Appendix F:
Grand Canyon National Park
Wildland and Prescribed Fire Monitoring & Research Plan

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F.1 Introduction

One of the central goals of the Grand Canyon National Park (GRCA) Fire Management Program is to promote a science-based program that relies on current and best-available information and incorporates adaptive management practices. The GRCA Fire Ecology Program is responsible for providing short- and long-term data on vegetation and fuel change and for generating burn severity mapping data. Working in collaboration with Prescribed Fire Burn Bosses and fire Incident Commanders, the GRCA Fire Ecology Program also provides support for fire observation monitoring in the park. The environmental monitoring and additional short- and long-term resource monitoring that contribute to fire management decisions are the responsibility of the individuals or groups outlined in sections F.5.1 and F.5.5 of this plan.

Since 1990 GRCA has maintained an active fire effects monitoring program that allows fire managers to evaluate the effectiveness of the prescribed fire program and adapt future practices to better meet management objectives. The first formal GRCA fire effects monitoring plan (NPS 2000) outlined procedures for monitoring active fires in the park and monitoring long-term vegetation and fuel load changes as a result of prescribed burning. In the time since the first monitoring plan was formalized, the GRCA Fire Management Program has revised its program goals and objectives in the form of a new Fire Management Plan (FMP) based on current Federal Wildland Fire Management Policy (U.S. Government 2001) and National Park Service (NPS) Wildland Fire Management policy (NPS 2008b). Other changes that have occurred since the previous monitoring plan was finalized include (1) 36 fires totaling over 90,000 acres have burned in the park, (2) the park has participated in nine years of burn severity mapping through the Joint NPS-USGS National Burn Severity Mapping Project, (3) over 20 research papers specific to the park have been published relating to reference conditions, fire regimes, vegetation, and fuel, (4) Mexican spotted owl critical habitat has been designated within the park (USFWS 2004), (5) a sentry milk-vetch recovery plan has been finalized (USFWS 2006), (6) new desired conditions have been formulated for the major vegetation types in the park, and (7) a Fire Ecologist position has been established to manage the Fire Ecology Program.

As an appendix to the 2010 GRCA FMP, this monitoring plan describes the current and planned framework for collecting, managing, evaluating and integrating fire monitoring information. Fire monitoring is a critical component of fire management and is aimed at providing information on the effectiveness of the Fire Management Program. The primary focus of the GRCA fire monitoring program is the assessment of vegetation and fuel conditions and the determination of how these conditions are affected by fire management activities. However, the program also monitors fire and weather conditions during prescribed and unplanned fires, conducts burn severity assessments under the National Burn Severity Mapping Program, and facilitates the collection of site-specific information used for compliance and consultation requirements under the National Environmental Policy Act, Endangered Species Act, and National Historic Preservation Act.

Monitoring programs are intended to continuously inform fire managers about the effects of management activities so that fire management programs can adapt to changing conditions using the best available information. As new information and research results are obtained, relevant changes to the monitoring and/or fire management programs are made. These changes may include new or alternative monitoring techniques, changes in treatment prescriptions, or refinement of management objectives. Integration of fire monitoring data is a shared responsibility between the park's fire management and natural and cultural resource management staff. Changes to the GRCA Fire Ecology Program will be reflected in annual updates to this monitoring plan.

F.2 Fire and Fuel Management

The GRCA Fire Management Program uses a variety of strategies to achieve the goals of protecting human safety and property, restoring and maintaining ecosystems, and protecting park values. GRCA has used prescribed fire since 1980 to meet resource management goals and objectives and has managed wildfires to meet resource objectives since 1987. In addition to managing prescribed and unplanned fires, the GRCA Fire Management Program will employ non-fire manual and mechanical fuel treatments to protect human safety and property and cultural and natural resource values. The role of fire management in meeting park stewardship goals and the strategies employed to meet management goals are discussed in detail in section 1.6 and 2.6, respectively, of the GRCA Fire Management Plan EIS/AEF (NPS 2009a).

To facilitate fire and fuel management planning, the park is divided into eight Fire Management Units (FMUs) based on fuel characteristics and fire regimes. The eight FMUs have dissimilar levels of development, meteorology, history, and values at risk (including cultural resources and species of concern) that are described in detail in section 2.6.5.2 of the GRCA Fire Management Plan EIS/AEF (NPS 2009a). The FMU division is used for strategic planning and management; however the fire monitoring program is based on vegetation types which cross FMU boundaries. The relationship between the eight FMUs and the park's major vegetation types, fire history, and monitoring types is summarized in Table F.2.1.

Table F.2.1. Relationship between the eight FMUs and the park's major vegetation types, fire history, and monitoring types. WUI = Wildland Urban Interface.

FMU	Acres (% of Park)	Vegetation Types	Role of Fire	Fire Regime Alteration	Management Focus	Monitoring Focus[1]	Monitoring Units[2] (# plots)
Kaibab Summit	15,879 (1.33%)	Spruce-fir forest with some mixed conifer on drier sites and meadows and aspen groves interspersed	Spruce-fir forest species are intolerant of fire; mixed-severity fire regime and infrequent stand-replacing fire occurs	Little change to fire regime, possibly some meadow encroachment and fewer aspen	Maintain native ecosystems	Levels 1, 2, 3, and 4; Severity Mapping	PIEN (8), PIAB (4)
Plateau	32,564 (2.73%)	Transitions from ponderosa pine to mixed conifer to spruce-fir with elevation; large and small meadows and aspen stands interspersed	Mixed-conifer forest structure depends on mixed-severity fire	Relatively homogeneous forest structure developed in absence of fire	Restore and maintain native ecosystems	Levels 1, 2, 3, and 4; Severity Mapping	PIEN (9), PIAB (4), PIPN (1), GRED (5), GRIN (9)
Peninsulas	48,807 (4.09%)	Predominantly ponderosa pine	Ponderosa forest structure depends on frequent surface fires	Heavy understory developed in absence of fire, much restored to open understory by managed fire	Restore and maintain native ecosystems	Levels 1, 2, 3, and 4; Severity Mapping	PIAB (19), PIPN (29), GRED (1), GRIN (1), PIPO (8)
Fire Islands	13,454 (1.13%)	Ponderosa pine, piñon-juniper	Ponderosa forest structure depends on frequent surface fires; mixed fire regimes in other types require more research	Essentially unaltered, cited in literature as best relics of pre-Euro-American conditions	Preserve best regional examples of natural fire regimes	Levels 1 and 2; Severity Mapping	none
Backcountry Uplands	119,069 (9.98%)	Piñon-juniper woodlands, sagebrush meadows, juniper savannas, some stringers of ponderosa pine	Mixed fire regimes may occur in this type; more research is needed	Unknown; possibly canopy closure	Restore and maintain native ecosystems	Levels 1 and 2; Severity Mapping	none
WUI Developed Areas	14,611 (1.22%)	Piñon-juniper woodlands, ponderosa pine, some mixed conifer and riparian types	See Peninsulas & Backcountry Uplands description	Heavy understory developed in absence of fire, little restored to open understory by managed fire	Protect life and property in a natural setting	Levels 1, 2, 3, and 4; Severity Mapping	PIPO (15), PIED (11)

FMU	Acres (% of Park)	Vegetation Types	Role of Fire	Fire Regime Alteration	Management Focus	Monitoring Focus[1]	Monitoring Units[2] (# plots)
Secondary WUI	15,188 (1.27%)	Ponderosa pine, piñon-juniper woodland	See Peninsulas & Backcountry Uplands description	Heavy understory developed in absence of fire, much restored to open understory by managed fire	Augment WUI protection with native ecosystems	Levels 1, 2, 3, and 4; Severity Mapping	PIPO (17), PIED (6)
Inner Canyon	933,032 (78.23%)	Desert shrublands, riparian, some piñon-juniper and forested communities on upper canyon walls	Sparse vegetation and fuel do not support fire as a major disturbance agent	Extensive growth of annual exotics could fundamentally alter fire regime	Maintain native ecosystems	Levels 1 and 2; Severity Mapping	none

[1]Monitoring focus levels are defined and described in section F.5.

[2]Monitoring Units are defined and described in section F.5 and appendix F.12.1.

F.3 Ecology and Landscape Management

Grand Canyon National Park fire management and fire monitoring activities are concentrated above the rim of Grand Canyon. Fires that begin within the canyon generally remain small due to lack of fuel continuity or are suppressed at small sizes. The associations that occur only below the rim or that are not included in planned fire management activities are not discussed in this monitoring plan.

The vegetation associations that occur above the rim are divided into five broad vegetation types for fire management purposes. These vegetation types are distributed primarily along an elevational gradient and secondarily along a topographic-moisture gradient in which moisture availability is determined largely by topographic position (e.g., valley bottoms are moist and ridge tops dry) (Figure F.3.1). Only the lower elevation vegetation types (piñon-juniper and ponderosa pine) are represented on the south rim of Grand Canyon. All five vegetation types are found on the north rim of Grand Canyon with gradual transitions between the types along the elevational gradient and patchy distribution of the types associated with topographic position.

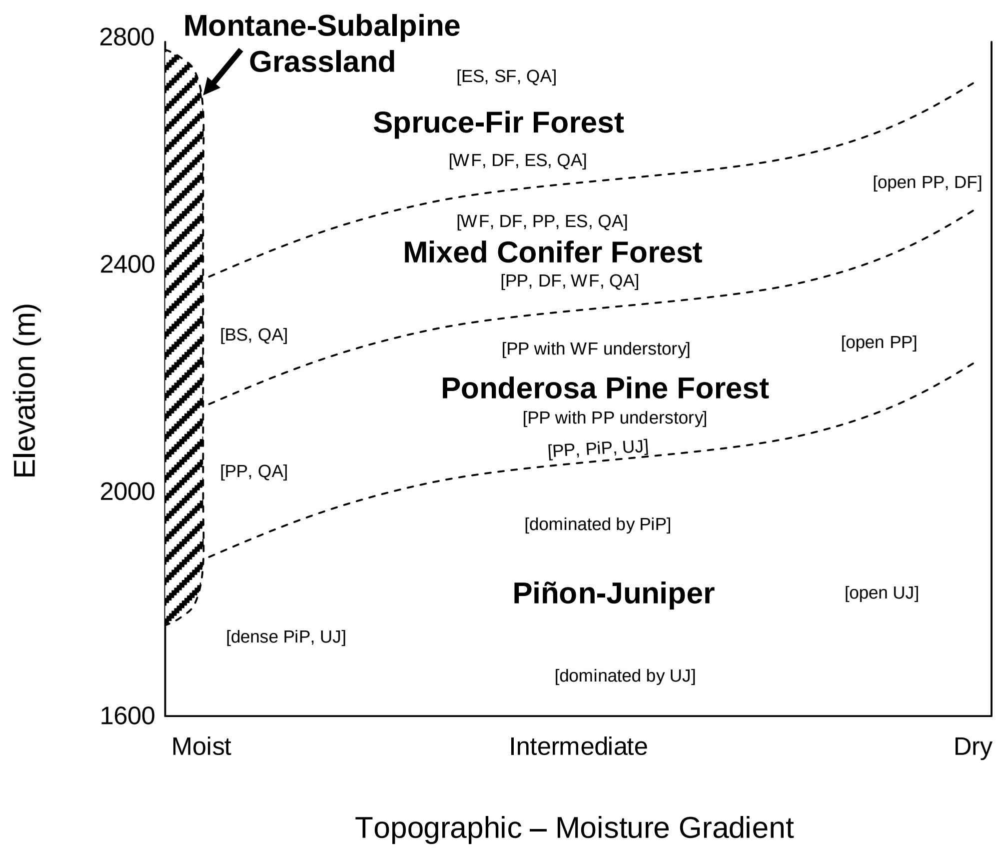

Figure F.3.1. Distribution of vegetation types in GRCA. Dominant tree species for are listed in brackets. BS = blue spruce, DF = Douglas-fir, ES = Engelmann spruce, PiP = piñon pine, PP = ponderosa pine, QA = quaking aspen, SF = subalpine fir, UJ = Utah juniper, and WF = white fir.

Fire management activities have affected all of the vegetation types above the rim over the past several decades. Grand Canyon managed over 158,000 acres of fire (prescribed and unplanned) between 1984 and 2009. These fires burned almost 94,000 acres of total land area above the rim, and approximately 40% of this land area burned more than once during the 26-year period (Table F.3.1). The majority of second- and third-entry fires occurred in the ponderosa pine forests on the South Rim.

Table F.3.1. Land area burned between 1984 and 2009 by vegetation type and number of times an area has burned during this time period. Area burned in 1 fire includes acres burned only once and does not include areas that have burned multiple times.

Forest Type	Area (acres) burned in 1 fire	Area (acres) burned in 2 fires	Area (acres) burned in 3 fires	Area (acres) burned in 4 fires	Total area (acres) burned	Total area (acres) in forest type
Piñon-Juniper	9,233	3,816	1,204	0	14,253	113,248*
Ponderosa pine	25,874	22,430	3,966	487	52,757	59,821
Mixed-conifer	15,623	3,421	2,259	11	21,314	37,616
Spruce-Fir	5,072	386	0	0	5,458	17,653
Total	55,802	30,053	7,429	498	93,782	228,338

*There are 309,881 total acres of piñon-juniper mapped in park, with 63% of this acreage below the rim of Grand Canyon. Only acres located above the rim of Grand Canyon are represented in this table.

Literature reviews and conceptual ecosystem models outlining the current and historical role of fire in the five vegetation types are available in the GRCA Fire Management Plan EIS/AEF (sections 2.4 and 3.1.1; NPS 2009a), the NPS Inventory and Monitoring Program's Southern Colorado Plateau Network (SCPN) Vital Signs Monitoring Plan (supplements I and II, Thomas et al. 2006), and The Nature Conservancy's Southwest Forest Assessment Project (SWFAP; Gori and Bate 2007, Smith 2006a-c, Smith 2007). Additionally, the GRCA Fire Management Plan EIS/AEF (NPS 2009a) contains detailed information on plant and wildlife species of concern in each vegetation type (sections 3.1.2 and 3.1.5, respectively), exotic plant species concerns for fire management (sections 3.1.3 and 4.2.3), the use of fire and fuel management techniques in cultural landscapes (sections 3.2.4 and 4.3), and existing fuel conditions and expected fire behavior (sections 2.4 and 2.6.5). Given the large amount of information available in the above-mentioned documents, the descriptions in this monitoring plan briefly describe each vegetation type, but focus mainly on the relationship of each vegetation type to the GRCA fire monitoring units and on the information used to refine management objectives for each monitoring type. Special status and exotic species of concern for fire management are listed in Appendix F.12.7.

F.3.1 Spruce-Fir Forest

Spruce-fir forest in Grand Canyon is characterized by Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and quaking aspen (*Populus tremuloides*) and occurs in the highest elevation sites (generally above 2,500 m (8,200 ft) on the North Rim. In the lower portion of its elevational range, spruce-fir forest is distributed in topographically determined patches with mixed conifer forest (reviewed in supplement II, Thomas et al. 2006). Historic (pre-1880) spruce-fir forest dynamics included dense (>40% canopy cover) old growth and mid-successional forests that experienced 200-400 year stand-replacing fire intervals, 33-100 year insect outbreak intervals, and succession lasting 150 years at high elevations (Figure F.3.2; Smith 2006c and references therein). At lower elevations, historic old growth and mid-successional forests had similar dynamics to high elevation forests with the addition of 8-31 year surface fire intervals (Figure F.3.2; Smith 2006c and references therein). Following crown fire or severe insect outbreaks, historic early successional (<70 years) forests were dominated by either Engelmann spruce and subalpine fir or by aspen and had 10-40% canopy cover (Figure F.3.2; Smith 2006c and references therein). Current stands undergo similar dynamics to historic stands except that the surface fire component has been eliminated in many areas. However, this eliminated surface fire regime has done little to alter landscape-scale conditions in spruce-fir forest (Smith 2006c and references therein).

For monitoring landscape-scale fire effects at GRCA, the spruce-fir forest type is represented by the Rocky Mountain Subalpine Conifer (PIEN) monitoring type which contains overstory trees dominated by Engelmann spruce, quaking aspen, and white fir (*Abies concolor*) with subalpine fir, ponderosa pine (*Pinus ponderosa*), and Douglas-fir (*Pseudotsuga menziesii*) occasionally present. The woody understory contains scattered pole and seedling trees of the same species as the overstory. Shrubs include common juniper (*Juniperus communis*) and creeping barberry (*Mahonia repens*). Common herbaceous species include sedges (*Carex* spp.), mutton grass (*Poa fendleriana*), blueleaf strawberry (*Fragaria virginiana*), and bracken fern (*Pteridium aquilinum*).

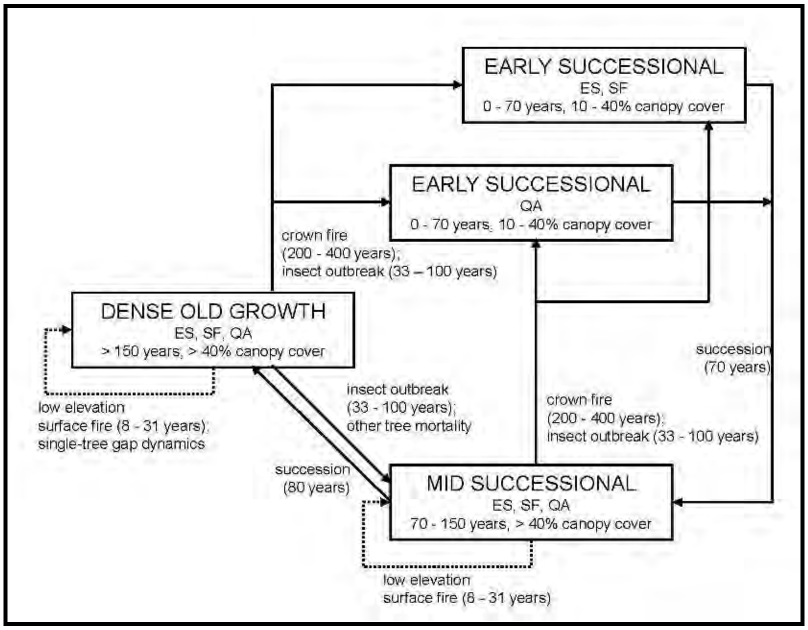

Figure F.3.2. Ecological model of spruce-fir forest (adapted from Smith 2006c and supplement II, Thomas et al. 2006). Solid lines and boxes represent states and processes occurring in both historic and current forests, dotted lines indicate historic processes that have been altered. Dominant tree species codes are listed in Figure F.3.1.

