Preface

"Fire is the most aggressive form of resource management practiced in national parks. Prescribed fires, and wildfires with their associated suppression impacts, have the potential to drastically alter parks for hundreds of years. Management actions taken in regard to either of them may be the most significant actions taken by park management in regard to their resources. Every fire is significant if you consider the perpetual management of parks." (NPS-18, 1986)

National Park Service fire management guidelines (NPS-18) state that parks with prescribed fire programs must monitor those fires to ensure that fire behavior is assessed, and resource management objectives are met. NPS-18 does not specify how the monitoring is to be done. This Handbook outlines standardized methods to be used within the Western Region of the National Park Service for documenting both wildfires and prescribed fires. It is intended to provide managers with the feedback necessary to either affirm that park objectives are being met or to identify and correct deficiencies.

The Handbook is designed to insure that all parks collect at least the minimum information deemed necessary to evaluate their respective fire management programs. There are many benefits to establishing these minimums and standardizing data collection procedures. Uniformly gathered data will facilitate information exchange between parks, and provide historical program documentation and data bases useful for refinements of the park’s fire management program. Fire monitors will be able to move to or assist other parks without additional training.

A standardized system to cover the wide diversity of areas within the Western Region is not without its problems. Each park’s monitoring program, therefore, will be reviewed annually by the FMH Program Manager, and refinements to this Fire Monitoring Handbook will be made as necessary. Until then, this release will serve to guide all fire monitoring in Western Region parks. Any park unable to comply with the required standards will terminate their prescribed fire management programs until compliance can be assured.

The monitoring protocol for prescribed burns is to be applied only in parks having approved prescribed fire management programs, and where fire effects on plant communities are already documented. This monitoring system does not provide a methodology to compare burn and non-burn areas to assess fire effects with scientific precision. If such information is needed, parks should contact the Western Region Division of Natural Resources and Research for assistance in designing the appropriate studies.
1992 Changes to Standards and Protocols

The Western Region Fire Monitoring Handbook was originally published and released for field use on February 14, 1990. A fire monitoring training course, RX-80 -- Preburn Inventory Techniques, based on the standards outlined in the Handbook, was developed and taught soon after. The monitoring protocols were rigorously tested during this course and through the 1990 field season. Handbook users and managers attended two post-season critiques to discuss the Handbook's developmental needs. Relatively minor changes in standards and protocols resulted from these reviews.

Monitoring protocols continued to be tested in two 1991 sessions of RX-80 and in the 1991 field season. In addition, instructors further refined course materials for RX-80. In November, managers and monitors met for a thorough review of the handbook using Yosemite National Park as a model. Relatively minor changes in standards and protocols resulted from this review.

This 1992 version of the Handbook was developed to address deficiencies in the 1990 and 1991 releases, and to respond to recommendations made by the course developers and field crews. System changes have been incorporated into the appropriate sections of text. Summarized here are the principal modifications made to discussions, standards, and protocols. The changes in standards and protocols will be considered modifications to Western Region fire monitoring policy.

Summarized here are the principle modifications to the 1991 release of the handbook (page numbers from the 1991 handbook are printed in italics). The changes to the 1990 release are listed separately.

CHANGES TO STANDARDS

A program manager has been hired to supervise the program, answer questions from monitors and managers, act as a liaison between the parks and the Regional Office, and maintain the fire effects database.

A monitoring program can be customized to address specific park needs. However, any modifications to FMH protocols must be reviewed and recommended by the park's resource management specialist, fire management officer, and scientist or local CPSU researcher. These proposed changes should then be sent to the Western Regional Office for approval.
PROTOCOL CLARIFICATIONS AND CHANGES

Protocols have changed slightly for level 1 (reconnaissance) through level 4 (long-term change) plot installation and data collection. The handbook has been partially rewritten to reflect changes in protocols. These changes are summarized here in order of presentation within the text.

PREFACE (page iii - - iii )
The last two paragraphs have been modified to agree with changes in protocol.

CHAPTER 1

Minimum Acceptable Standards (MAS) (page 4 - - 1.4 )
Elimination of elements categorized as minimum without Regional approval is unacceptable.

Program Responsibilities of NPS Personnel (page 10 - - 1.11 )
Program responsibilities have been clarified.

Analyzing and Interpreting Trend Data (page 19 - - 1.19 )
Joint review of data by fire, research, and resource personnel will help define and identify trends.

Evaluating the Program (page 20 - - 1.20 )
Due to the involvement of fire management officers in this program, FMOs have been added to the regional review committee.

