risk" and "habitat not at risk" were then delineated by identifying habitat groups of mid- and late-seral habitat outside HRV and within HRV, respectively. Persistence hazard ratings were then developed to reflect the likelihood that suitable habitat will not persist. The rating system assumes that the more extensive the vegetation outside HRV, the higher the likelihood that extensive, catastrophic wildfire might occur, and that mid- and late-seral habitats would not persist. Subwatersheds with moderate

to high hazard (rated 3 or higher on the 1–5 scale) for wildlife habitat persistence include those where 15% or less of the subwatershed would remain as late-successional habitat following wildfire, with only one (or no) patch at least 350 acres (141 hectares) in size. (Low-elevation subwatersheds which primarily consist of grass, brush, and shrublands are not included in this analysis.)

Wildfire burning in an altered regime in dense, late-successional habitat could alter the successional pathway, changing the current vegetation structure to shrub-brushfields and displacing or eliminating populations dependent on the late-successional habitat for several hundred years. Large, severe wildfire could also result in ecosystem simplification, with greater landscape homogeneity, and loss of biodiversity (Neuenschwander 1995).

### Watershed Hazard (Erosion and Sedimentation Potential)

The watershed hazard submodel is based on inherent differences in natural (undisturbed) sedimentation rates from landtypes (areas with similar soils and landforms, and therefore similar hazards and capabilities) within a subwatershed. Following wildfire, there is the potential for accelerated sedimentation (Megahan and Molitor 1975, Helvey 1980, Schultz et al. 1986, Trendel and Bevenger 1994). The submodel is based on the assumption that erosion and sedimentation rates will increase following wildfire, relative to their natural rates. Consequently, this submodel evaluates potential natural sediment yield, as determined from landtypes. Moderate to high subwatersheds (rated 3 or higher on the 1–5 scale) for watershed hazard are those with an average potential natural sediment yield of 35 tons per square mile per year (0.06 metric tons per hectare per year) or more.

### Fisheries Condition

The fisheries condition submodel selects spring-summer chinook salmon and bull trout as indicator species, because in Idaho chinook have been listed as "endangered," and bull trout as "threatened" under the Endangered Species Act of 1973. The submodel uses a scheme to prioritize watersheds for species protection, along with population strength and fragmentation factors identified by Rieman and McIntyre in 1993. Ratings for each of three components (species, relative population strength and isolation) were assigned to each subwatershed, based in part on sampling information located in the BNF's Aquatic Survey Database. These components were used to identify the most abundant chinook salmon and bull trout populations, as well as nearby weakened populations with the greatest chance for recovery. The three components were then averaged to calculate an overall hazard rating for each subwatershed. In general, for chinook salmon, moderate and high hazard subwatersheds (rated 3 or higher on the 1–5 scale) are those where spawning and rearing habitat for chinook salmon exists. For bull trout, moderate and high hazard subwatersheds are those with relatively large regional populations. There is risk that local populations will not persist: i.e., those populations relatively lower in abundance, smaller in areal extent, isolated from other populations and therefore less likely to recover from catastrophic fire.

The fisheries condition submodel assumes that large wildfires burning in conditions outside HRV would lead to environmental disturbances that decrease the likelihood of persistence for those fish populations low in abundance (chinook salmon) or important to regional populations (local bull trout populations).

3. An overall "high risk" rating was assigned to a subwatershed if it received moderate ("3") or higher hazard ratings from ALL FIVE submodels.
4. A watershed was rated as "high risk" if at least ONE subwatershed within it received an overall high risk rating. (The 82 watersheds on the BNF are larger drainages, about 30,000 acres [12,111 hectares] in size, which consist of several subwatersheds.) This assignment reflects the observation that the recent catastrophic wildfires are burning across vast landscapes and entire watersheds.

## RESULTS

The hazard-risk assessment was designed in part to answer two questions:

*Where are forest ecosystems most at risk to severe, large wildfires burning outside HRV?*

Based on current information and analysis, the forest ecosystems most at risk to catastrophic wildfires include large areas of moderate and dense forest where ponderosa pine is or was a major seral species, *and* where moderate to high numbers of fires (i.e., > 4 fires in any one section in a subwatershed) have occurred over the last 38 years. By linking the fire ignition submodel (which can identify those subwatersheds with moderate to high levels of fire ignition), with the forested vegetation outside HRV submodel (which can identify those subwatersheds with moderate to high hazard for forested vegetation outside HRV), the assessment estimates that up to 152 subwatersheds (total of 1,196,781 acres [484,526 hectares) are those most at risk to catastrophic wildfire. Many of these subwatersheds are located in steep canyons associated with the Boise and Payette River systems.