Between 1984 and 2009, approximately 31% (5,458 acres) of the spruce-fir forest in the park burned in unplanned wildfires (Table F.3.1). Moderate-high and high severity fire has played a larger role in this vegetation type than in the other vegetation types in the park. More than half of the spruce-fir forest that has burned in the park in recent decades burned with moderate-high to high severity effects (see patch size discussion in Appendix F.12.5 and burn severity mapping overview in section F.5.3.). To date, no prescribed fires have been conducted in this vegetation type in the park.

Seventeen FMH-style forest monitoring plots (section F.5.2) have been installed in the spruce-fir forest type. Five of the 17 plots were installed after the Outlet Fire of 2000 to monitor post-fire regeneration in moderate-high and high severity areas and do not have pre-fire data. Two additional plots that burned in the Outlet Fire have pre- and post-fire data as do three plots that burned in resource benefit wildfires. Monitoring data indicate that unplanned fires in this forest type reduce total surface fuel loading by 45 – 84% (average 60% ± 14) and reduce conifer tree density by 28 – 100% (average 70% ± 21) (Appendix F.12.5). Prior to fire, total fuel loading averaged 66.2 ± 8.1 tons/acre with 44% of the total loading contributed by 1000-hr timelag fuel moisture (TLFM) woody fuel and 46% of the total fuel loading contributed by litter + duff. Immediately after fire, total fuel loading averaged 24.9 ± 6.7 tons/acre with 73% of the total loading contributed by 1000-hr TLFM woody fuel. By five years after fire, total fuel loading increased to 41.6 ± 5.8 tons/acre with 72% of the total loading contributed by 1000-hr TLFM woody fuel.

One prescribed fire (Thompson-North Boundary) is planned for this type in the current FMP. The Thompson-North Boundary prescribed fire is designed primarily as a boundary protection burn to protect sensitive natural resources on the Kaibab National Forest from wildfires originating in the park. Even though most of this vegetation type has not had a fire in the last 100 years, the historic fire regime in this type is highly variable and likely to have moderate/long return intervals (Fulé et al. 2003a). Planned fire management activities are not currently focused on this type.

F.3.2 Mixed-Conifer Forest

The mixed-conifer forest type occurs on the north rim of the Grand Canyon at approximately 2,380 - 2,793 m (7,800 – 9,165 ft) elevation. GRCA mixed-conifer forest consists of a mosaic of topographically-determined patches dominated by different combinations of ponderosa pine, white fir, Douglas-fir, Engelmann spruce, subalpine fir, blue spruce (*Picea pungens*), and quaking aspen. Studies by Fulé et al. (2003a) and Laughlin et al. (2005) in the Little Park area demonstrate that plots representing ponderosa pine, mixed-conifer, aspen, and spruce-fir forest are highly intermixed in the mid- to high-elevation areas of the park. The patchy nature of the mixed-conifer forest on the North Rim and the intermixing of mixed-conifer with other forest types make characterization and management of the mixed-conifer zone challenging.

Conceptual models based on landscape position can be used to understand the dynamics of mixed-conifer forests in the Southwest (Thomas et al. 2006). Dry ridgetops, south-facing slopes, and lower elevation sites are generally dominated by open (<30% canopy cover) old growth (>160 years) ponderosa pine with occasional other conifer species present (Figure F.3.3). These dry sites were historically maintained by surface fires with occasional small patches (<0.25 acre) of higher severity fire (Fulé et al. 2003a). At current sites where the surface fire regime has been interrupted, forests are either open (<30% canopy cover) old growth (>120 years) ponderosa pine and other conifers with a dense understory of white fir or dense (>30% canopy cover) old growth (>120 years) or mid-successional (80-119 years) ponderosa pine with Douglas fir and white fir (Figure F.3.3). In areas with recent higher severity fire activity, sites range from early successional ponderosa pine and other conifers with >10% canopy cover to grassland and shrubland states with no conifers (Figure F.3.3).

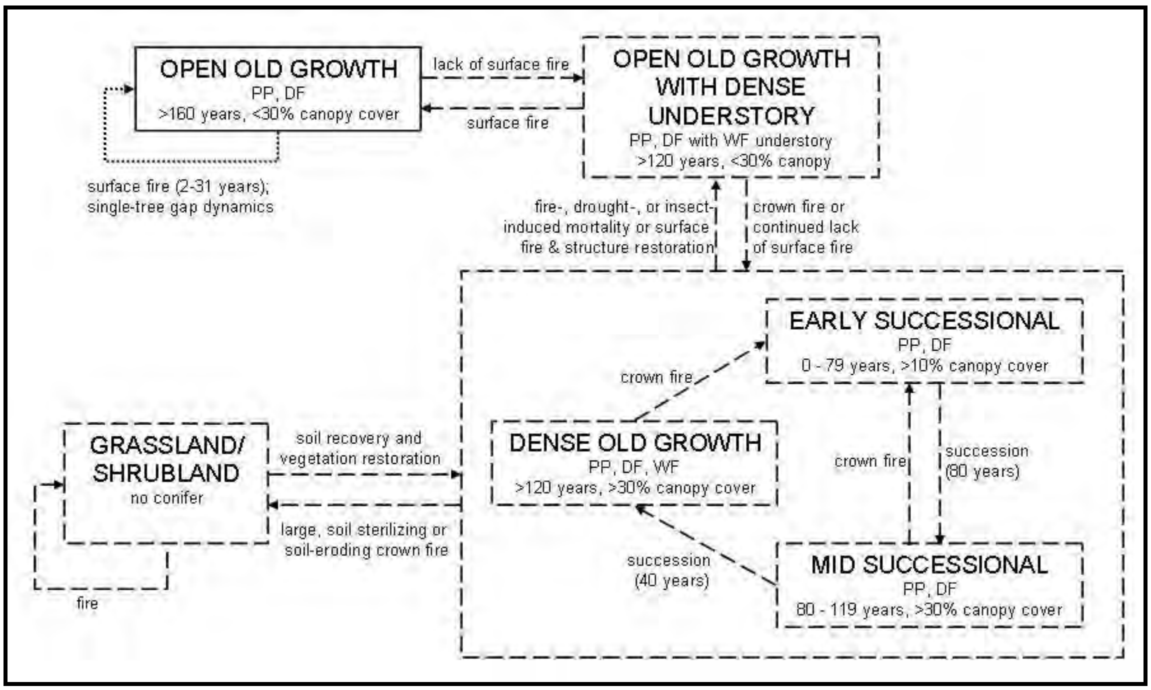

Figure F.3.3. Ecological model of mixed-conifer forest on dry ridgetops and south-facing slopes (adapted from Smith 2006b and supplement II, Thomas et al. 2006). Solid lines and boxes represent states and processes occurring in both historic and current forests, dotted lines indicate historic processes that have been altered, dashed lines and boxes indicate current states and processes without significant historic occurrence. Dominant tree species codes are listed in Figure F.3.1.

Mesic, higher elevation, and/or northerly aspect sites historically supported moderately dense (20-60% canopy cover) old growth (>200 years) forest comprised of a mix of conifer species (Figure F.3.4) and maintained by less frequent surface fires with occasional higher intensity fires (Fulé et al. 2003a). Early successional (<99 years) and mid-successional (100-199 years) mixed-conifer forests were also present in the historic landscape. In the absence of fire, dense (>40% canopy cover) old growth and uncharacteristically dense (>40% canopy cover) mid-successional states occur on the landscape (Figure F.3.4) and increase the probability of higher severity fire patches. Moist drainages within the mixed-conifer zone are generally similar to higher elevation spruce-fir forests (Figure F.3.2).

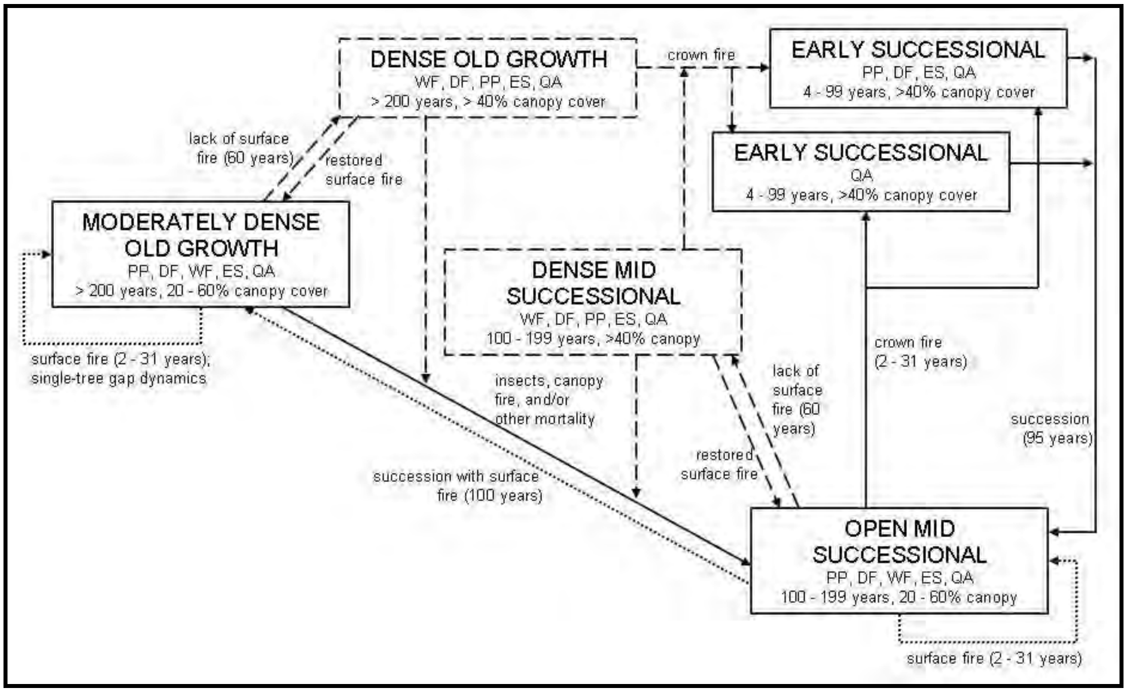

Figure F.3.4. Ecological model of mixed-conifer forest on mesic sites such as north-facing slopes (adapted from Smith 2006a and supplement II, Thomas et al. 2006). Solid lines and boxes represent states and processes occurring in both historic and current forests, dotted lines indicate historic processes that have been altered, dashed lines and boxes indicate current states and processes without significant historic occurrence. Dominant tree species codes are listed in Figure F.3.1.

Between 1984 and 2009, approximately 57% (21,314 acres) of the mapped mixed-conifer forest in the park burned and 5,691 of these acres burned more than once (Table F.3.1). The majority of the burned mixed-conifer acres burned in the Poplar resource benefit wildfire of 2003. Several prescribed fires and wildfires on the northern end of the Walhalla Plateau also burned in this vegetation type over this time period and account for the majority of the multiple-entry acres. The mixed-conifer forest has burned with mixed severity effects in recent decades. Around 20% of the mixed-conifer forest that has burned in the park burned with moderate-high to high severity effects (see patch size discussion in Appendix F.12.5 and burn severity mapping overview in section F.5.3.). The current FMP includes prescribed fires and resource benefit wildfires in this vegetation type. The planned prescribed fires will occur in the higher elevation mixed-conifer forests and will be first-entry fires following decades of active fire suppression in these areas.

For landscape-scale fire monitoring purposes, the subset of mixed-conifer forest that is located between 2,380 to 2,650 meters (7,800 to 8,700 feet) elevation and is dominated by ponderosa pine, white fir, and quaking aspen, with the greatest basal area in ponderosa pine and the understory trees dominated by white fir, is defined as the Ponderosa Pine with White Fir Encroachment (PIAB) monitoring type (Appendix F.12.1). Other possible overstory species in this monitoring type include Douglas-fir, blue spruce, and Engelmann spruce, and total canopy cover is generally 30% or greater. The woody understory is composed of mostly white fir (25 to 100%), ponderosa pine, quaking aspen, and Douglas-fir. Common shrub species are creeping barberry, New Mexico locust (*Robinia neomexicana*), and mountain snowberry (*Symphoricarpos oreophilus*). Common herbaceous species include sedges, sticky starwort (*Pseudostellaria jamesiana*), mutton grass, bracken fern, dwarf lousewort (*Pedicularis centranthera*), goldenrod (*Solidago* spp.), and common yarrow (*Achillea millefolium*). This type is transitional between ponderosa pine and mixed-conifer forest and does not represent conditions in the higher elevation mixed-conifer areas.

Twenty-seven FMH-style forest monitoring plots have been installed in the Ponderosa Pine with White Fir Encroachment (PIAB) monitoring type to date. A total of 24 PIAB plots have burned in a first-entry fire and 11 plots have burned a second time since installation. Of these plots, 11 have burned in prescribed fires, 9 in resource benefit wildfires, and 4 in the Outlet Fire of 2000. Seven plots that burned twice burned in resource benefit wildfires that occurred 8 years apart. Four plots that burned twice burned in prescribed fires that occurred between 3 and 14 years apart. This monitoring type generally falls within the lower elevation portions of the mixed-conifer zone. Since future prescribed fire management activities are focused primarily on the higher elevation portions of the mixed-conifer zone, an additional monitoring type may be developed in the future to capture the expected differences in fire effects between these areas.

Monitoring data indicate that in the lower elevation areas of the mixed-conifer zone (i.e. PIAB monitoring type) change in total fuel loading following first-entry fire ranged from a slight increase in fuel loading (due primarily to fallen logs) to an 83% reduction in fuel loading in individual plots (does not include plots burned in the Outlet Fire of 2000 where total fuel loading was reduced 77-99%). The average reduction in total fuel loading during first-entry fire (excluding Outlet Fire) was 50.1% ± 9.0. All fuel loading components were reduced following fire, and the largest reductions were in litter and duff loading (Appendix F.12.5). Total fuel loading averaged 17.1 ± 3.4 tons/acre immediately following fire (excludes Outlet Fire) with equal distribution of fuel loading between the litter + duff and 1000-hr TLFM components. Five years after fire, total fuel loading had increased to an average of 30.5 ± 5.2 tons/acre. Litter + duff loading remained at around half of pre-burn levels five years after fire, but 1000-hr TLFM increased dramatically from pre-fire levels in some plots leading to landscape-scale average total fuel loading as high as pre-fire values. During second-entry fires in the PIAB monitoring type, change in total fuel loading ranged from an increase in fuel loading (due primarily to fallen logs) to an 88% reduction in fuel loading in individual plots (average reduction in total fuel loading was 34.5% ± 35.6). Small woody fuel loading and litter and duff loading were reduced in second-entry fire, but coarse woody fuel loading was unchanged by second entry fire (Appendix F.12.5). Total fuel loading averaged 17.5 ± 7.6 tons/acre immediately following second-entry fire with 80% of the fuel load contributed by 1000-hr TLFM woody fuel.

Tree density also decreased following fire in the PIAB monitoring type. Pole-sized white fir tree density was reduced by 10 – 100% in individual plots (average decrease of 76% ± 9) and total pole-sized conifer tree density (including white fir) was reduced 12 – 100% in individual plots (average decrease of 71% ± 9). Total pole-sized conifer density averaged 72.5 ± 22.2 trees/acre two years after fire (Appendix F.12.5). Large ponderosa pine tree density decreased by 0 – 100% in individual plots (average of 32% ± 12) and total large conifer tree density (including ponderosa pine) decreased by an average of 41% ± 11. Even though both pole-sized and large tree density decreased following fire, white fir remained the dominant understory tree and ponderosa pine remained the dominant canopy tree.

F.3.3 Ponderosa Pine Forest

Ponderosa pine forest occurs on both the north and south rims of Grand Canyon between 1,950 m and 2,600 m (6,400 – 8,530 ft) in elevation. GRCA fire management distinguishes between North Rim and South Rim ponderosa pine forest due to the differences in historic and current conditions between the drier South Rim type and the more mesic North Rim type. South Rim ponderosa pine forests historically had slightly longer fire intervals (Fulé et al. 2003b) and much lower tree density (Fulé et al. 2002a, b) than did North Rim ponderosa pine forests. In addition, Laughlin et al. (2005) describe North Rim ponderosa forests as floristically more similar to Rocky Mountain forests than to typical ponderosa pine forests of the southwest.

Ponderosa pine forests historically had open (<30% canopy cover) stand structures maintained by frequent, low intensity fires and only occasional patches of dense forest (reviewed in Thomas et al. 2006 and Smith 2006b). In the absence of fire, some areas of the park have transitioned to the open old growth ponderosa pine with dense ponderosa pine or white fir understory state (Figure F.3.5.; both South and North Rims) or to the dense (>30% canopy cover) old growth ponderosa pine or ponderosa pine with white fir state (Figure F.3.5.; North Rim, especially at the transition with mixed-conifer). Crown fire patches have occurred in the transition zone between ponderosa pine and mixed-conifer (e.g. the PIAB monitoring type) on the North Rim. These crown fire patches have generated a range of states from early successional (<79 years) ponderosa pine and ponderosa pine with gambel oak to grassland/shrubland with no pine present (Figure F.3.5.).