The program will be evaluated periodically, not annually for the first 5 years.

CHAPTER 2

The last sentence of the first paragraph has been modified.
Drought Index (page 29 - - 2.7)
The drought index is related to the fire danger rating.

Duff Moisture (page 29 - - 2.7)
Duff moisture also affects smoke production; and should not be measured with a moisture probe.

Fuel Model (page 30 - - 2.8)
The first sentence has been modified.

Fire Spread Direction (page 31 - - 2.9)
Fire spread direction (FSD) can also be the projected spread direction of a portion of the fire.

Table 2. Smoke Monitoring Variables (page 33 - - 2.11)
The wording in the footnote has been clarified.

Ocular estimate has been added to the list of techniques in calculating mixing height.

The wording under the Threshold for Complaints has been changed.

Minimum Acceptable Visibility (page 36 - - 2.14)
The 31 in the MAV column has been corrected to 50.

Mitigating Reduced Visibility Situations (page 37 - - 2.15)
The wording in the examples has been changed.

Supplements
Supplements have been moved the back of the handbook, and are now appendices.

CHAPTER 3

LEVEL 3 VARIABLES (page 48 - - 3.2)
The first two paragraphs in this section have been rewritten.

A paragraph has been added at the end of this section outlining the new procedure for customizing the program.

MONITORING DESIGN (page 54 - - 3.8)
All customized methods must be approved by the Western Regional Office.
Representative Area (page 54 - - 3.8)
The last paragraph in this section has been moved below the fourth paragraph.

The subsequent paragraphs are now denoted as "Areas of Special Concern or Constraint."

A new section has been added addressing incomplete databases due to the smallness of an area.

Supplements
Supplements have been moved the back of the handbook, and are now appendices.

CHAPTER 4 - GENERAL METHODS

SELECT AND DEFINE MONITORING TYPES

Step 1: Establish Selection Criteria

Fuel Characteristics (page 66 - - 4.6)
Several monitoring types may be included within a single fuel model.

Step 2: Describe the Monitoring Type

Prescription Criteria (page 67 - - 4.7)
Burn goals and monitoring type variables have been added to the prescription criteria.

Plot Protocols (page 68 - - 4.7)
Plot protocols are now defined on the second page of the Monitoring Type Description Sheet (FMH-4).

LOCATE INDEX PLOTS

Step 1: Randomly Locate Plots on a Map or Other Locator (page 70 - - 4.9)
The random point that is established is called the plot location point throughout this section.

Method 1: Grid Map Method (page 71 - - 4.9)
50m² and 30m² has been replaced by 50 x 50 and 30 x 30.

Step 5: Complete Location Data Sheet
Index Plot Location Data Sheet, Example #2 (page 77 - - 4.16)
The dates on the data sheet have been altered to clarify the fact that plots do not have to be read biennially, but they must be read within two years of the burn.

PLOT PLACEMENT PROBLEMS

Small Areas (page 56, 79 - - 3.10, 4.17)
A paragraph has been added to clarify the solution to this problem.

MONITORING SCHEDULE

Cautionary Notes (page 84 - - 4.22)
The number of index plots per monitoring type should be limited to twenty-five or thirty. Consult the WRO Prescribed Fire Specialist or Program Manager if minimum plot calculations exceed this limit.

Preburn (page 84 - - 4.22)
Plots do not have to be read biennially, but they must be read within two years of the burn.

FILES MAINTENANCE (page 86 - - 4.24)
Each file folder should be labeled with the plot identification code and burn unit.

CHAPTER 4 - SPECIFIC METHODS

LAY OUT INDEX PLOT

Establish the Plot Boundaries (page 91 - - 4.30)
The last sentence in the second paragraph has been rewritten.

MONITOR PREBURN VEGETATION CHARACTERISTICS

Plot Specifications

Seedling Trees (page 97 - - 4.35)
Seedlings are tallied by species and by height.

Brush and Herbaceous Layer (page 97 - - 4.35)
Sparse and extremely sparse brush, forb, and grass elements are more clearly defined.
Overstory Trees (page 98 - - 4.36 )
The dbh of a leaning tree is measured by leaning with the tree.

If the bole of a fallen tree is below dbh, and the individual is resprouting, the sprouting branches should be treated as individuals.

Crown Position (page 99 - - 4.37 )
Crown position is a recommended variable for living trees, and is an optional variable for dead trees.

A graphic has been added to illustrate crown position.