*What important resources are at risk to these severe wildfires?*

To determine what important resources are at risk to these fires, the hazard-risk assessment estimated where catastrophic wildfires would affect specific wildlife, watershed, and fisheries resources. By linking all five submodels included in the assessment, analysis indicates that in 20 watersheds (total of 610,389 acres [247,121 hectares]), all of these important resources could be affected by catastrophic wildfire (Table 1).

Table 1. Percentages of Boise National Forest most at risk from catastrophic wildfire.

| | Acres[2] | % of Forest[1] |
|---|---|---|
| Most at risk to large, catastrophic fire | 1,196,781 | 40% |
| Important resources affected by fire | 610,389 | 20% |

[1] Percentage relative to Boise National Forest (BNF) encompassed area of 3,000,000 acres (1,214,575 hectares), as captured in 1992 LANDSAT satellite imagery. Includes about 350,000 acres (141,700 hectares) intermingled state, other federal and private land. Net BNF is about 2,650,000 administered acres (1,072,874 hectares).
[2] Figure represents all acres within 152 subwatersheds, including some grass and shrublands, subalpine fir (*Abies lasiocarpa*), etc.

## DISCUSSION

The hazard-risk assessment is designed to evaluate the relative size and extent of the BNF's challenge in managing sustainable ponderosa pine ecosystems. It also tells land managers where to begin evaluating site-specific conditions at a finer scale, where to begin determining a desired future condition for a landscape at risk, and finally, what kinds of specific projects might be designed. Some managers are tempted to use the hazard-risk assessment as rationale for site-specific thinning and prescribed fire. Generally the assessment has been used correctly to prioritize area, for further analysis.

The assessment is intended to fall in a hierarchy between large-scale analysis undertaken as part of the Upper Columbia River Basin (UCRB) assessment, and the more site-specific evaluation performed for watershed- and landscape- or project-level analyses. The assessment is compatible with the Forest Service National Hierarchical Framework of Ecological Units. The forest lies in Section M332A (Idaho Batholith) of Province M332 (Middle Rocky Mountain Steppe—Coniferous Forest—Alpine Meadow) [McNab and Avers 1994]. Habitat types developed as a basis for the wildlife persistence model were in turn developed based on section information established by the UCRB assessment. Information from the hazard-risk assessment can thus be aggregated to ecological sections at a larger scale.

Because the assessment was developed to analyze conditions on a forestwide basis, it should not be used for more site-specific watershed- and landscape- or project-level work without further evaluation and refinement.

The hazard-risk assessment represents an important addition to the analytical toolbox available to today's land managers. It recognizes the potential for large, severe wildfires burning with altered fire regimes to damage important resources, and acknowledges the large-scale interruption of successional pathways that have helped create today's catastrophic conditions. Because it focuses on potential effects to fisheries populations, late-successional wildlife habitat, and sedimentation, the hazard-risk assessment highlights the consequences of severe, stand-replacing fire burning outside historical patterns to disturb the structure and function of an entire ecosystem.

Given the potential loss of ponderosa pine-dominated forests on the BNF in the next 20 years, the hazard-risk assessment can be a primary tool for prioritizing areas most at risk, for further evaluation. The model's structure is particularly well suited to examine situations like this in which time and resources for assessment and resolution are limited, because the assessment uses selected criteria to progressively narrow the area of consideration to one which can be accomplished. Although the assessment involved the work of several resource specialists over three years' time, costs for any future effort (or any similar effort on another national forest) would be reduced because technology and data availability have increased substantially in recent years. Similar efforts could be easily reproduced by another group of qualified specialists, contingent upon appropriate understanding of the Boise team's assumptions and methodology.

The assessment's use of GIS as the modeling medium is particularly appropriate in examining landscape conditions, because GIS can analyze large amounts of data and sophisticated relationships across extensive areas. Since GIS is a widely-used, state-of-the-art analysis tool, it lends itself especially well to sharing information among resource specialists from different agencies and organizations. It also facilitates expansion of the hazard-risk assessment to incorporate different ownerships and boundaries, since the challenges to ecosystem health cross jurisdictional boundaries and affect resources and resource users at many scales.

Forest scientists recognize that to restore the resistance and resilience of ecosystems with altered fire regimes, land managers must use several tools, including fire and timber harvest (Agee 1995, Mutch 1995). People will need to conduct low-intensity fire under prescribed conditions to begin restoring fire-dependent ecosystems and to remove ground fuels and recycle nutrients, and thinning to remove less fire-resistant trees such as Douglas-fir and grand fir, while leaving the larger, fire-resistant ponderosa pine. (In today's altered landscapes, thinning is needed to remove trees from dense areas where prescribed fire alone could result in a lethal, stand-replacing wildfire.) By identifying the areas most at risk, the hazard-risk assessment takes land managers "to the ground" to look closer, with the possible outcome that some of these restoration treatments may be prescribed. If so, the hazard-risk assessment may then support the adjustment in management needed to incorporate different types of timber harvest, and more extensive use of prescribed fire, than traditionally undertaken.

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