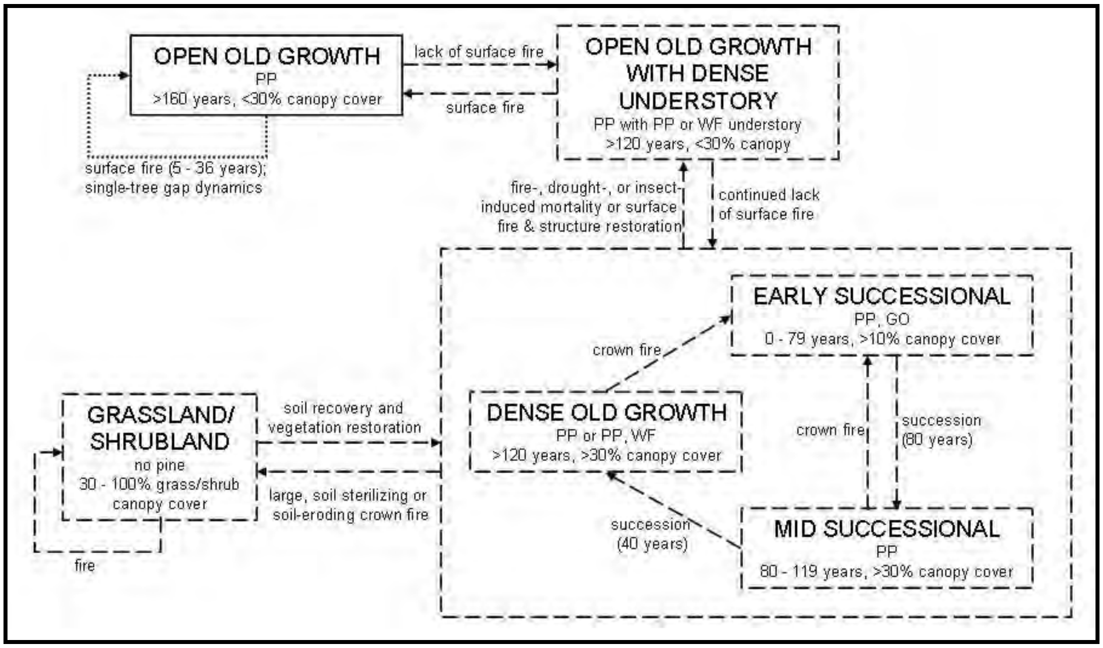

Figure F.3.5. Ecological model of ponderosa pine forest (adapted from Smith 2006b and supplement II, Thomas et al. 2006). Solid lines and boxes represent states and processes occurring in both historic and current forests, dotted lines indicate historic processes that have been altered, dashed lines and boxes indicate current states and processes without significant historic occurrence. Dominant tree species codes are listed in Figure F.3.1. GO = Gambel oak.

Between 1984 and 2009, approximately 88% (52,757 acres) of the ponderosa pine forest in the park burned. Most of the burned ponderosa pine acres burned multiple times within this time period: 22,430 acres burned twice, 3,966 acres burned three times, and 487 acres burned four times (Table F.3.1). The multiple entry activity in South Rim ponderosa is due almost entirely to GRCA’s active prescribed fire program over the past 20 years. The North Rim ponderosa sites have burned in a combination of prescribed fires and wildfires. Fires in ponderosa pine forests have burned primarily with low and moderate-low severity. Approximately 2% of the ponderosa pine forest that has burned in the park burned with moderate-high to high severity effects (see patch size discussion in Appendix F.12.5 and burn severity mapping overview in section F.5.3.).

The South Rim Ponderosa Pine (PIPO) monitoring type is defined by a pre-fire tree canopy cover of 20-60%, >50% of the overstory stems as ponderosa pine, and <50% of the overstory stems as piñon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), and Gambel oak (*Quercus gambellii*). Common shrubs include creeping barberry, big sagebrush (*Artemisia tridentata*), snakeweed (*Gutierrezia sarothrae*), and gray rabbitbrush (*Ericameria nauseosa*). Common herbaceous plants include mutton grass, blue grama (*Bouteloua gracilis*), mountain muhly (*Muhlenbergia montana*), squirreltail (*Elymus elymoides*), sedges, and lupines (*Lupinus* spp). The North Rim Ponderosa Pine (PIPN) monitoring type is defined by a pre-fire tree canopy cover >25% and at least 80% of the overstory stems and 75% of the understory stems as ponderosa pine. Common shrub species are creeping barberry, Wood’s rose (*Rosa woodsii*), New Mexico locust, Fendler's ceanothus (*Ceanothus fendleri*), and gray rabbitbrush. Common herbaceous species include sedges, mutton grass, lupines, squirreltail, common yarrow, and bracken fern.

To date, 40 FMH-style forest monitoring plots have been installed in the ponderosa pine forest type on the South Rim (PIPO) and 30 plots have been installed in the ponderosa pine forest type on the North Rim (PIPN). On the South Rim, 35 PIPO plots have burned in first-entry prescribed fires, 19 plots have burned in second-entry prescribed fires, and 11 plots have burned in third-entry prescribed fires. On the North Rim, 29 PIPN plots have burned in first-entry fires (14 plots burned in prescribed fires and 15 in resource benefit wildfires), 10 plots have burned in second-entry fires (5 plots burned in prescribed fires and 5 in resource benefit wildfires), and 2 plots have burned in third-entry fires (resource benefit wildfires). The time between first and second entry plot burns on the South Rim ranged from 5 to 11 years (average 6.5 years) and the time between second and third entry plot burns on the South Rim ranged from 7 to 9 years (average 7.9 years). The time between first and second entry plot burns on the North Rim ranged from 5 to 15 years (average 7.9 years).

Monitoring data show that pre-fire total fuel loading values are approximately twice as high in North Rim ponderosa pine forests (31.4 ± 3.6 tons acre) than in South Rim ponderosa pine forests (15.4 ± 1.5 tons acre) (Appendix F.12.5). Litter + duff loading is the largest component of surface fuel loading in both South and North Rim ponderosa pine forests and litter + duff loading also undergoes the largest reductions during fire. On the South Rim, total fuel loading was reduced by 6 – 85% in individual PIPO plots (average 48% ± 6) during first-entry fires. Total fuel loading measured immediately after second-entry fire did not differ from values measured before second-entry fire. However, during third-entry fires, total fuel loading was reduced by 3 – 86% from values measured before third-entry fire in individual PIPO plots (average 38% ± 10). PIPO plots are burned an average of every 6.5 years in prescribed fires on the South Rim and are measured 5 years and ten years after each fire if they are not burned again before the measurements occur. Monitoring data indicate that total fuel loading measured five years after first and second entry fire did not differ from fuel loading measured immediately following these fires. This indicates that prescribed fire treatments successfully reduce fuel loading in South Rim ponderosa pine for at least five years and potentially longer. To date, 10-year post-fire measurements have been taken on only three PIPO plots prior to the plots burning again, so no statistical assessment of fuel accumulation between five and ten years after fire can occur.

On the North Rim, monitoring data show that during first-entry fires change in total fuel loading ranged from slight increases (due to large woody debris falling after fire) to reductions of 96% in individual PIPN plots (average 57% ± 6). Total fuel loading was 3 – 90% lower in individual PIPN plots (average 54% ± 12) immediately following second-entry fires than prior to second-entry fires. Monitoring data indicate that total fuel loading measured five years after first-entry fire was similar to fuel loading measured immediately following these fires. However, second-entry fires in North Rim ponderosa pine forest burned an average of 7.9 years after first-entry fires and an unknown amount of fuel accumulation could have occurred between five and eight years after the first fire. To date, 10-year post-fire measurements have been taken on only two PIPN plots prior to the plots burning again and only two PIPN plots have burned in third-entry fires, so no statistical assessment of fuel changes can occur for these time periods.

Pre-fire pole-sized ponderosa pine density was slightly higher in North Rim ponderosa pine forests (131.2 ± 42.6 trees/acre) than in South Rim ponderosa pine forests (106.7 ± 33.6 trees/acre) and pre-fire large ponderosa pine density was over twice as high in North Rim ponderosa pine forests (45.6 ± 3.2 trees/acre) than in South Rim ponderosa pine forests (20.2 ± 2.4 trees/acre) (Appendix F.12.5). Pole-sized ponderosa pine density decreased 0 – 100% in individual PIPO plots (average 30% ± 8) following first-entry fire and 0 – 30% in individual PIPO plots (average 7% ± 4) following second-entry fire. Large ponderosa pine density was unchanged following both first- and second-entry fire in South Rim ponderosa pine plots. On the North Rim, pole-sized ponderosa pine density decreased 0 – 100% (average 61% ± 9) and large ponderosa pine density decreased 0 – 100% (average 12% ± 7) in individual PIPN plots following first-entry fire (Appendix F. 12.5). Since tree density values are assessed two and five years following fire, there is currently not enough data to assess the effects of second-entry fire on tree density in North Rim ponderosa pine forests.

Current and future fire management in both South and North Rim ponderosa pine forests is designed to continue moving these forests toward the desired conditions (section F.4.3.). Fire management activities to date have been successful in reducing pole-sized (1 – 6 inches dbh) tree density in the ponderosa pine forests. However, after burning twice, average pole-sized ponderosa pine density in South Rim plots is 420% greater than the desired condition and average total ponderosa pine density is 285% greater than the desired condition. Pole-sized trees currently comprise approximately half of the tree density in South Rim ponderosa pine forests, and future restoration treatments will be targeted at this size class. On the North Rim, average pole-sized ponderosa pine density is 156% greater than the desired condition and average total ponderosa pine density is 162% greater than the desired condition, with tree density evenly distributed among size classes. Future restoration and maintenance treatments on the North Rim will include reductions in both pole-sized and mid-sized trees. The current FMP includes management of ponderosa pine forests using a combination of prescribed fires and wildfires on both rims of Grand Canyon.

F.3.4 Piñon-Juniper

Piñon-juniper vegetation types dominated by piñon pine and Utah juniper occur below 2,290 m (7,500 ft) and extend into the canyon in many areas. Piñon-juniper types are limited to the southern tips of the plateaus that extend into the canyon on the North Rim, but are the most dominant vegetation type on the South Rim. Various piñon-juniper associations also occur within the canyon, but fire management activities are not planned for these areas.

Limited research and high historic and current variability in piñon-juniper vegetation types (Romme et al. 2009) has led to uncertainty about the role of fire in these types. Grand Canyon plateau areas are best described as persistent piñon-juniper woodlands (Romme et al. 2009) with some wooded shrublands on the plateau and in the inner canyon. Current information suggests that in piñon-juniper woodlands fire historically occurred as single-tree events or in small patches with occasional higher-intensity events that killed all trees within the fire area (Huffman et al. 2008, Romme et al. 2009). Spreading surface fires were not common in this type and small trees were not regularly thinned by fire as in adjacent ponderosa pine forests (Huffman et al. 2008, Romme et al. 2009). Very long fire rotations on the order of centuries are thought to occur in this vegetation type and current vegetation structure is thought to be similar to historic conditions (Figure F.3.6; Gori and Bate 2007, Huffman et al. 2008, Romme et al. 2009).

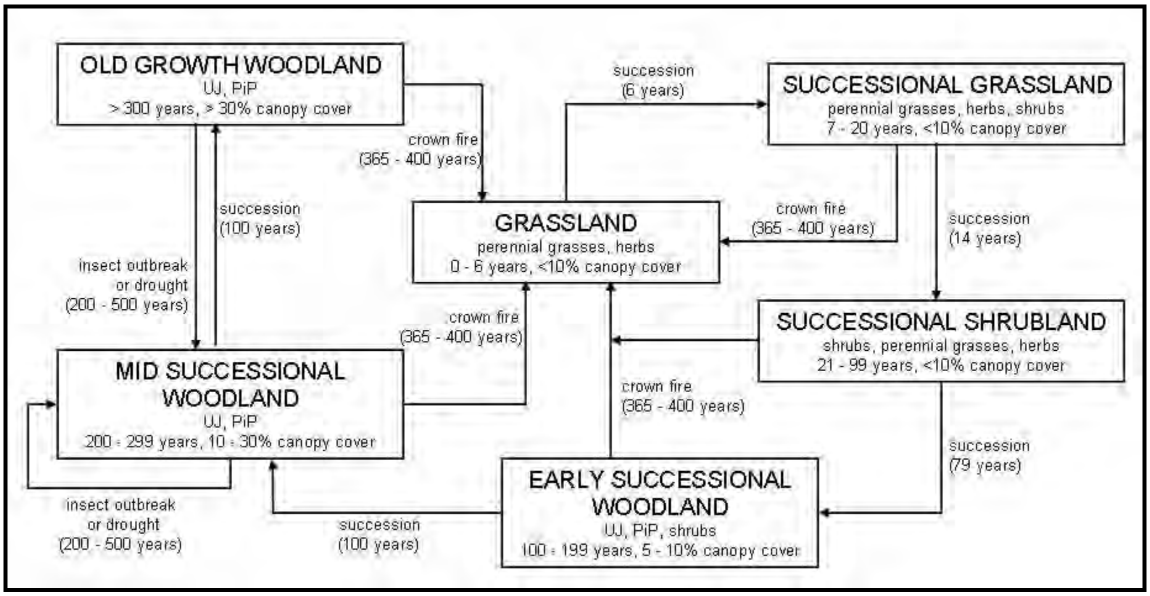

Figure F.3.6. Ecological model of piñon-juniper woodlands (adapted from Gori and Bate 2007). Solid lines and boxes represent states and processes occurring in both historic and current forests. Dominant tree species codes are listed in Figure F.3.1.

Approximately 13% (14,253 acres) of the piñon-juniper above the rim burned between 1984 and 2009, and 5,020 of those acres have burned multiple times within this time period (Table F.3.1). The multiple entry activity is due almost entirely to GRCA's active prescribed fire program over the past 20 years. Fires in piñon-juniper have burned primarily with low and moderate-low severity. Less than 1% of the piñon-juniper that has burned in the park burned with moderate-high to high severity effects (see patch size discussion in Appendix F.12.5 and burn severity mapping overview in section F.5.3.).

The Great Basin Conifer Woodland (PIED) monitoring type (Appendix F.12.1) was used until 2000 to monitor the effects of fire management in the piñon-juniper woodlands near Grand Canyon Village on the South Rim. However, this monitoring type was suspended due to data quality concerns and variation in the fire treatments in this monitoring type. Seventeen FMH-style forest monitoring plots were installed in piñon-juniper woodlands prior to the monitoring type suspension. Of these plots, 14 burned in first-entry prescribed burns. The majority of the 14 burned plots occur in areas that burned a second time, but no post-fire monitoring was conducted. Monitoring data indicate that prescribed fires in this vegetation type reduce total surface fuel loading by 5 – 51% in individual PIED plots (average 25% ± 6) immediately following fire. Prior to fire, total fuel loading averaged 17.5 ± 2.3 tons/acre with 65% of the total loading contributed by litter + duff. Immediately after fire, total fuel loading averaged 12.9 ± 1.9 tons/acre with 63% of the total loading contributed by litter + duff. Total conifer tree density shows slight increases (due to small trees moving into the >1 inch size class) to 40% reductions in individual PIED plots (average 13% ± 7) five years after fire (Appendix F.12.5).

Generally, the piñon-juniper woodlands near Grand Canyon Village do not carry continuous surface fire and burn only near jackpots of coarse woody debris or large duff areas at the base of trees. Although, crown fires may occur in this type during high wind events. Piñon-juniper is intermixed with ponderosa pine on the South Rim and is often included in prescribed fires designed to restore or maintain the ponderosa component of the burn unit. The current FMP contains plans for prescribed fires to continue in these areas.

F.3.5 Montane-Subalpine Grassland

Montane-subalpine grasslands dominated by fescues (*Festuca* spp.) and other grass species occur throughout the coniferous forest elevational range and into the piñon-juniper vegetation zone on the north rim of the Grand Canyon. Two monitoring types (GRIN and GRED; Appendix F.12.1) were established in grassland areas, but these types have been suspended due to changing management priorities. The grasslands are generally described as mixed meadows of grasses and herbs with vegetation less than 1.5 feet tall and total cover ranging from 35 to 100%. Grasses as a whole dominate but the species present may vary from meadow to meadow. Grass species include mountain muhly, blue grama, pine dropseed (*Blepharoneuron tricholepis*), Kentucky bluegrass (*Poa pratensis*), and mutton grass. Herbaceous species include hairy false goldenaster (*Heterotheca villosa*), lupines, common yarrow, horse cinquefoil (*Potentilla hippiana*), gray goldenrod (*Solidago nana*), and Carruth's sagewort (*Artemisia carruthii*).

The montane-subalpine grasslands on the North Rim are not well studied or well understood. In the only research paper addressing North Rim grasslands, Moore and Huffman (2004) found that tree invasion into these grasslands has increased over time. More than 60% of the tree encroachment into North Rim grasslands has occurred since 1973, with most occurring during the 1980s (Moore and Huffman 2004). Aspen and spruce are the most abundant invading tree species; however, many of the invading aspen stems are in an unhealthy or declining condition (Moore and Huffman 2004). Many factors such as climate, fire exclusion, and changes in ungulate populations may have contributed, either alone or in combination, to the increased tree invasion (Figure F.3.7.; reviewed in Moore and Huffman 2004, Thomas et al. 2006, Smith 2007). Prescribed fire has been considered for grassland areas in the past, but given the uncertainty surrounding the dynamics of these grasslands, there are no current plans to use fire to maintain or enhance grassland areas in the park.