Tree Damage (page 100 - - 4.37 )
Tree damage is a recommended variable for living trees, and is an optional variable for dead trees.

Damage codes are more clearly defined.

Epicormic Sprouting (EPIC), basal sprouting (SPRT), and human-caused damage (UMAN) have been added to the list of tree damage codes.

CONC is now more correctly spelled CONK.

Seedling Trees (page 103 - - 4.40 )
The definition of seedling trees has been clarified and it is now possible to measure the diameter of multi-branched trees at some other point than breast height, probably basal height.

MAS Procedures (pages 104 - - 4.41 )
The NUM category has been changed to TALLY to avoid confusion. It is now optional to give individual seedlings map numbers, similar to the tag numbers given to other tree classes, for increased precision in mapping.

Brush and Herbaceous Layer

Collect # of Transect Hits, Relative Cover, and % of Non-native Species Data (pages 105 and 121 - - 4.42 and 4.57 )
Moss has been removed from the substrate examples.

Collect and Record Brush Density Data (pages 106 and 122 - - 4.43 and 4.58 )
Brush age classes have been changed to seedling/immature (S), resprout (R), and mature/adult (M).
**Record Species Used** (page 106 and 122 - - *4.43 and 4.58*)
This paragraph has been moved above "Precisely Measure Brush Individuals (recommended)."

**Measure Brush and Herbaceous Layer Height** (page 107 and 122 - - *4.43 and 4.61*)
Height is measured in meters to the nearest decimeter.

**Deal with Sampling Problems** (page 107 and 123 - - *4.44 and 4.59*)
Height is measured in meters to the nearest decimeter.

**Make Voucher Collection** (pages 108 and 124 - - *4.45 and 4.60*)
The following additional information will be recorded on a sheet of paper with the pressed specimen: if the plant is a annual, biennial or perennial; flower color; and the height of the plant.

**MONITOR PREBURN FUEL CHARACTERISTICS**

**Dead and Downed Fuel Load** (pages 110 - - *4.47*)
Determine the slope in percent of each fuel inventory transect in the direction of the transect.

**MAS Procedures** (page 110 - - *4.47*)
Tallied material is measured perpendicular to the point where the tape crosses the central axis.

Do not count dead woody material attached to standing brush or trees.

Rotten wood is obviously deteriorating or punky wood.

75% of all fuel inventory transect lines within a monitoring type should intercept a 3-inch or larger log; if they do not, the standard length of the sampling plane should be increased.

Twigs and larger stems are not measured in the litter depth.

The paragraph dealing with dead and downed fuel sampling problems has been moved to the end of this section, and is now titled "Dealing with Sampling Problems."

**Deal with Sampling Problems** (page 111 - - *4.47*)
If a log is in the middle of the litter or duff measuring point, move the data collection point 1 foot perpendicular to the sampling plane.
MONITOR POSTBURN VEGETATION AND CHARACTERISTICS (page 115 and 130 - - 4.52 and 4.66)
Brush and Herbaceous Layer Transect (FMH-17 and -23) and Herbaceous Layer Species Density (FMH-19) are optional postburn variables.

MONITOR POSTBURN CONDITIONS

Scorch Height (page 116 - - 4.52)
A graphic has been added to illustrate the variety of scorch heights one should expect to encounter at a site, and the concept of average scorch height.

Burn Severity (page 117 and 130, 131 - - 4.54 and 4.67)
A new category has been added to the burn severity table: Not Applicable (0). This category is to be used if no vegetation and/or no substrate is present.

GRASSLAND AND BRUSH METHODS

Mark the Plot (page 119 - - 4.55)
30P is now placed at 30.3 meters to prevent stake interference at the 30 meter data point (point #100).

Brush Density (page 122 - - 4.58)
If there is a question regarding which side of the transect is uphill, the MAS default is the right side of the transect as one is facing 30P from OP.

Brush and Herbaceous Layer Height (page 122 - - 4.61)
This section has been moved from above the Optional Monitoring Procedures to above "Deal with Sampling Problems."

Optional Monitoring Procedures

Herbaceous Layer Species Density (page 125 - - 4.61)
If there is a question regarding which side of the transect is uphill, the MAS default is the right side of the transect as one is facing 30P from OP.

MONITOR FIRE WEATHER AND BEHAVIOR CHARACTERISTICS (page 128 - - 4.64)
Observation areas for brush and grassland fire behavior are called FBOI (fire behavior observation intervals) not FBOC (fire behavior observation circles).