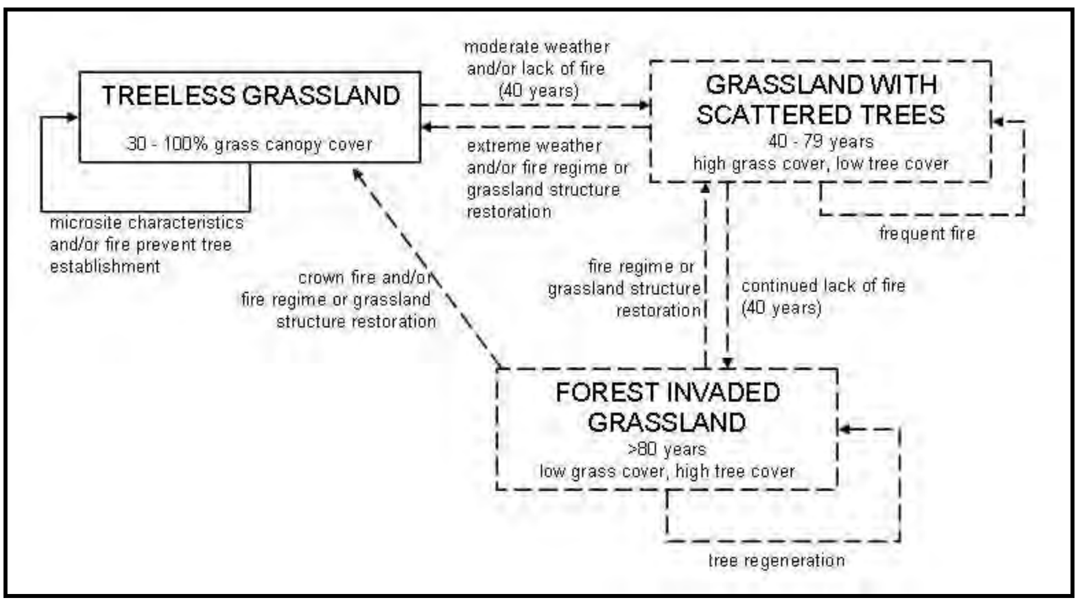

Figure F.3.7. Ecological model of montane-subalpine grassland (adapted from supplement II, Thomas et al. 2006 and Smith 2007). Solid lines and boxes represent states and processes occurring in both historic and current grasslands, dashed lines and boxes indicate current states and processes without significant historic occurrence.

F.4 Management Goals and Objectives

This fire monitoring plan is an appendix to the GRCA Fire Management Plan, which is tiered to the GRCA Resource Management (NPS 1997) and General Management (NPS 1995) plans. The purpose of a fire monitoring plan is to outline specific procedures used to evaluate the goals and objectives of a fire management plan and higher level park resource and general management plans. The overall goal of the fire monitoring program is to provide information to fire and resource managers that allows them to evaluate whether park and fire management objectives are being met and, if necessary, to make program adjustments.

F.4.1 Resource Management, Fire Management, and Fire Ecology Goals

Park-wide General Management Plan and Resource Management Plan goals and objectives relating to fire management are summarized in section 1.6 of the GRCA Fire Management Plan EIS/AEF (NPS 2009a). GRCA Fire Management Program goals and objectives are described in section 1.4 of the Fire Management Plan EIS/AEF (NPS 2009a).

The goals and objectives of the GRCA Fire Ecology Program are:

Goal 1 – Support a science-based fire management program.

Objectives:
- Establish and implement a peer-reviewed sampling design, data collection protocol, and data management protocol for vegetation communities to be treated with fire or non-fire fuel treatments.
- Record fire behavior and weather information during all prescribed fires.
- Document and analyze short- and long-term fire effects to vegetation and fuel.
- Provide information for adaptive management decisions related to treatment and management objectives, management strategies, and desired conditions.
- Review the fire monitoring plan annually and make changes to reflect new information gained.
- Identify research needs and facilitate research on natural fire regimes as well as fire effects to natural and cultural resources (see section F.8.2).

Goal 2 - Promote a safe and effective fire monitoring program.

Objectives:
- Provide personnel with the equipment and information needed to manage risks and perform monitoring and fire activities safely.
- Provide training opportunities for crew members in the form of both formal classes and in-park and out-of-park fire assignments.

Goal 3 - Facilitate communication within the park, the region and the NPS, between agencies, with the public, and with the scientific community.

Objectives:
- Annually analyze, report, and interpret fire monitoring data for fire and resource managers and interpretive staff.
- Present monitoring data at conferences and/or as journal publications, as appropriate.
- Participate in cross-training activities with other fire management personnel and personnel from other divisions within the park, in other parks within the region, within the NPS, and with other agencies.

F.4.2 Treatment and Monitoring Objectives

Treatment objectives

The previous version of this monitoring plan (2000 Plan; NPS 2000) identified prescribed fire project objectives for first entry burns in the South and North Rim Ponderosa Pine (PIPO and PIPN), Ponderosa Pine with White Fir Encroachment (PIAB), and the Great Basin Conifer Woodland (PIED) monitoring types. A Monitoring Type Description Sheet (FMH-4) for the Rocky Mountain Subalpine Conifer (PIEN) monitoring type was drafted in 1993 and revised in 1997, but was not included in the 2000 Plan. Burn objectives were included in the 1997 version of the PIEN FMH-4. The two grassland monitoring types (GRIN and GRED) were established in 2001 after the 2000 Plan was finalized; however no treatment objectives were established for the grassland monitoring types.

Because of the amount of new information available since the 2000 Plan was finalized, the landscape-scale treatment objectives for each monitoring type were reevaluated for this plan and adjustments were made where needed. The process of evaluating and adjusting the landscape-scale treatment objectives was a collaborative effort between the Fire Ecologist and the individuals listed in section F.10.1 of this plan. One outcome of the evaluation and adjustment process for the landscape-scale objectives was a move from defining objectives based on the number of prescribed fire treatments completed (i.e. first entry vs. second entry vs. third entry objectives) to defining objectives based on the overall goal of applying treatments to an area (i.e. restoring vs. maintaining the vegetation type). Details of the first entry burn objectives from the 2000 Plan and the restoration and maintenance objectives to be implemented with this plan are summarized in table F.4.1. Monitoring objectives and additional information related to the revised treatment objectives are in Appendix F.12.1. Treatment objectives for individual prescribed fire units and non-fire fuel treatment projects will be outlined in specific burn or treatment plans. Objectives for specific treatment units are expected to support the achievement of the landscape-scale objectives and the desired conditions for each vegetation type, but the objectives for specific treatment units may vary from those listed in table F.4.1. depending on the condition of the unit and the other values present in the treatment unit.

Table F.4.1. First entry burn objectives from the 2000 Plan and the 2010 restoration and maintenance objectives to be implemented with this plan for each monitoring type within GRCA.

	Treatment Objectives from 2000 Monitoring Plan	**2010 Revisions to Treatment Objectives**	
Monitoring Unit (Code)	**First Entry Burn**	**Restoration**	**Maintenance**
South Rim Ponderosa Pine (FPIPO1D09)	1. Reduce total fuel load by at least 30% on average, as measured over the landscape immediately post-burn (fuel reduction efforts will continue until the Desired Future Condition of 0.2-9.3 tons/acre is achieved). 2. Limit crown scorch to 30% on *Pinus ponderosa* with dbh greater than or equal to 16” (40 cm). 3. Reduce *Pinus ponderosa* poles with dbh of 1-6 inches (2.5-15 cm) to average 0-200 trees/acre (0-494 trees/ha). 4. Achieve and maintain a five-year post-burn density of 19-25 trees/acre of *Pinus ponderosa* in the 16”+ size class.	1. Reduce total fuel load to an average of 0.2 - 9.3 tons/acre, as measured over the landscape immediately after fire. 2. Maintain a landscape in which higher severity fire (determined through burn severity mapping) occurs in patches smaller than 5 acres and across no more than 5% of the monitoring type over any ten year period. 3. Reduce *Pinus ponderosa* pole-sized (1-6 inches, 2.5-15 cm, dbh) tree density to an average of 40 – 200 trees/ha (16 – 81 trees/acre), as measured over the landscape two years after fire. 4. Maintain *Pinus ponderosa* overstory (>16 inches, 40.6 cm, dbh) tree density at an average greater than 35 trees/ha (14 trees/acre), as measured over the landscape five years after fire.	1. Maintain average total fuel load between 0.2 and 9.3 tons/acre across the landscape. 2. Maintain a landscape in which higher severity fire occurs in patches smaller than 5 acres and across no more than 5% of the monitoring type over any ten year period. 3. Maintain average total (all trees greater than 1 inch, 2.5 cm, dbh) *Pinus ponderosa* tree density at 106 - 333 trees/ha (43 - 135 trees/acre) across the landscape.

Monitoring Unit (Code)	Treatment Objectives from 2000 Monitoring Plan First Entry Burn	2010 Revisions to Treatment Objectives Restoration	Maintenance
North Rim Ponderosa Pine (FPIPN1D09)	1. Reduce total fuel load by at least 30% on average, as measured over the landscape immediately post-burn (fuel reduction efforts will continue until the Desired Future Condition of 0.2-9.3 tons/acre is achieved). 2. Limit crown scorch to 30% on *Pinus ponderosa* with dbh greater than or equal to 16" (40 cm). 3. Reduce *Pinus ponderosa* poles with dbh of 1-6 inches (2.5-15 cm) to average 0-200 trees/acre (0-494 trees/ha). 4. Achieve and maintain a five-year post-burn density of 40-56 trees/acre of *Pinus ponderosa* in the 16"+ size class	1. Reduce total fuel load to an average of 0.2 - 15.7 tons/acre, as measured over the landscape immediately after fire. 2. Maintain a landscape in which higher severity fire (determined through burn severity mapping) occurs in patches smaller than 5 acres and across no more than 5% of the monitoring type over any ten year period. 3. Reduce pole-sized (1-6 inches, 2.5-15 cm, dbh) conifer tree density to an average of 40 – 200 trees/ha (16 – 81 trees/acre), as measured over the landscape two years after fire. 4. Maintain overstory (>16 inches, 40.6 cm, dbh) conifer tree density at an average greater than 42 trees/ha (17 trees/acre), as measured over the landscape five years after fire.	Allow unplanned fire to maintain ponderosa pine forests on the North Rim. If unplanned fires are regularly suppressed and movement toward desired conditions is not occurring then reintroduce prescribed fire to: 1. Maintain average total fuel load between 0.2 and 15.7 tons/acre across the landscape. 2. Maintain average pole-sized (1-6 inches, 2.5-15 cm, dbh) conifer tree density below 200 trees/ha (81 trees/acre) across the landscape. 3. Maintain a landscape in which higher severity fire occurs in patches smaller than 5 acres and across no more than 5% of the monitoring type over any ten year period.

Monitoring Unit (Code)	Treatment Objectives from 2000 Monitoring Plan First Entry Burn	2010 Revisions to Treatment Objectives Restoration	 Maintenance
Ponderosa Pine with White Fir Encroachment (FPIAB1D09)	1. Reduce total fuel load by at least 30% on average, as measured across the landscape immediately post-burn (fuel reduction efforts will continue until the Desired Future condition of 0.2 to 20 tons/acre (average) is achieved). 2. Limit crown scorch to 30% on *Pinus ponderosa* with dbh greater than or equal to 16” (40 cm). 3. Reduce *Abies concolor* poles in 1-6” (2.5-15 cm) size class by 20-70% to average less than 100 trees/ac (247 trees/ha). 4. Achieve and maintain a five-year post-burn density of 19-25 trees/acre of *Pinus ponderosa* in the 16”+ size class	1. Reduce total fuel load to an average of 1.7 - 19.0 tons/acre, as measured over the landscape immediately after fire. 2. Maintain a landscape in which higher severity fire (determined through burn severity mapping) occurs in patches smaller than 10 acres and across no more than 15% of the monitoring type over any ten year period. 3. Reduce pole-sized (1-6 inches, 2.5-15 cm, dbh) conifer tree density to an average of 40 – 247 trees/ha (16 – 100 trees/acre), as measured over the landscape two years after fire. 4. Maintain overstory (>16 inches, 40.6 cm, dbh) conifer tree density at an average greater than 49 trees/ha (20 trees/acre), as measured over the landscape five years after fire.	Allow unplanned fire to maintain these forests on the North Rim. If unplanned fires are regularly suppressed and movement toward desired conditions is not occurring then reintroduce prescribed fire to: 1. Maintain average total fuel load between 1.7 and 19.0 tons/acre across the landscape. 2. Maintain average pole-sized (1-6 inches, 2.5-15 cm, dbh) conifer tree density below 247 trees/ha (100 trees/acre) across the landscape. 3. Maintain a landscape in which higher severity fire occurs in patches smaller than 10 acres and across no more than 15% of the monitoring type over any ten year period.
Rocky Mountain Montane Conifer Forests (mixed-conifer) – no established monitoring type	None established	1. Maintain a landscape in which higher severity fire (determined through burn severity mapping) occurs across no more than 30% of the monitoring type.	Quantitative objectives will be established as restoration activities progress. Management goals in this type are outlined in the desired conditions for mixed-conifer forest.

Monitoring Unit (Code)	Treatment Objectives from 2000 Monitoring Plan First Entry Burn	2010 Revisions to Treatment Objectives Restoration	Maintenance
Rocky Mountain Subalpine Conifer (FPIEN1D10)	No objectives listed in 2000 Monitoring Plan. The FMH-4 from 1997 lists the following: 1. Reduce total fuel loading by 40-80% immediately post-burn 2. Thin white fir < 6" dbh by 40-60% within 2 years post-burn 3. Limit overstory Engelmann spruce tree scorch to < 30 feet 4. Limit overstory Engelmann spruce mortality to 20% within 5 years post-burn	No restoration targets are needed in this monitoring type because these areas are thought to be within the natural fire regime.	Quantitative objectives were not identified for this monitoring type because prescribed fires are not the management focus in these areas. Management goals in this type are outlined in the desired conditions for spruce-fir forest.
Great Basin Conifer Woodland (FPIED1D02)	1. Reduce total average fuel load (including all woody material, litter, and duff) so as not to exceed 20 tons/acre (49 tons/ha). 2. Limit overstory mortality of all species to an average of 20% within 5 years post-burn	No restoration targets are needed because this monitoring type is thought to be within its natural fire regime.	Quantitative objectives were not identified for this monitoring type. Management goals in this type are outlined in the desired conditions for piñon-juniper vegetation.
Grassland Interior (BGRIN1D01)	None established	None established; no prescribed fire activities are currently targeted at this monitoring type	None established; no prescribed fire activities are currently targeted at this monitoring type
Grassland Edge (FGRED1D02)	None established	None established; no prescribed fire activities are currently targeted at this monitoring type	None established; no prescribed fire activities are currently targeted at this monitoring type

Monitoring objectives

Monitoring activities are conducted by staff from GRCA Branch of Fire and Aviation, GRCA Science and Resource Management Division, and GRCA Office of Planning and Compliance. Details of each type of monitoring and responsible parties are in section F.5. The following objectives are the responsibility of the staff associated with the applicable monitoring activity (section F.5).

Environmental monitoring

1. Monitor weather and fire danger rating as outlined in the annually updated Grand Canyon National Park and Kaibab National Forest National Fire Danger Rating System Operating Plan (NPS 2010b).
2. Coordinate with GRCA Science and Resource Management Division and Office of Planning and Compliance staff to complete compliance for planned fire and non-fire fuel treatment activities as described in the Fire Management Plan Record of Decision (NPS 2010a), Biological Opinion (FWS 2009), and Programmatic Agreement with the State Historic Preservation Officer (NPS 2009b).

Fire observation monitoring

1. Record information on weather and fire conditions for prescribed fires and unplanned fires that extend beyond initial attack in the park.
2. Record information on resource concerns and mitigation measures outlined in the Fire Management

Plan Record of Decision (NPS 2010a), Biological Opinion (FWS 2009), and Programmatic Agreement with the State Historic Preservation Officer (NPS 2009b).

Short- and long-term vegetation and fuel monitoring

1. Provide high quality data that can be used by fire and resource managers to evaluate and refine treatment objectives and desired conditions.
2. Install enough permanent plots in each monitoring type to reach the specified confidence that sample means are within the specified percentage of the true population mean for primary and secondary monitoring variables. *Note: confidence and precision levels are specified in Appendix F.12.1.*

Burn severity mapping

1. Obtain differenced Normalized Burn Ratio (dNBR) satellite imagery each year for all fires >300 acres in size that occurred in the park in the previous year.
2. Validate assigned burn severity classes with field data during the year following fire events >300 acres in size.

F.4.3 Desired Conditions

Spruce-Fir Forest

Maintenance of a diverse landscape with patches of variable tree densities through management and monitoring of natural ecosystem processes (fire, insects and disease, drought).

Desired conditions include:

- Fire processes managed according to the current NPS policy
- Topographic heterogeneity of vegetation types restored and a mixed-severity fire regime maintained
- Stand-replacing fire event characteristics returned to the range described in reference conditions (NPS 2009a section 2.4.1 and section F.3.1 of this document).
- Processes that provide structural complexity allowed
- Fuel loads managed at levels consistent with reference conditions (NPS 2009a section 2.4.1)
- Cross-boundary fires managed through collaboration with adjacent agencies
- Post-fire vegetation response monitored to provide information for the adaptive management process

Mixed-Conifer Forest

Maintenance of a climate-adapted, mixed-conifer structure and associated function through management and monitoring of natural ecosystem processes (fire, insects and disease, drought).

Desired conditions include:

- Fire processes managed according to the current NPS policy
- Mixed-severity fire regime maintained
- Topographic heterogeneity of vegetation types restored
- Fuel loads managed to retain mixed-severity fire regime and limit high-severity burned patch size
- Cross-boundary fires managed through collaboration with adjacent agencies
- Post-fire vegetation response monitored to provide information for the adaptive management process

Additional specific desired stand structure conditions may include:

Tree densities greater than 31 cm dbh should range from 54 to 105 trees/ha with a few dense stands approaching 254 conifers/ha. Scattered patches will lack trees due to the fire-effects mosaic characteristic of a mixed-severity fire regime.

Trees greater than 61 cm dbh should be maintained at 16 to 32 trees/ha. Scattered patches will lack trees due to the fire-effects mosaic characteristic of a mixed-severity fire regime.

The large number of small diameter trees established since Euro-American settlement should be reduced, and vegetation and fire regime topographic heterogeneity should be reestablished.

Ponderosa Pine Forest

Ponderosa pine forests depend upon fire to maintain their ecological integrity. Desired conditions include reduced tree density and ladder fuel, restoration of fire as a process (predominantly surface fire with some passive crown fire), and increased herbaceous ground cover and overall biodiversity levels (Allen et al. 2002).

Desired conditions in ponderosa pine stands include:

- Fire processes allowed to move across the landscape, where appropriate
- A mosaic of diverse landscapes with patches of variable tree densities
- Rare stand-replacing fires generally occur in small patches
- A robust and diverse herbaceous understory where supported by soils and environmental factors
- Post-fire vegetation response monitored to provide information for the adaptive management process

Desired structure conditions for ponderosa pine are outlined in Table F.4.2. Lower limits for desired conditions generally begin at the level of reconstruction studies on North and South Rims, while upper limits are the level of present day relict areas plus 10 to 20%. Added percentage for number of stems/ha at the upper limit is somewhat arbitrary, but reflects the fact that relict areas are generally drier ponderosa sites near the rim.

Table F.4.2. Ponderosa pine forest desired conditions for GRCA.

Tree Density (stems/ha), Composition, Size Classes (dbh)	
40% of the landscape (South Rim and drier North Rim sites) with ponderosa pine density in the following size classes. Gambel oak should be well-represented on the landscape with 50 to 300 stems/ha contributing a basal area of 1 to 3 m^2/ha.	
Ponderosa pine dbh (cm)	**Ponderosa pine density (trees/ha)**
2.5 - 15.1	40 - 70
15.2 - 40.1	30 - 40
40.2 - 91.2	35 - 50
> 91.2	1 - 2
Total (all size classes)	106 - 162
50% of the landscape (North Rim mesic sites tending toward mixed-conifer transition) with ponderosa pine density in the following size classes	
Ponderosa pine dbh (cm)	**Ponderosa pine density (trees/ha)**
2.5 - 15.1	40 - 100
15.2 - 40.1	40 - 70
40.2 - 91.2	40 - 70
> 91.2	2 - 3
Total (all size classes)	122 - 243
10% of the landscape in aggregate patches of dense stands of ponderosa pine and areas with a component of other conifers	
Ponderosa pine dbh (cm)	**Ponderosa pine density (trees/ha)**
2.5 - 15.1	110 - 140
15.2 - 40.1	110 - 140
40.2 - 91.2	20 - 50
> 91.2	1 - 3
Total (all size classes)	241 - 333

Montane-Subalpine Grassland

Desired conditions will be developed for the grasslands if fire is reconsidered as a management option for this vegetation type in the future.

Piñon-Juniper Communities

Maintenance of resilient piñon-juniper structure and associated function by through management and monitoring of natural ecosystem processes (fire, insects and disease, soil fertility, upland hydrologic function).

Desired conditions include:

- Expected fire behavior in the WUI reduced by manual/mechanical treatments near values at risk
- Fuel loading from manual/mechanical treatments reduced by prescribed fire
- Adaptive management used to refine treatment prescriptions
- Fire allowed as a process in piñon-juniper woodlands
- Information on natural fire regimes and vegetation dynamics used to maintain diverse landscapes with patches of variable tree and understory plant densities and canopy cover

F.5 Monitoring Design

GRCA employs the NPS Fire Monitoring Handbook (NPS 2003) standard four-level approach to fire monitoring (Table F.5.1). The remainder of this section provides details on how and when each monitoring variable is collected. Following the outline of required and recommended monitoring activities in NPS Reference Manual 18: Wildland Fire Management (NPS 2008b), each GRCA fire management strategy has a defined monitoring approach. Monitoring elements measured for each fire management strategy are summarized in Table F.5.2.

Table F.5.1. NPS four-level approach to fire monitoring and potential variables for each level.

Monitoring Level	Monitoring Variables
Level 1: Environmental	Weather, fire danger rating, fuel conditions, concerns and values to be protected, and other biological, geographical, or sociological data
Level 2: Fire Observation	Reconnaissance - fire cause, fire location and size, fuel and vegetation description, fire regime and condition class, current and predicted fire behavior, potential for spread, current and forecasted weather, resource or safety threats and constraints, and smoke volume and movement Fire Conditions - topographic variables, fire weather, fuel model, fire characteristics, smoke characteristics, Resource Advisor concerns
Level 3: Short-term Change	Change in fuel load, vegetation structure, and vegetation composition, or other objective-dependent variables, within 2 years post-burn
Level 4: Long-term Change	Trends in Level 3 variables over time (5+ years)

Table F.5.2. Monitoring elements measured for each fire management strategy.

	Fire Management Strategy		
Monitoring Level	Unplanned Fire	Prescribed Fire	Non-Fire Treatment
Level 1: Environmental	Yes	Yes	Yes
Level 2: Fire Observation	Yes	Yes	n/a
Level 3: Short-term Change	Yes[1]	Yes	Yes[2]
Level 4: Long-term Change	Maybe	Yes	Maybe

[1] burn severity mapping for fires >300 acres
[2] conducted using Rapid Assessment Protocol plots or photopoint monitoring

F.5.1 Environmental Monitoring

Level 1 environmental monitoring provides the information needed for decision-making before and during fire events. Depending on the variable of interest, environmental monitoring can occur throughout the year. Environmental monitoring at GRCA is conducted by staff from both the Fire and Aviation Branch and the Science and Resource Management Division.

Weather and Fire Danger Rating

Weather and fire danger rating are monitored by the Williams Interagency Dispatch Center as outlined in the annually updated Grand Canyon National Park and Kaibab National Forest National Fire Danger Rating System (NFDRS) Operating Plan (NPS 2010b). The monitoring outlined in the NFDRS Operating Plan is designed to assist with planning and operational decisions relative to fire danger, preparedness, resource needs, personnel briefing, situational awareness, and implementing fire restrictions. The NFDRS Operating Plan describes the six remote automatic weather station (RAWS) units used for fire management planning in GRCA and the Kaibab National Forest. In addition, the NFDRS Operating Plan outlines the process for calculating and communicating the daily burning index (BI), energy release component (ERC), and adjective fire danger rating. The NFDRS Operating Plan also describes the process for preparing annual fire danger pocket cards.

Fuel Conditions

Fuel conditions are monitored by the Fire Management Program operations sections (South Rim District and North Zone) throughout the fire season (generally April to November). Sampling procedures generally follow those outlined in the Southwest Area Fuel Moisture Monitoring Program: Standard Methods and Procedures (SWCC 2004). Litter, 1-hr, 10-hr, 100-hr, and sound 1000-hr timelag fuel moisture (TLFM) class fuels are collected on both rims. Live fuel moisture samples are collected based on the dominant species at the sampling site. On the South Rim, dominant species may include ponderosa pine, piñon pine, Utah juniper, and Gambel oak. On the North Rim, dominant species may include white fir, subalpine fir, Douglas-fir, Engelmann spruce, blue spruce, and ponderosa pine. Duff samples are also collected on the North Rim.

Sensitive natural resources

Background monitoring of sensitive natural resources is the responsibility of the GRCA Science and Resource Management Division. Pre-treatment project specific monitoring to identify sensitive natural resources in prescribed fire and non-fire fuel treatment units is coordinated by the GRCA Science and Resource Management Division in collaboration with the GRCA Fire and Aviation Branch. Required pre-project monitoring activities are identified in the Record of Decision (ROD) for the Fire Management Plan (NPS 2010a) and in the Biological Opinion (BO) for the Fire Management Plan (FWS 2009). Sensitive natural resources that occur within project units will be identified prior to project implementation and mitigation measures consistent with the ROD and the BO will be implemented as outlined in those documents.

Cultural-archeological resources

Identification and background monitoring of cultural-archeological resources is the responsibility of the GRCA Science and Resource Management Division. Pre-treatment project specific monitoring to identify cultural-archeological resources in prescribed fire and non-fire fuel treatment units is coordinated by the GRCA Science and Resource Management Division in collaboration with the GRCA Fire and Aviation Branch. Required pre-project monitoring activities are identified in the Record of Decision (ROD) for the Fire Management Plan (NPS 2010a) and in the Programmatic Agreement (PA) with the State Historic Preservation Officer (SHPO) for the Fire Management Plan (NPS 2009b). Sensitive cultural-archeological resources that occur within project units will be identified prior to project implementation and mitigation measures consistent with the ROD and the PA will be implemented as outlined in those documents.

F.5.2 Fire Observation Monitoring

Level 2 fire observations provide the information needed for decision-making during and after fire events. Fire observation monitoring occurs during active fires within the park. Fire observation monitoring, which includes reconnaissance and fire conditions monitoring, occurs to some extent on all fires in GRCA; however, every element may not be recorded on each fire. This section outlines standard procedures for monitoring prescribed fires in GRCA. These procedures may also be applicable to monitoring unplanned fire events.

Fire behavior and weather observations are collected during each operational period on prescribed fires using the GRCA fire monitoring forms (Appendix F.12.3), forms FMH-1, -2, and -3 from the NPS Fire Monitoring Handbook (NPS 2003), or the forms found in the Interagency Fire Use Module Handbook. When smoke production begins to noticeably impact the Grand Canyon Class I airshed, smoke observations are recommended. The fire observation information requested may differ between Prescribed Fire Burn Bosses, and the following guidelines are intended to provide monitors with information on how the requested information is typically collected at GRCA. For additional information on the variables collected during fire observation monitoring, see the NPS Fire Monitoring Handbook (NPS 2003).

Weather

Three weather observations are preferred prior to requesting a spot weather forecast, although the forecast can be obtained with only one observation. Weather observations are recorded from a variety of locations (valley bottoms, ridgetops, southwest slopes, etc) and generally are taken one hour apart the afternoon preceding the prescribed fire or prior to ignition on the day of the prescribed fire. Cloud types can be important to fire weather forecasters, so monitors should attempt to identify cloud types and cloud cover. A spot weather forecast is requested using the GRCA modified Spot Forecast Request form (Appendix F.12.3). The spot weather forecast is included in the daily monitoring report with other fire observation monitoring forms.

The Prescribed Fire Burn Boss decides how often weather observations are taken and reported throughout the burn period. Monitors should be familiar with the fire prescription, indicate when critical levels are reached (low fuel moistures, gusty winds), and inform the Prescribed Fire Burn Boss if weather observations fall outside of desired conditions. The GRCA Weather Observation form (Appendix F.12.3) is used to record burn-day weather observations.

Fire Behavior

In general, monitors take a fire behavior observation around the same time and location as a weather observation; however, there is no set number of required fire behavior observations. Monitors attempt to capture an accurate representation of the range of fire behavior and fire types. For instance, if fire is burning in heavy fuel, creeping in litter, and smoldering in duff, separate observations are made for each fuel type. Additionally, if fire is backing, heading, and/or flanking, individual observations to capture different fire types are made. On prescribed fires, monitors should be familiar with the prescribed fire plan prescription and inform the Prescribed Fire Burn Boss if fire behavior is not in prescription. Monitors record fire behavior observations on the GRCA Fire Behavior Observations form (Appendix F.12.3).

Smoke

Smoke observations are taken on most fires within the park. A pilot balloon (pibal) can be released before a prescribed fire to indicate where smoke will travel in relation to sensitive areas (highways, canyon, villages, and trails). Monitors record pibal information on the Winds Aloft Computation form (Appendix F.12.3), calculate wind speed and direction using the National Weather Service Pibal Plotting Program, and relay this information to the Prescribed Fire Burn Boss. Smoke observations are best recorded from a site removed from the fire with a good perspective of the entire smoke column and smoke impacts to the canyon or heavy visitor use areas. During prescribed fires, monitors should consult with the Prescribed Fire Burn Boss and read the prescribed fire plan to understand smoke issues for the fire. The GRCA Smoke Observations form (Appendix F.12.3) is used to monitor smoke during prescribed fires.

If smoke is making a consistent impact on sensitive areas, photo points can be established where photos are taken repeatedly from the same location, in the same direction, and at approximately the same time of day. If time permits, monitors may take two sets of photos: one in the morning to capture nighttime subsidence and inversion impacts and one in the afternoon to capture the height of smoke production. Observations from these locations are documented on the GRCA Smoke Observations form, and descriptions of the photo point locations are written on a photographic log form. A brief summary of smoke impacts and photos should be sent via email on a daily basis to air quality specialists identified by GRCA fire managers.

DataRAM or E-BAM air quality sampling devices are used when smoke production has the potential to affect sensitive areas, or as requested by GRCA fire managers or air quality specialists. GRCA currently owns two functioning DataRAM 2000 devices. These devices are outdated and provide trend data only (i.e. the exact particulate measurements are generally unreliable). When it is important to obtain accurate particulate measurements, a DataRAM-4 or E-BAM should be borrowed from Arizona Department of Environmental Quality (ADEQ) or the Boise Fire Cache. Pre-established deployment sites with weather shelters are set up at Cottonwood Ranger Station, Phantom Ranch, Tusayan, and the Hance burn unit on the South Rim. Monitors use one of these sites or set up a new site in the North Rim developed area or Grand Canyon Village where the sampling device has electrical power, shelter from the elements, and relative security.

Resource Concerns

Resource concerns for prescribed fires are addressed in the prescribed fire plan for a particular project unit. Resource concerns for unplanned fire events are identified by resource specialists from the GRCA Science and Resource Management Division. Monitoring and mitigation measures outlined in the Fire Management Plan ROD (NPS 2010a), BO (FWS 2009), and PA (NPS 2009b) will be followed during each fire event. Resource Advisors should be assigned to prescribed fires and unplanned fires that exceed initial attack to ensure that the monitoring and mitigation measures are implemented. Implementation of mitigation measures includes identification of rehabilitation needs.

Photographs

Photographs provide some of the best documentation of fire observations. Digital photographs are filed on the Fire & Aviation (O:\) drive under a folder with the fire name and date. Monitors should take photographs to match fire behavior observations (i.e. not photograph big flames only but rather document the range of fire conditions). Comparable photos over time are very useful for documenting fire conditions and effects. If possible, monitors should establish photo points and photograph the area days and/or weeks after the fire to document fire effects.

Reports

At the end of the monitoring period, all weather, fire behavior, and smoke observations from the fire are collected into a legible package. In addition to forms with the raw data, a narrative summary is written. This report includes a description of who monitored the fire, monitor activities during the monitoring period, a summary of observed fire behavior, a summary of observed weather, and any other pertinent information. Digital images to illustrate weather, smoke, and fire behavior are included, if possible. A Daily Fire Monitoring Report (example in Appendix F.12.3) can be used to summarize monitoring information for each day. Ideally, this form would be completed on the day of the observations. During multi-day fires, events can run together and narratives may become less detailed and less informative.

Monitoring forms and notes generated by the assigned Resource Advisor should be compiled at the end of each fire event. Resource Advisor information should be given to the Prescribed Fire Burn Boss (or Incident Commander), the appropriate specialists in the GRCA Science and Resource Management Division, and the GRCA Office of Planning and Compliance. This information will be used to develop rehabilitation plans, if needed, and to generate the required annual reports to USFWS and Arizona SHPO (section F.7).

F.5.3 Short- and Long-term Vegetation and Fuel Change

Monitoring short- and long-term changes in vegetation and fuel characteristics is an essential part of the adaptive management process. The goals of the short- and long-term vegetation and fuel monitoring program are to provide managers with feedback on (1) whether progress is being made toward achieving the desired conditions for a monitoring type and (2) whether project objectives have been achieved. In order to adequately address both of these goals, the GRCA monitoring program design for vegetation and fuel incorporates both landscape- and project-level monitoring. Landscape-level short- and long-term change monitoring began in GRCA in 1990 with the installation of the first permanent NPS Fire Monitoring Handbook (FMH) plots. Project-level monitoring is a new addition to the GRCA monitoring program. The first pilot Rapid Assessment Protocol (RAP) plots for project monitoring were installed in scheduled prescribed fire units during the 2008 field season.

Landscape-Level Monitoring

To monitor landscape-level short- and long-term vegetation and fuel changes, GRCA fire management personnel defined seven monitoring types representing the major vegetation types where prescribed fire has been either used or planned for use as a management tool. Between 1990 and 2009, 159 permanent FMH plots were installed in these seven monitoring types. Of these plots, 114 are currently monitored on the recommended post-fire schedule and are used to assess the landscape-level objectives of the fire management program (see section F.3 and Appendix F.12.5 of this plan for analysis of these plots). Two grassland monitoring types (GRED and GRIN) containing 16 total plots are currently inactive due to changes in priorities in the grasslands. One monitoring type (PIED) containing 17 plots was suspended in 2000 due to data quality concerns and variation in the applied treatments. Twelve plots installed early in the monitoring program were removed from the monitoring schedule in the late 1990s due to inconsistencies with the monitoring type descriptions.

Monitoring Units **Landscape-Level Monitoring**

Standard NPS FMH-4 Monitoring Type Descriptions specifying monitoring objectives and desired conditions have been completed for four currently monitored forest types and one suspended forest type (Appendix F.12.1). In addition, protocols, but not desired conditions or management objectives, have been completed for the two inactive grassland monitoring types (Appendix F.12.1). Suspended and inactive types will no longer be read, but rebar will be left in place to reinitiate these types if management priorities change.

Descriptions of the vegetation types associated with each monitoring type can be found in section F.3 of this monitoring plan. To date, all active monitoring types have had plots burn during first-entry fires and some types have had plots burn during suppression fires, resource benefit wildfires, and/or second-entry and third-entry prescribed and unplanned fires (Table F.5.3). A monitoring schedule that lists the years of past and future (2010-2014) plot reads by monitoring unit can be found in Appendix F.12.2.

Table F.5.3. Overview of GRCA FMH monitoring types and number of plots burned in prescribed fire (RX), wildfire with resource benefit objectives (WRB), and suppression wildfire (S). Entry designations (1st, 2nd, 3rd) refer to the number of times a particular plot has burned in any fire type.

Monitoring Type (# plots installed)	Vegetation Type	# Plots Burned 1st-entry			# Plots Burned 2nd-entry			# Plots Burned 3rd-entry			Monitoring Status
		RX	WRB	S	RX	WRB	S	RX	WRB	S	
FPIPO1D09 (n = 40)	Ponderosa pine forest	35	--	--	19	--	--	11	--	--	Active
FPIPN1D09 (n = 30)	Ponderosa pine forest	14	15	--	5	5	--	--	2	--	Active
FPIAB1D09 (n = 27)	Ponderosa pine/ Mixed conifer forest	11	9	4	4	7	--	--	--	--	Active
FPIEN1D10 (n = 17)	Mixed conifer/ Spruce-fir forest	--	3	7[a]	--	--	--	--	--	--	Active
FPIED1D02 (n = 17)	Piñon-juniper woodland	14	--	--	[b]	--	--	[b]	--	--	Suspended
FGRED1D02 (n = 6)	Montane-subalpine grassland	--	--	--	--	--	--	--	--	--	Inactive
BGRIN1D01 (n = 10)	Montane-subalpine grassland	--	--	--	--	--	--	--	--	--	Inactive

[a]Only two of the seven PIEN plots burned in suppression fire have pre-fire data available.