Text was added to clarify that the fire behavior observation intervals in Figure 13 are examples of possible scenarios, and are not required data collection intervals.
MONITOR POSTBURN CONDITIONS

Burn Severity (Page 130, 131 - 4.66)
A section describing burn severity codes has been added.

Monitoring Forms (Appendix A -- Supplement 4A)

All Data Sheets
Year 3 has been removed from all data sheets, as plots are not read 3 years after the burn.

Fire Behavior/Fire Weather Data Sheet (FMH-2)
Shading (0-3), has been changed to % to agree with the text.

Fire Direction has been changed to Fire Spread Direction to agree with text and 1-5 has been removed to agree with the text.

Monitoring Type Description Sheet (FMH-4)
Park Unit 4-character Alpha Code, Monitoring Type Variable(s), and Burn Goals have been added to page 1 of the form.

Page 2 is now available for preparers to indicate optional and recommended procedures, and other variables that will be used for a monitoring type.

Index Plot Location Data Sheet (FMH-5)
Places to indicate Transect Azimuth, Declination, and Photo Roll ID have been added.

Species Code List (FMH-6)
A column has been added for indicating whether a plant is annual, biennial or perennial.

Overstory Tagged Tree Data Sheet (FMH-8)
The new damage codes have been added to the bottom of the data sheet.

Full Plot Tree Map (FMH-9)
A grid has been added to assist in tree mapping.

Quarter 1 Pole-sized Tree Map (FMH-12)
A grid has been added to assist in tree mapping.
Seedling Tree Data Sheet (FMH-14)
NUM has been replaced with TALLY.

A column has been added to record the map number (equivalent to overstory or pole-size tag number).

Live is now considered an optional column, for those who wish to record dead seedlings.

50m² Seedling Tree Map (FMH-15)
A grid has been added to assist in tree mapping.

Quarter 1 Seedling Tree Map (FMH-16)
A grid has been added to assist in tree mapping.

50 Meter Transect Data Sheet (FMH-17)
Pages 2, 3, and 4 have a place to indicate which transect is being read.

Belt Transect Data Sheet (FMH-18)
A place has been provided to indicate which side of the transect was read for brush density.

The new brush age codes have been added to the bottom of the sheet.

An alternate form that has been used in Pinnacles NM for tallying brush species is made available as FMH-18-A.

Herbaceous Density Data Sheet (FMH-19)
A place has been provided to indicate which side of the transect was read for brush density.

Overstory Postfire Assessment Data Sheet (FMH-21)
(CHAR) (optional) has been changed to (CHAR) (recommended).

Forest Plot Burn Severity Data Sheet (FMH-22)
A new category has been added to the burn severity table: Not Applicable (0). This category is to be used if no vegetation and/or no substrate is present.

30 Meter Transect Data Sheet (FMH-23)
A space has been provided to record the photographic roll ID number.
A new category has been added to the burn severity table: Not Applicable (0).
This category is to be used if no vegetation and/or no substrate is present.

The definition of total gross weight has been clarified.

A place has been provided to indicate lens type.

SCAT has been added as a code to the table.

SDEAD has been changed to SDED to allow this code to be entered in the FMH software.

The plot identification code has been corrected in the example.

The checklist has been expanded for prescribed natural fire assignments.

The following words have been added to the glossary: abundance, adult, AFFIRMS, anemometer, aspect, barrier, canopy, char height, confine, contain, control, creeping fire, crown fire, crown scorch, dry bulb, duff, emissions, escaped fire situation analysis (EFSA), fine fuels, FBOI, fire season, fire situation analysis (FSA), frequency, fuel model, hygrothermograph, litter, live fuel moisture, mature, perimeter, prescribed burn boss, relative cover, relative humidity, remote automatic weather station (RAWS), running, seedling, sling psychrometer, slope, smoldering, snag, spotting, suppression, surface winds, timelag, torching, wet-bulb temperature, wildfire.

References are now all compiled in the compiled reference section between the glossary and the index.
Index
An index has been added, to assist with handbook navigation.

Table of Contents
The table of contents has been expanded.

Page numbering
Page numbering is now sequential regardless of chapter number.

Charisse Sydoriak
Patti Haggarty
Paul Reeberg
Handbook Review Committee
June 19, 1992
1991 Changes to Standards and Protocols

Summarized here are the principle modifications to the 1990 release of the handbook (page numbers from the 1991 handbook are printed in italics).

CHANGES TO STANDARDS

Brush recruitment has been added as a MAS variable in forest and brush vegetation types. The variable is expressed by age class and species.