[b]PIED plots may have burned more than once, but this monitoring type was suspended in 2000 and post-fire reads have not been completed since then.

Sampling Design

Landscape-Level Monitoring

Plot layout and monitoring frequency of GRCA FMH plots follow the guidelines in the NPS Fire Monitoring Handbook (NPS 2003) with modifications noted on the FMH-4 Monitoring Type Description Sheets (Appendix F.12.1). The North Rim forest plots (FPIPN1D09, FPIAB1D09, FPIEN1D10) are standard FMH forest plots (Figure F.5.1). The South Rim forest plots (FPIPO1D09, FPIED1D02) are standard FMH forest plots with modified 100-foot fuel inventory transects. The grassland edge (FGRED1D02) plots are modified FMH forest plots with the origin stake at the forest/meadow edge and the 0P-50P line perpendicular to the forest/meadow edge. The grassland interior (BGRIN1D01) plots are standard FMH brush plots as illustrated in the NPS Fire Monitoring Handbook (p. 64, NPS 2003). Plots in all seven monitoring types are designed to be monitored before fire, immediately after fire, and one, two, five, ten, and twenty years post-fire. No formal control plots exist in the GRCA FMH plot network. However, some plots have been visited multiple times before fire (see Appendix F.12.2) due to changing prescribed fire schedules and may be used to detect trends in unburned areas.

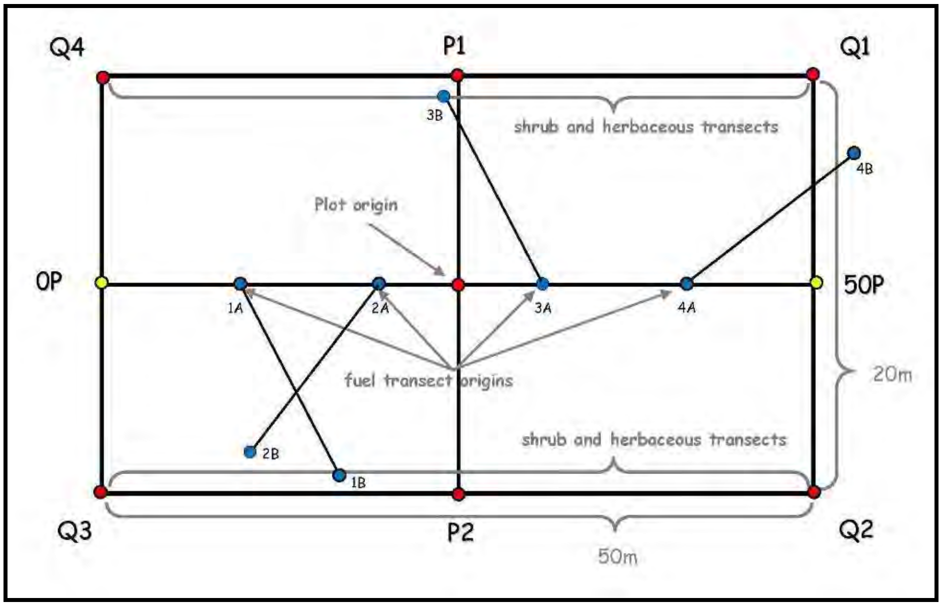

Figure F.5.1. Standard plot layout for FMH monitoring plots (adapted from NPS 2003). Red, yellow, and blue circles represent rebar locations. Modifications are noted on the FMH-4 Monitoring Type Description Sheets (Appendix F.12.1).

FMH monitoring plots are distributed within monitoring types that contain many prescribed fire units. The FMH plots are designed to monitor trends in vegetation at a landscape level, and not to detect change in individual prescribed fire units. Due to the large area burned in both prescribed fires and wildfires each year in GRCA, new monitoring plot locations are randomly chosen from areas scheduled to burn within the next three years rather than the five years recommended in the NPS Fire Monitoring Handbook (NPS 2003). Prior to 2000, GRCA FMH plots were randomly located using the grid map method described in the NPS Fire Monitoring Handbook (p. 59-61, NPS 2003) and the rejection criteria for each monitoring type (Appendix F.12.1). Now, with a large number of plots already installed and a relatively small unburned area available in some monitoring types, new plot installation points are randomly assigned using GIS to identify areas that have not previously burned, occur within the appropriate vegetation type, and are unlikely to contain any of the rejection criteria elements (Appendix F.12.1).

The GRCA Fire Monitoring Program has installed enough plots to assess minimum plot numbers for post-fire assessments, and both pre- and post-fire minimum plot estimates are provided in Table F.5.4. For the three primary variables of interest (large tree density, total fuel loading, and pole-sized tree density), the expectation is that fire will result in a decrease in average values during the monitoring period of interest. Therefore, minimum sample size calculations using one-tailed *t*-values are appropriate for these variables, but calculations using two-tailed *t*-values are also provided in Table F.5.4 as a conservative estimate. Minimum sample size calculations are based on the equations given in Appendix D of the NPS Fire Monitoring Handbook (NPS 2003).

The monitoring objective for the large tree density and total fuel loading management objective variables is a monitoring design that provides 80% confidence that variable estimates are within 20% of the population mean. For the pole-sized tree density management objective, the monitoring objective is a monitoring design that provides 80% confidence that variable estimates are within 25% of the population mean. The GRCA Fire Monitoring Program has installed enough plots in all active monitoring types to adequately evaluate the large tree density and total fuel loading objective variables (Table F.5.4). However, additional plots may be needed in the North Rim Ponderosa Pine and Ponderosa Pine with White Fir Encroachment monitoring types to adequately evaluate the pole-sized tree density objective variable after fire (Table F.5.4) since post-fire pole-sized tree density values are more variable than pre-fire values. This increase in variability after fire is likely due to the fact that these two North Rim monitoring types are (and will likely continue to be) managed using both prescribed fire and unplanned fire (see Table F.5.3) to meet restoration and maintenance objectives.

Table F.5.4. Results of minimum sample size calculations by monitoring type and management objective variable for both pre- and post-fire conditions. North Rim Ponderosa Pine and Ponderosa Pine with White Fir Encroachment plots have burned in both prescribed and unplanned fires, and post-fire calculations are for all fire types combined. PIPO=*Pinus ponderosa*, total fuel load includes litter, duff, and 1-, 10-, 100-, and 1000-hr TLFM woody fuels.

Monitoring Type	Primary Management Objective Variable	Secondary Management Objective Variable	Tertiary Management Objective Variable
South Rim Ponderosa Pine (FPIPO1D09)	**PIPO (>16"dbh) Density 80% confidence, R = 20** *n=40 Pre* one-tailed = 7 two-tailed = 16 *n=24 Post YR5* one-tailed = 6 two-tailed = 13	**Total Fuel Load 80% confidence, R = 20** *n=40 Pre* one-tailed = 4 two-tailed = 10 *n=34 Immediate Post* one-tailed = 5 two-tailed = 12	**PIPO (1-6"dbh) Density 80% confidence, R = 25** *n=40 Pre* one-tailed = 27 two-tailed = 64 *n=34 Post YR2* one-tailed = 36 two-tailed = 84
North Rim Ponderosa Pine (FPIPN1D09)	**Conifer (>16"dbh) Density 80% confidence, R = 20** *n=30 Pre* one-tailed = 2 two-tailed = 4 *n=26 Post YR5* one-tailed = 4 two-tailed = 8	**Total Fuel Load 80% confidence, R = 20** *n=30 Pre* one-tailed = 5 two-tailed = 10 *n=29 Immediate Post* one-tailed = 6 two-tailed = 14	**Conifer (1-6"dbh) Density 80% confidence, R = 25** *n=30 Pre* one-tailed = 21 two-tailed = 48 *n=29 Post YR2* one-tailed = 47 two-tailed = 111
Ponderosa Pine with White Fir Encroachment (FPIAB1D09)	**Conifer (>16"dbh) Density 80% confidence, R = 20** *n=27 Pre* one-tailed = 3 two-tailed = 7 *n=14* Post YR5* one-tailed = 2 two-tailed = 5	**Total Fuel Load 80% confidence, R = 20** *n=27 Pre* one-tailed = 3 two-tailed = 6 *n=19* (RX=10) Immediate Post* one-tailed = 9 two-tailed = 20	**Conifer (1-6"dbh) Density 80% confidence, R = 25** *n=27 Pre* one-tailed = 4 two-tailed = 10 *n=20* Post YR2* one-tailed = 11 two-tailed = 26
Rocky Mountain Subalpine Conifer (FPIEN1D10)	Minimum plot calculations will be completed if prescribed fire becomes a focus of this monitoring type and quantitative objectives are developed. Current data summaries for this monitoring type are available in Appendix F.12.5.		
Great Basin Conifer Woodland (FPIED1D02)	Minimum plot calculations will be completed if prescribed fire becomes a focus of this monitoring type and quantitative objectives are developed. Current data summaries for this monitoring type are available in Appendix F.12.5.		
Grassland Interior (BGRIN1D01)	Minimum plot calculations will be completed if prescribed fire becomes a focus of this monitoring type and quantitative objectives are developed.		
Grassland Edge (FGRED1D02)	Minimum plot calculations will be completed if prescribed fire becomes a focus of this monitoring type and quantitative objectives are developed.		

* FPIAB1D09 post-fire excludes 4 plots that burned under moderate-high or high severity in Outlet Fire of 2000.

Field Measurements

Landscape-Level Monitoring

Each forest plot is marked by seventeen 3/8 inch rebar stakes (Figure F.5.1) and one 3/8 inch rebar stake at the plot reference point. All stakes are painted red except for 0P and 50P, which are painted yellow, and the "B" ends of the fuel transects, which are painted blue. Each rebar stake on the plot and each reference feature is labeled with a round brass tag. The origin and reference tag labels include the location code (ORIGIN or REF RX), the monitoring type dominant species code (4-letter) and plot number (2-digit), and the date (6-digit code to represent month, day, and year, such as 070598 for July 5, 1998). The other plot stake labels include only the stake position code (Q1, 50P, etc).

For most variables, GRCA FMH field measurements follow recommendations in the NPS Fire Monitoring Handbook (NPS 2003). For each monitoring type, information is gathered using different parameters but the same field methods. For example, seedlings are counted in a 25 x 10 meter area in some monitoring types and a

5 x 10 meter area in others. Specific parameters for each monitoring type are noted in the Monitoring Type Description Sheets (FMH-4s) located in Appendix F.12.1. For each forest plot, information is gathered on overstory trees, pole-sized trees, seedling trees, surface fuel, herbaceous species, and shrubs. Some of the measurements taken are not tied to formal objectives (Table F.4.1), but these measurements assist the fire management program in assessing the general condition of the forest community and identifying resource concerns (e.g. exotic species invasion) and research needs.

Eight photographs are taken of each plot using the protocols outlined in the NPS Fire Monitoring Handbook (NPS 2003). Photographs are taken from each end of the three 50 m transects (starting from Q1, 50P, Q2, Q3, 0P, and Q4; Figure F.5.1) facing into the plot and from each end of the center 20 m transect (starting at P1 and P2; Figure F.5.1) facing into the plot. Repeat photographs are taken with the aid of printed copies from the previous photographs of a particular plot in order to capture comparable scenes.

Plot monitoring generally proceeds phenologically from the warmest to coolest ecosystems in the park. Plot reads begin on the South Rim and then proceed from the lowest to highest elevation North Rim forest types. If reinitiated, the meadows on the North Rim should be sampled from late July to early September. There are numerous forms used for FMH plot monitoring available in the NPS Fire Monitoring Handbook (NPS 2003). To lessen confusion and reduce recording and data entry errors, many of the FMH data sheets have been customized to include methods specific to GRCA, reminders for some methods, and crosswalks with the FFI database. Modified data sheets are available in Appendix F.12.3.

Project-Level Monitoring

Project-level monitoring is a new addition to the GRCA Fire Ecology Program and, as such, is in the beginning stages of pilot sampling. Project-level monitoring is designed to provide information on whether short-term management objectives have been met for a particular fire or manual/mechanical treatment. With the 2010 Fire Management Plan, GRCA will begin manual/mechanical treatments in the Primary WUI FMU, will begin implementing prescribed fire in the higher elevation mixed-conifer and spruce-fir vegetation types, and will continue maintenance fires in the ponderosa pine forests. High elevation forests make up a relatively small area on the North Rim and are of high resource concern, so monitoring and evaluation through the adaptive management process is currently planned on a unit-by-unit basis. Unit-by-unit monitoring may also occur in manual/mechanical treatment units and multi-entry ponderosa pine forests. Since project-level monitoring will require a greater number of plots in each unit than the landscape-level monitoring, new Rapid Assessment Protocol (RAP) plots are being developed to accommodate this need.

Monitoring Units — Project-Level Monitoring

For project-level monitoring, the monitoring unit is the prescribed fire or manual/mechanical treatment unit described in the approved project implementation plan. Similar to landscape-level monitoring, monitoring within an individual project unit may be stratified by vegetation type. Vegetation types could be used to stratify monitoring plots if current conditions, desired conditions, and project objectives differ by vegetation type within an individual monitoring/treatment unit.

Sampling Design — Project-Level Monitoring

Plot layout and monitoring frequency of GRCA RAP plots were developed by the Fire Ecologist and Lead Fire Effects Monitor in consultation with the NPS Fire Ecology Program contract statistician (Dr. Ken Gerow, University of Wyoming) and other fire ecology programs within the NPS. Data from current FMH plots in equivalent vegetation types were used to determine plot size and the minimum number of plots to install in each monitoring unit. Since the project-level monitoring is still in the early stages of development, protocol evaluation is ongoing and adjustments may be required in the future.

Pilot RAP plots are circular plots with a 10 m radius sample area and one or two 50 ft fuel transects (Figure F.5.2). New plot installation points are randomly assigned within a treatment unit using GIS to identify areas that are unlikely to contain any of the rejection criteria elements. RAP plots are designed to efficiently answer three to five management questions about fire effects to vegetation and fuel. For this reason, monitoring frequency depends on the management objectives in the monitoring unit. All variables of interest are measured prior to the planned treatment and surface fuel loading and post-fire severity variables are measured immediately following treatment. FMH data to date indicates that large tree and pole-sized tree density values differ between post-fire year 1, post-fire year 2, and post-fire year 5 measurements for all monitoring types except South Rim Ponderosa Pine. At this time, pilot RAP plots are scheduled for measurement during post-fire year 2 to assess tree and understory species variables. This measurement schedule may need reevaluation in the future as pilot data become available.

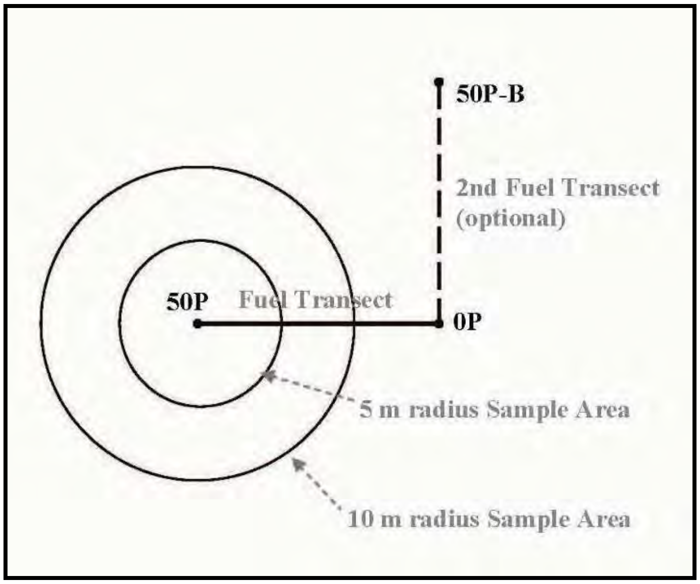

Figure F.5.2. Pilot RAP plot layout. Rebar are located at 0P, 50P, and 50P-B (optional).

Field Measurements — Project-Level Monitoring

Measurement variables for RAP plots may differ for each monitoring unit, but measurement protocols are designed to stay consistent across monitoring units. To date, protocols have been developed for plot establishment and photography, overstory tree measurement, pole-sized tree measurement, seedling tree measurement, herbaceous and shrub measurement, fuel transect measurement, and post-fire severity measurement. These protocols include optional elements that can be added or subtracted based on the data needs in a particular project unit. Additional protocols may be developed in the future if new management objectives or questions arise.

Plots are located using randomly assigned UTM coordinates. Each plot is marked by 3/8 inch rebar stakes placed at the ends of the 50 ft fuel transect(s) (Figure F.5.2). The 0P stake is located at the random UTM coordinate and a random azimuth is used to locate the 50P stake. If a second fuel transect is installed, it is installed at a 90 degree angle clockwise on the compass from the first fuel transect and the end stake is labeled 50P-B. The rebar stakes are labeled with a round brass tag that include the treatment unit abbreviation, plot number, date, and stake position code. Plot photographs are taken from each end of the fuel transect(s). The 50P stake serves as the center point for the 10 m radius sample area of the plot. Field data sheets are available in Appendix F.12.3.

Measurements of overstory trees, pole-sized trees, herbaceous species, shrub species, and non-native plant species are conducted in the 10 m radius sample area. Seedling tree measurements are conducted in a 5 m radius sample area centered on 50P. Definitions of overstory, pole-sized, and seedling trees follow the standard NPS FMH protocols (NPS 2003). Surface fuel and post-fire severity are measured along the 50 ft fuel transect(s) following standard NPS FMH protocols (NPS 2003).

Overstory trees: Measurements of individual overstory tree diameter and condition variables follow the NPS FMH protocols (NPS 2003). Crown base height (optional) is measured at the lowest point of the continuous crown and tree height (optional) is measured at the highest point on the tree for overstory trees. No identification tags are installed on the trees, but an azimuth measured from 50P is recorded for each tree.

Pole-sized and seedling trees: Pole-sized and seedling trees are tallied by species and height (optional). No location (azimuth) or diameter measurements are recorded for pole-sized or seedling trees.

Herbaceous and shrub cover: Total herbaceous and total shrub cover in the sample area is recorded by percent cover class (0-5%, 6-25%, 26-50%, 51-75%, 76-95%, and 96-100%). Native herbaceous and shrub species are not identified to species. Non-native species are identified to species and percent cover class is recorded for each species within the sample area.

Surface fuel: Dead woody material in the 1-hr and 10-hr TLFM classes is tallied within the first 6 feet of the fuel transect. Dead woody material 100-hr TLFM class is tallied within the first 12 feet of the fuel transect. Dead woody material greater than 3 inches diameter that intersects the 50 ft transect is recorded as either sound or rotten and the exact diameter measurement is recorded. Litter and duff depth measurements are recorded at the standard locations (1, 5, 10, 15, 20, 25, 30, 35, 40, and 45 ft from 0P) along the transect.

Post-fire severity: Severity observations for the substrate and vegetation are recorded at the standard locations (1, 5, 10, 15, 20, 25, 30, 35, 40, and 45 ft from 0P) along the fuel transect. The six-level fire severity coding matrix follows the standard NPS FMH protocols (p. 110, NPS 2003).

F.5.4 Burn Severity Mapping

Burn severity mapping incorporates remote sensing data, standard image processing techniques, and field validation plots to provide landscape-scale information on the magnitude of ecological change caused by fire. GRCA participates in the Monitoring Trends in Burn Severity (MTBS) project and has conducted burn severity mapping for most prescribed and wildland fires >300 acres since 2001. Between 2001 and 2009, 880 Composite Burn Index (CBI) plots (Appendix F.12.3) were installed in the park to calibrate the differenced Normalized Burn Ratio (dNBR) satellite imagery for 36 fires, totaling over 91,000 acres. In addition, 29 CBI research plots were installed in the Vista and Outlet fires in 2001 and 61 initial assessment CBI plots were installed immediately after the Poplar Fire in 2003. GRCA burn severity mapping data is used to determine whether fire severity objectives are met and to help determine whether landscape-scale fire effects are within the desired range of variability.

Sampling Units — Burn Severity Mapping

For burn severity mapping, the sampling units are burn severity classes initially identified by calculating the difference in the Normalized Burn Ratio (NBR) between pre-fire and post-fire Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images (for information on the NBR and satellite image processing refer to the NBSMP website: http://burnseverity.cr.usgs.gov/). A maximum of five burn severity classes, or sampling units, are mapped within each fire >300 acres. The five burn severity classes distinguish areas of a fire that are unburned and areas that have undergone low, moderate-low, moderate-high, and high levels of ecological change (Table F.5.5) due to fire. Burn severity mapping is conducted during the peak growing season the first year after fire (generally 9-16 months post-fire), and the sampling units and field measurements for each year are determined based on the fires that occurred in the previous year.

Table F.5.5. Severity classes and associated ecological changes described by the burn severity mapping program.

Burn severity class	Ecological change	Typical fire intensity
Unburned	none	N/A
Low	Fire was non-lethal to the dominant vegetation and did not alter the structure of the dominant vegetation. Scattered small, unburned patches intermixed within burn area. Scorching of vegetation generally limited to 1 meter high or less. Small organic material on ground scorched, but not entirely consumed. Most foliage and twigs intact. Mineral soil rarely exposed.	Usually results from low-intensity surface fire; torching is extremely rare.

Burn severity class	Ecological change	Typical fire intensity
Moderate-Low	Partial scorching, with minimal consumption, of foliage and fine materials on aboveground vegetation. Most green vegetation remains in overstory. Limited overstory tree mortality. Few, if any, unburned patches within the burn area. Most fine organic materials partially consumed, with minimal consumption of large logs. Rotten wood scorched to partially burned. Mineral soil intermittently exposed.	Usually results from low- to moderate-intensity surface fire with isolated single tree torching.
Moderate-High	Considerable scorching, with partial consumption, of foliage and fine materials on aboveground vegetation. Minimal green vegetation remains in overstory. Some overstory tree mortality likely. Consistent patches within burn area have large logs as well as all organic materials consumed to bare mineral soil. Most woody debris consumed. Mineral soil generally exposed but intact. May include up to 10% stand-replacing fire with extremely vigorous vegetative regrowth.	Usually results from moderate- to high-intensity surface fire with single tree and small-scale group torching.
High	Fire killed aboveground parts of all vegetation, resulting in stand-replacement and changing the forest structure substantially. All foliage and fine materials on vegetation consumed. Most large logs as well as all organic material on the ground consumed. All forest litter and duff consumed, exposing bare mineral soil.	Usually results from crown fire or large-scale group torching.

Sampling Design and Field Measurements — Burn Severity Mapping

The goal of field sampling in the burn severity mapping framework is to validate the severity classes initially identified by the difference in pre- and post-fire NBR (dNBR) calculation and to assist with refining the range of dNBR values that represent each severity class for a particular fire. From nine years of experience in mapping burn severity at GRCA, we know that the range of dNBR values representing a severity class can differ between fires, especially if the fires occur in areas that have burned in the recent past. For this reason, we conduct field validation for each severity class in every fire analyzed under the burn severity mapping program in GRCA.

Field validation is conducted using the Composite Burn Index (CBI) plots described in the FIREMON Landscape Assessment protocol (Key and Benson 2006). The number of 30-meter diameter CBI plots installed per fire depends on fire size and complexity. Since the primary purpose of these plots is to refine the severity classes identified from the dNBR values, the plots are not randomly placed within the fire. Instead, the locations of the CBI plots are strategically chosen to provide representative samples of each dNBR-identified severity class and are typically installed in the center of 60 × 60 meter blocks that are homogeneous in terms of burn severity. In addition, CBI plot locations may be targeted in areas representing the upper and lower dNBR values for a severity classes in order to help refine the range of dNBR values that correspond to a severity class.

Using the CBI plot framework, monitors quantify burn severity as a function of the degree of surface fuel consumption, soil alteration, and fire effects to overstory, midstory, and understory vegetation. Under this protocol, 21 indices of fire severity are evaluated and rated on a scale of 0 to 3, from no effect to highest severity (see plot data sheet in Appendix F.12.3). The average rating of these indices is used as the plot CBI value. In addition to the severity ratings, digital photographs are taken from two different angles to visually document fire severity and notes on community type, percent mortality of trees, and percent ground area covered by dead and down trees from the fire are recorded. It is important to note that the GRCA CBI data sheet differs slightly from the current FIREMON version. GRCA first initiated burn severity mapping in 2001 and has an interest in maintaining a consistent dataset over time. Therefore, updates to the national CBI data sheet since 2001 have not been incorporated into the park's CBI protocols.

F.5.5 Additional Short- and Long-term Resource Monitoring

In addition to short- and long-term change in vegetation and fuel, GRCA managers are interested in understanding fire-related changes to other natural, cultural, and social resources. Some of this information can be gained through research collaborations, while other information will need to be generated by short- and long-term monitoring. Monitoring values outside those discussed in the previous sections (F.5.3 and F.5.4) is not a standard responsibility of the GRCA Fire Ecology Program. The additional monitoring discussed in this section will be conducted using either park base funds or project funds attained specifically for the monitoring described.

Cultural-Archeological Resource Monitoring

The Programmatic Agreement (PA) with the SHPO for the Fire Management Plan (NPS 2009b) describes post-fire monitoring requirements for cultural-archeological resources. This monitoring is not a component of the GRCA Fire Ecology Program and will be conducted using either park base funds or project funds attained specifically for the monitoring. Monitoring requirements in the PA include monitoring of the degree of success of mitigation treatments for preserving National Register eligible properties, which includes monitoring of fire-sensitive cultural resources receiving treatments and sites within moderate and high severity areas. In addition, the PA requires monitoring of protected fire-sensitive sites following treatment to insure effectiveness of treatments and the physical removal of protection devices and monitoring of a sample of sites not considered fire-sensitive in at least one project burn area annually.

Wilderness Character Monitoring

More than 94% of Grand Canyon National Park is proposed Wilderness or proposed potential Wilderness. Park managers are interested in understanding how wilderness character in the park is changing over time and how stewardship actions affect trends in wilderness character. Wilderness character monitoring is conducted in part by compiling existing datasets generated for other purposes and interpreting them in the context of wilderness character (Landres et al. 2008). The GRCA Wilderness Coordinator is responsible for conducting wilderness character monitoring, but datasets generated for the GRCA Fire Management Program may be useful for assessing whether wilderness character and its four qualities are improving, stable, or degrading over time. Information from the fire management program that may be included in on-going wilderness character monitoring includes the number of actions taken to manage fire, the percent of natural fire starts that receive a suppression response, the departure from natural fire regime, the type and amount of motorized equipment and vehicles used for emergency and non-emergency actions, the type and extent of management restrictions on recreation, and the extent and magnitude of intrusions on the natural soundscape. The information from fire management is compiled with the information from all other park management activities to assess the overall trends in wilderness character in the park over time.

F.6 Data Management and Analysis

F.6.1 Data Management and Quality Control

Environmental Monitoring Data

The Williams Interagency Dispatch Center manages fire weather and fire danger rating data and is responsible for quality control of that data. The Fire Management Program operations sections (South Rim District and North Zone) are responsible for data management and quality control of fuel moisture monitoring data. GRCA Science and Resource Management Division staff are responsible for managing data on sensitive natural and cultural-archaeological resources.

Fire Observation Monitoring Data

The assigned lead Fire Effects Monitor (FEMO) is responsible for data management and quality control of burn-day fire observation data. Fire observation data can be collected with the standardized forms (Appendix F.12.3) on either hardcopy sheets or with Personal Digital Assistants (PDAs). Fire observation data from prescribed fires are not managed in a comprehensive electronic database; however, data from individual fires are typically managed in Microsoft Excel files. Prescribed fire observation data collected on hardcopy sheets are entered into Microsoft Excel and posted on the Fire & Aviation (O:\) drive of the HQ – GRCA Primary File & Print Server. Prescribed fire observation data collected with PDAs and fire observation digital photographs are uploaded to the Fire & Aviation (O:\) drive. A copy of each completed fire observation data form is given to the Prescribed Fire Burn Boss and filed in the appropriate fire binder in the Fire and Aviation Office on the South Rim. In addition, the GRCA Fire Effects Monitoring Crew maintains backup copies of all burn-day fire observation data collected in the park by crewmembers.

Air quality monitoring data collected with a DataRAM during a fire are downloaded to a laptop computer. DataRAM monitoring data are transferred to the Arizona Department of Environmental Quality (ADEQ) and the GRCA Air Quality Specialist for analysis, interpretation, and management. Air quality monitoring data collected with an E-BAM are satellite-linked to the Interagency Real Time Smoke Monitoring website (http://www.satguard.com/usfs/default.asp) and managed there.

The assigned lead Resource Advisor (READ) is responsible for data management and quality control of natural and cultural resource observation data during fires. The assigned lead READ is also responsible for management of data collected during fires to fulfill year-end reporting requirements.

Short- and Long-term Vegetation and Fuel Change Monitoring Data

FMH and RAP plot data are managed in the FEAT-FIREMON Integrated (FFI) software system (http://frames.nbii.gov/ffi). The Fire Ecologist is responsible for ensuring that data quality checks are taking place for the vegetation and fuel monitoring program. The Fire Ecologist is also responsible for monitoring design and interpretation, ensuring plot visits are scheduled at the appropriate time of year, and ensuring monitoring crews are properly trained. The Fire Ecologist may delegate these responsibilities to the Lead or Assistant Lead Fire Effects Monitor. All personnel are responsible for recording and entering monitoring information accurately and minimizing impacts to the plots during monitoring activities.

Hardcopy data for the vegetation and fuel monitoring program are entered into the appropriate database and checked for errors by the Fire Effects Monitoring Crew. Error checking is performed by comparing each paper data sheet, in its entirety, with the data entered in the database. The error checking process is performed by two people, with one person reading the data line-by-line and the other person verifying the accuracy of the database. After large data entry and quality checking sessions, the database is backed up on an external USB drive. Once all hardcopy data from the season are entered and quality checks performed, the data sheets are filed in the appropriate plot binder in the Fire Effects Office on the South Rim. Backup copies of the hardcopy data sheets are stored in the GRCA Fire Cache on the South Rim. The complete electronic database is stored and backed up on the Fire & Aviation (O:\) drive.

Plot and reference photographs taken prior to the 2005 field season are stored as a combination of slides, digital CDs, digital scans, and/or hardcopy prints in the GRCA Fire Effects Office on the South Rim. Since 2006, plot and reference photographs have been taken with digital cameras and printed for field reference. Digital photographs are stored in a database on the Fire Effects Monitoring Crew computer and are backed up on an external hard drive.

The GIS coverage of the vegetation and fuel monitoring plot locations is updated annually by the Fire Effects Monitoring Crew or the Fire Geographic Information System (GIS) Specialist. The plot location coverage is included in the park GIS files and is backed up on external hard drives by the Fire GIS Specialist.

Burn Severity Mapping Data

Burn severity mapping data management and quality control is the joint responsibility of the Fire GIS Specialist and the Lead Fire Effects Monitor. Field data for burn severity mapping are collected on PDAs, downloaded to the Fire Effects Monitoring Crew computer, and transferred to the Fire GIS Specialist for analysis and backup. CBI field data collected in conjunction with burn severity mapping are currently managed in Microsoft Excel files and are scheduled for conversion to FFI by national-level contractors. Digital field data, plot location points, and plot photographs are maintained by the Fire GIS Specialist and the Fire Effects Monitoring Crew and backed up on external hard drives.

Additional Short- and Long-term Resource Monitoring Data

Data collected for additional resource monitoring projects is the responsibility of the lead investigator/ resource specialist assigned to the project.

F.6.2 Data Analysis

Trends in environmental monitoring data are assessed prior to planned prescribed fire by the specialists responsible for collecting the data. Long-term trend analysis occurs for weather, fire danger rating, and fuel moisture variables. Analysis of natural and cultural-archaeological resource variables is conducted by staff from the GRCA Science and Resource Management Division.

The Fire Ecologist and Lead Fire Effects Monitor analyze vegetation and fuel monitoring data for all major management objectives annually in conjunction with the preparation of the GRCA Fire Ecology Annual Report. Analysis may be performed on variables not included in management objectives at the request of fire or natural resources staff or external park partners. Prior to analysis, data are tested for normal distribution. If data are normally distributed, analyses are performed using either the parametric tests available in FFI (*F*-test and Dunnett's multiple comparison procedure) or appropriate tests available in external statistics software packages. If data are not normally distributed, the non-parametric tests available in FFI (Friedman's chi-square and non-parametric multiple comparisons based on Friedman's Rank Sums) or equivalent tests available in external statistics software packages are used for analysis.

The Fire GIS Specialist analyzes CBI field data for burn severity mapping. Based on the final CBI plot value, plots are categorized as unburned, low, moderate-low, moderate-high, and high severity. The data from the plots within each severity class are used to finalize the numerical cut-off points between severity classes on the dNBR image.

F.6.3 Data Sharing

Data relevant to fire management are collected by other divisions in the park, by other programs in the NPS (e.g. the Southern Colorado Plateau Inventory and Monitoring Program), and by outside researchers (government and university). In addition, data collected by the Fire Ecology Program may be relevant to addressing other resource management questions in the park. There is currently no formal mechanism to combine these data and use them in an integrated format to inform fire or resource management. However, intermittent data sharing has occurred between the GRCA Fire Ecology Program and other programs within and outside the park. Data from the vegetation and fuel monitoring program is available in the FFI database program by December 31 of each year and can be queried by interested parties at that time.

F.7 Reporting and Adaptive Management

Monitoring data provide the basis for adaptive management and communication of monitoring results is a key step in the process to determine whether treatments are meeting objectives or whether they need modification. Monitoring data are incorporated into GRCA fire planning documents and used to evaluate and, if necessary, refine monitoring designs, treatment strategies, and/or monitoring and treatment objectives. Monitoring data may also raise additional questions about the effects of fire management on the GRCA landscape and highlight the need for research projects.

The data analysis and communication step of adaptive management occurs on a number of time scales. Information may be available within the day (fire weather and behavior observations), at the completion of the treatment (overall treatment effectiveness or initial fire effects), or a year or more after treatment (burn severity, long-term effects on target or non-target vegetation). The evaluation step in adaptive management includes both targeted and synoptic assessment of the program. In some cases, this evaluation can be quantitative (comparing measured effects with predicted effects), while in other cases, a qualitative, or even subjective analysis may be required (for example, trade-offs between visibility impact and fuel reduction). The evaluation process occurs after each treatment in the form of After Action Reviews, after each season during the annual review, and once every five years in a comprehensive program review. Based on the program evaluation, opportunities for improvement may become apparent. Monitoring and evaluation of different resources may occur on different time scales (ranging from days to a few years), so the adjustment phase may be ongoing, rather than a specific action. Overall, the adjustment phase is most likely to occur daily for tactical issues on a given fire, post-fire for immediate resource concerns, annually as part of the Fire Management Plan annual review, and as needed in the development or revision of prescribed fire plans. Additional details on the Fire Management Program's adaptive management process can be found in section 2.6.4 of the GRCA Fire Management Plan EIS/AEF (NPS 2009a).

Annual Reports

Monitoring accomplishments and results from vegetation and fuel monitoring data analysis are reported each year in the GRCA Fire Ecology Annual Report. This report includes a summary of monitoring activities from the year, results from data analysis, interpretation of data in the context of adaptive management, and discussion of the degree to which treatment objectives are being met. The annual report is shared with fire management staff, resource management staff, and upper division managers at the park as well as with regional office staff and interested parties outside of the NPS. It is also posted on the internal Wildland Fire Fuels, Science, and Ecology intranet site (InsideNPS) by national office staff. The information presented in the annual report will help guide the annual review of the monitoring plan.

An annual report to USFWS is required as part of the Biological Opinion (BO) for the Fire Management Plan (FWS 2009). The report is completed each year by the GRCA Science and Resource Management Division, Office of Planning and Compliance, and Branch of Fire and Aviation staff. The BO annual report outlines calendar year's actions in relation to listed species, documents effects to species and their habitat from fire management activities, documents the implementation and effectiveness of the terms and conditions of the biological opinion, and outlines rehabilitation efforts.

Two annual reports are required as part of the Programmatic Agreement (PA) with the State Historic Preservation Officer (SHPO) for the Fire Management Plan (NPS 2009b). These reports are completed each year by the GRCA Science and Resource Management Division, Office of Planning and Compliance, and Branch of Fire and Aviation staff. The pre fire season project planning report outlines plans to survey planned project units, the status of cultural inventories in the units, and the Assessments of Effect for the coming year. The post fire season report includes a summary of all fire activity for the year, summary of protection measures employed and their effectiveness, and the results of inventory and monitoring conducted during the year's incidents.

Reports are provided to appropriate internal and external stakeholders to aid in the evaluation of program activities. In addition to these annual reports, reporting occurs via conversation, phone, and email on a routine basis between the Fire Ecologist, Lead Fire Effects Monitor, other GRCA Fire and Aviation staff, GRCA Science and Resource Management Division staff, and GRCA Office of Planning and Compliance staff.

External publications and presentations

Monitoring results may be presented at conferences and other special meetings or submitted for publication in appropriate journals. Results that both support and contradict published literature are of special interest.

F.8 Fire Research

The Mission Goals for the NPS Wildland Fire Management Program outlined in Director's Order DO-18 include science-based management and integration of Wildland Fire with other NPS programs (NPS 2008a). Both of these goals are achieved, in part, through fire research. In addition, Federal Wildland Fire Management Policy (U.S. Government 2001) states that "Fire management plans and programs will be based on a foundation of sound science. Research will support ongoing efforts to increase our scientific knowledge of biological, physical, and sociological factors…and must be made available to managers in a timely manner, and must be used in the development of…fire management plans, and implementation plans."

Conducting research that will help define natural fire regimes, refine prescriptions, provide data for fire behavior models, and effectively implement the Fire Management Program is an objective of the GRCA FMP. In addition to understanding the historic and current role of fire in park ecosystems, fire-related research at GRCA aims to acquire the knowledge necessary to improve fire management practices that affect the park's natural, cultural, and social values.

F.8.1 Past and Current Research

Much of the completed fire-related research relevant to GRCA is referenced throughout the Fire Management Plan EIS/AEF (NPS 2009a). Past fire-related research within GRCA includes studies on:

- forest reference conditions (Schumutz et al. 1967, Covington et al. 2000, Fulé et al. 2000, Rowlands and Brian 2001, Fulé et al. 2002ab, Mast and Wolf 2004, Mast and Wolf 2006),
- fire regimes (Bennett 1976, Duhnkrack 1982, Wolf and Mast 1998, Covington et al. 2000, Fulé et al. 2003ab, Meigs 2004, Baker 2006, Fulé et al. 2006ab, Haire and McGarigal 2009),
- restoration (Fulé et al. 2002ab, Fulé et al. 2004ab, Fulé et al. 2006ab),
- fire effects to vegetation (Bennett 1976, Harrington and Hawksworth 1988, White and Vankat 1993, Kaufmann 2000, Gildar et al. 2004, Laughlin et al. 2004, Huisinga et al. 2005, Laughlin et al. 2005, Laughlin and Grace 2006, Fulé and Laughlin 2007, Laughlin and Fulé 2008, Haire and McGarigal 2008, Kim et al. 2009)
- fire effects to wildlife (Bennett 1976, Muleady-Mecham 2003)
- fire effects to soils (Bennett 1976)
- fuel and fire behavior (Fulé et al. 2004ab)
- air quality and smoke (Stearns 1988)
- information and education (Baas et al. 1985, Muleady-Mecham 2003)

GRCA Fire Management Program personnel are currently working with university researchers to investigate the short- and long-term implications of fire severity on forest vegetation through three on-going research collaborations. The first of these collaborations aims to produce a comparable set of burn severity mapping values for examining past and future fires and a park-wide map of fire severity in all fires within the park from 1984 to the present. Building on this map, the second project aims to determine the present-day differences in vegetation recovery in areas burned under different burn severities at different time intervals before the present. The third project will then model expected future forest conditions after different severity fires and under various management strategies. These projects will allow fire managers to better understand how higher severity fire patches affect forest regeneration, the potential for different severity fires in the future, and the longevity of fire treatments.

F.8.2 Research Needs

Future fire research needs were compiled during an interdisciplinary meeting held on February 25, 2009 between GRCA Fire and Aviation, GRCA Science and Resource Management, and Southern Colorado Plateau Network Inventory and Monitoring personnel. Fire research needs related to vegetation, wildlife, cultural resources, air quality, hydrology, fuel management, and social and economic values were identified during this meeting. Research needs are currently not prioritized by discipline or by overall priority. The Fire Ecologist will facilitate the prioritization process with input from fire and resource management staff. Research needs will be disseminated to the research community through the Colorado Plateau Cooperative Ecosystem Studies Unit (CESU), the GRCA Research Coordinator, the Southwest Fire Science Consortium, and other partners.

Vegetation and Fuel

- Determine fire regime, reference conditions, and effects of fire on piñon-juniper vegetation types.
- Determine the effectiveness of multiple entry fires and temporal spacing of fire for fuel reduction.
- Investigate the effects of fire management activities, the influence of the spatial scale of fire patches, and post-fire succession on exotic plant species invasion.
- Model expected range of variation in mixed-conifer and spruce-fir forest structure in climates experienced now and predicted for the future.
- Model expected range of variation in fire regimes and fire behavior in climates experienced now and predicted for the future.
- Investigate patch age structure at the landscape scale to better define mixed-severity fire regime.
- Determine the effectiveness of post-fire rehabilitation techniques, refine rehabilitation methodologies, and develop a GRCA post-fire rehabilitation handbook.
- Mine existing data to determine the dominant understory plant species in each vegetation type and develop seed collection and storage protocols for these plants to fulfill the need for an in-park seed source for post-fire rehabilitation efforts.
- Develop a map of *Bromus* spp. (cheatgrass, red brome, and ripgut brome) locations in forested areas from existing data, determine threshold levels that would trigger control actions, and prepare an action plan that includes control measures and recommended fire management activities.
- Determine effects of burning in different seasons on fuel reduction, vegetation response, and exotic plant species invasion.
- Understand non-fire causes of canopy tree mortality in spruce-fir and mixed-conifer vegetation types and how this mortality affects fire management options.
- Mine existing data on the current status of invasive and rare plant species in burn units to inform prescribed fire plan objectives.
- Investigate the effects of prescribed fire size on fuel and vegetation.
- Understand meadow encroachment on the North Rim and whether fire affects this process.

Wildlife

- Understand Mexican spotted owl behavioral responses to fire and smoke.
- Investigate the effects of burn severity on Mexican spotted owl habitat components.
- Investigate the influence of spatial scale of fire patches and succession on bird communities.
- Determine effects of burning in different seasons on wildlife habitat and populations.
- Understand fire effects to small mammals in higher elevation forests.

Cultural Resources, Social and Economic Values

- Build a predictive model for locating archaeological sites in areas without survey. Determine a survey strategy by vegetation type or fire management unit for locating archaeological sites.
- Determine the effectiveness of mitigation measure treatments for cultural resources.
- Understand fire effects to cultural resources using post-fire archeological surveys.
- Understand the response of ethnographically important plants to fire.
- Understand tribal perspectives on managing fire effects to cultural resources.
- Determine the cost effectiveness of prescribed fires of varying size.
- Survey visitor understanding and opinions on fire management activities, fire management goals and benefits, and change in fire policy implementation.
- Understand effects of planned and unplanned fire management activities to visitor experience (closures, viewshed, soundscape, visibility).
- Examine whether wilderness stewardship mitigations are effective at meeting the goals of both wilderness management and fire management.

Air Resources

- Investigate smoke impacts in the Bodaway/Gap area.
- Investigate smoke penetration into the canyon and model the venting process.
- Understand the effects of prescribed fire size on air quality.

- Mine existing data on weather, fire conditions, and air quality parameters to understand their interactions.
- Determine the effectiveness of health hazard warnings related to air quality standards.

Water Resources

- Investigate changes in potential for debris flows and flash floods following fire.
- Determine fire effects to water quality in canyons.
- Understand fire effects to seeps, springs, sinkhole ponds, and wetlands.

F.9 Roles and Responsibilities

The Fire Ecology Program at GRCA is organized in the Division of Visitor and Resource Protection, Branch of Fire and Aviation. The Deputy Fire Management Officer supervises the Fire Ecologist and the Fire Geographic Information System (GIS) Specialist and has program oversight responsibilities. The Fire Ecologist oversees the Fire Effects Monitoring Crew, which consists of a permanent Lead Monitor, a permanent Assistant Lead Monitor, and seasonal crewmembers.

F.9.1 Staff roles and responsibilities

The roles and responsibilities of the Fire Management Officer and Deputy Fire Management Officer are described in Section 3.9.1. of the GRCA Fire Management Plan EIS/AEF (NPS 2009a). The responsibilities of the Fire Ecology and Fire GIS program staff are as follows:

Fire Ecologist

The Fire Ecologist serves as the program expert in fire ecology and coordinates with other resource managers to collect scientific information regarding long- and short-term effects of fire and fuel management activities. The Fire Ecologist is responsible for the development and implementation of the monitoring plan, which includes assessment and modification of the monitoring design and analysis of data. The Fire Ecologist is also responsible for ensuring that data management and quality control procedures are in place and for overseeing the hiring, training, and supervising of the Fire Effects Monitoring Crew. The role of the Fire Ecologist in the adaptive management process is to report monitoring results to fire and resource managers, conduct literature reviews and interpret results, identify fire- and fuel-related research needs, and coordinate research efforts. The Fire Ecologist assists with the development of quantifiable objectives for prescribed fire and non-fire fuel treatment plans and reviews fire management, prescribed fire, and non-fire fuel treatment plans. In addition, the Fire Ecologist coordinates with regional and national fire ecologists, the Inventory and Monitoring Program, and other resource management monitoring programs, and acts as a liaison with park natural and cultural resource programs. The Fire Ecologist has budget and fiscal responsibility for the Fire Monitoring Program.

Fire GIS Specialist

The Fire GIS Specialist provides a variety of support products to the Fire Management Program, such as geospatial expertise, data layers, and maps. In support of the Fire Monitoring Plan, the Fire GIS Specialist manages the burn severity mapping program and fire history database. The Fire GIS Specialist requests, maintains, and analyzes burn severity satellite imagery through the Monitoring Trends in Burn Severity program. The Fire GIS Specialist also coordinates location and installation of Composite Burn Index field plots, and maintains and analyzes burn severity data. In addition, the Fire GIS Specialist facilitates research on burn severity and spatial aspects of fire management.

Lead Fire Effects Monitor

The Lead Fire Effects Monitor oversees collection and storage of monitoring data needed to determine the effectiveness of the Fire Management Program in meeting objectives. The Lead Fire Effects Monitor is responsible for hiring and training the Assistant Lead Fire Effects Monitor and seasonal crewmembers, directing and overseeing the daily operations of the Fire Effects Monitoring Crew in the field and office, setting the monitoring schedule, and ensuring data quality. In addition, the Lead Fire Effects Monitor collaborates with the Fire Ecologist on planning and annual reporting documents. The Lead Fire Effects Monitor also assists with the implementation and monitoring of fire treatments as needed and as available.

Assistant Lead Fire Effects Monitor

The Assistant Lead Fire Effects Monitor performs and coordinates field and office duties associated with the collection and storage of fire effects monitoring data in order to determine effectiveness of the Fire Management Program in meeting objectives. The Assistant Lead Fire Effects Monitor is responsible for leading the crew in the absence of the Lead Fire Effects Monitor (see Lead Fire Effects Monitor duties).

F.9.2 Work plans and prioritization

The Deputy Fire Management Officer develops annual work plans and priorities for the Fire Ecologist and Fire GIS Specialist. The Fire Ecologist and Lead Fire Effects Monitor develop annual work plans and priorities for the Fire Effects Monitoring Crew prior to the arrival of the seasonal crewmembers.

F.10 Consultation, Collaboration and Review

This monitoring and research plan was compiled in consultation with many stakeholders. The implementation of this plan and future reviews will continue to involve collaborations with these and other interested parties.

F.10.1 Plan Input

Several meetings were held to solicit input into this monitoring plan. Fire Research was the focus of an interdisciplinary meeting conducted on February 25, 2009. Goals and Objectives and Monitoring Unit Descriptions were revised during meetings held on March 10 and 23, 2009 and February 16, 2010. The following individuals contributed to these and other sections through meetings and informal conversation:

Table F.10.1. Individuals who provided input during monitoring plan development. V&RP=Visitor and Resource Protection.

Name	Division/Association	Title	Section Input
Carl Bowman	GRCA, Science & Resource Management Division	Air Quality Specialist (former)	Fire Research
Li Brannfors	GRCA, V&RP, Branch of Fire & Aviation	Lead Fire Effects Monitor	Goals and Objectives, Monitoring Design, Data Management, Appendices
Jim DeCoster	NPS, Southern Colorado Plateau Inventory and Monitoring Network	Plant Ecologist	Fire Research
Ken Gerow	University of Wyoming, Department of Statistics	Professor	Monitoring Design (project-level monitoring plot size and sample size)
Eric Gdula	GRCA, V&RP Division, Branch of Fire & Aviation	Fire GIS Specialist	Monitoring Design (burn severity), Data Management, Fire Research
Arthur Gonzales	GRCA, V&RP, Branch of Fire & Aviation	South District Fire Management Officer	Goals and Objectives, Monitoring Unit Descriptions Appendix
Ed Hiatt	GRCA, V&RP, Branch of Fire & Aviation	North Zone Fire Management Officer	Goals and Objectives, Monitoring Unit Descriptions Appendix
Amy Horn	GRCA, Science & Resource Management Division	Archaeology Program Manager (former)	Fire Research
Mike Kearsley	GRCA, Science & Resource Management Division	Vegetation Mapping Program Coordinator	Fire Research
Lori Makarick	GRCA, Science & Resource Management Division	Vegetation Program Manager	Fire Research
Christopher Marks	GRCA, V&RP, Branch of Fire & Aviation	Deputy Fire Management Officer	Goals and Objectives, Monitoring Unit Descriptions Appendix, Fire Research
Steve Mietz	GRCA, Science & Resource Management Division	Deputy Chief Natural Resources Management(former)	Fire Research
Kathryn Parker	GRCA, Science & Resource Management Division	Climate Change Coordinator (former)	Fire Research
Jasper Peach	GRCA, V&RP, Branch of Fire & Aviation	Assistant Lead Fire Effects Monitor	Monitoring Design, Data Management
Dan Pearson	GRCA, V&RP, Branch of Fire & Aviation	South District AFMO	Goals and Objectives, Monitoring Unit Descriptions Appendix
Steven Rice	GRCA, Science & Resource Management Division	Hydrologist	Fire Research
Dave Robinson	GRCA, V&RP, Branch of Fire & Aviation	North Zone AFMO-Fuels	Goals and Objectives, Monitoring Unit Descriptions Appendix
Jane Rodgers	GRCA, Science & Resource Management Division	Deputy Chief Socio-Cultural Resources Management	Fire Research
Carmen Sipe	GRCA, Science & Resource Management Division	Fire Wildlife Biologist (former)	Goals and Objectives, Fire Research, Monitoring Unit Descriptions Appendix
Lisa Thomas	NPS, Southern Colorado Plateau Inventory and Monitoring Network	Program Manager	Fire Research
R.V. Ward	GRCA, Science & Resource Management Division	Wildlife Program Manager	Fire Research

F.10.2 Agency/Interagency Collaboration

The GRCA Fire Management Program will collaborate closely with the GRCA Science and Resource Management Division in the implementation of this plan. In addition, the Fire Management Program will collaborate with the GRCA Air Quality Specialist in implementing smoke and air quality monitoring and with the Vegetation Program Manager to assess the effects of fire management activities on invasive plant species.

The GRCA Fire Ecologist will also collaborate with the Southern Colorado Plateau Network (SCPN) Inventory and Monitoring Program to identify areas where monitoring data can be shared. The SCPN is currently in the early stages of installing long-term monitoring plots in the mixed-conifer forests of the North Rim and is evaluating the potential for installing long-term plots in one of the piñon-juniper communities within the park.

GRCA Science and Resource Management staff, with support from GRCA Fire Management staff, work with U.S. Fish and Wildlife Service, Arizona State Historic Preservation Officer, and affiliated Indian Tribes to keep these stakeholders informed of fire management activities and monitoring and research results.

F.10.3 Peer review

Peer/technical review for this plan was provided by both internal (Grand Canyon National Park) and external reviewers.

Grand Canyon National Park reviewers include:

	Name	Title
Visitor and Resource Protection Division, Branch of Fire & Aviation		
	Christopher Marks	Deputy Fire Management Officer
	Li Brannfors	Lead Fire Effects Monitor
Science & Resource Management Division		
	Jane Rodgers	Deputy Chief Socio-Cultural Resources Management
	Ian Hough	Archaeology Program Manager (acting)
	Linda Jalbert	Planner / Wilderness Coordinator
	Lori Makarick	Vegetation Program Manager
	Steven Rice	Hydrologist
	R.V. Ward	Wildlife Program Manager

External peer reviewers include:

Jim DeCoster, Plant Ecologist, National Park Service Southern Colorado Plateau Network
Peter Fulé, Associate Professor, School of Forestry and Associate Director for Ecological Research, Ecological Restoration Institute, Northern Arizona University
Cody Wienk, Regional Fire Ecologist, National Park Service Midwest Region

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F.12 Appendices

F.12.1 Monitoring Unit Descriptions (FMH-4s)
F.12.2 Monitoring Schedule
F.12.3 Data Sheets
F.12.4 Plant List
F.12.5 Monitoring Results
F.12.6 Calculations
F.12.7 Special Status and Exotic Species of Concern