Burn severity is now rated separately for substrate and vegetation impacts. A burn severity coding matrix and new forms must be used to rate burn severity.

File maintenance standards have been added (located in Chapter 4 under General Methods).

PROTOCOL CLARIFICATIONS AND CHANGES

Protocols for monitoring level 1 (reconnaissance) and level 2 (fire conditions) have not changed. However, the smoke monitoring datasheet (FMH-3) has been improved. Protocols have changed slightly for level 3 (immediate postfire effects) and level 4 (long-term change) plot installation and data collection. Chapter 4 has been partially rewritten to reflect changes in protocols. These changes are summarized here in order of presentation within the text.

CHAPTER 4 - GENERAL METHODS

LOCATE INDEX PLOTS

Step 2: Field Locate Selected Index Plots (page 71 - - 4.10 )
Sample plots in the order they are randomly selected.

Step 4: Field Map the Index Plot for Relocation (page 72 - - 4.11 )
On maps, each plot should be labeled by plot number (the number is described in step 5).
Step 5: Complete Location Data Sheet (page 72 - 4.11)
Plot number should be assigned sequentially within each monitoring type, with the first plot sampled given the number 01, the next 02, etc.

Deviations from monitoring protocols may now be noted on the index plot location data sheet (FMH-5, items 11 and 12).

Plot visits may now be recorded in a computerized plot history file. This database is created initially from the index plot location data sheet (form FMH-5) and then added to following each site visit.

Guidelines to standardize filing of raw data and maps has been added to chapter 4 at the end of the general methods section.

Data entry and processing instructions will be published as a companion document to the handbook. The section on data entry has been removed from chapter 4.

CHAPTER 4 - SPECIFIC METHODS

LAY OUT INDEX PLOT

Instructions on how to lay out a forest index plot have been rewritten to be more explicit and to address several omissions.

Orient the Plot Quarters (page 91 - 4.29)
The protocol for numbering plot quarters has been simplified. The quarters are numbered relative to the centerline azimuth and 0 point and not in relation to slope position.

Mark the Plot (page 92 - 4.30)
An option has been added to abbreviate the information etched onto the plot identification tags.

Plot Specifications (page 95 - 4.33)
A guideline for sampling smaller or larger areas for pole-sized and seedling trees has been added.

Selection of sample area for a particular variable must be consistent between plots within a monitoring type.

Overstory Trees (page 98 - 4.36)
a guideline for tagging non-sprouting verses sprouting trees has been added.

The Overstory Tree Map (form FMH-9) and the Alternate Overstory Tree Map (FMH-10) have been retitled to the Full Plot Tree Map and the Quarter Overstory
The Full Plot Tree Map may now be used to map any class of tree (overstory, pole, or seedling). A space has been added to the form to identify the tree class mapped.

Broken top (BROK) has been added to the list of tree damage codes.

**Pole-sized Trees (page 102)**
Tagging and mapping guidelines have been added.

**Brush and Herbaceous Layer (pages 105 and 121)**

**MAS Procedures**
Proper placement of the rangepole (rigid plumb bob) along the transect has been clarified.

A new minimum acceptable standard (MAS) variable has been added to the brush density monitoring protocols (applicable to forest and brush plots). The monitor must identify and code the relative age of brush by species. This **new standard** should help parks assess brush recruitment. More detailed investigations of stand structure are recommended, but no guidelines or protocols are given.

**Deal with Sampling Problems (pages 107 and 123)**
A section has been added suggesting ways of dealing with dramatic changes in brush density that may be a temporary result of burning.

**Monitor Preburn Fuel Characteristics (page 110)**
Guidelines for measuring duff depth where tree trunks, stumps, or logs occur have been added.

**Monitor Fire Weather and Behavior Characteristics (page 113)**
Fire behavior observation circles (FBOCs) are set-up by the fire behavior and weather specialist-II (FBWS-II) assigned to a burn. Biological technicians are responsible for establishing the plots, but **not** for recording fire characteristics, although they can be reassigned during burns as FBWS-IIs. Since the FBWS-II works under the direction of a prescribed burn boss, establishment of FBOCs is ultimately the burn boss' responsibility.

**Monitor Postburn Conditions**

**Burn Severity (pages 117 and 130)**
Burn severity relative to the substrate and to the vegetation is now rated and recorded separately. A coding matrix has been added. Burn severity for forest plots is no longer recorded on the Overstory Tree Postfire Assessment Data Sheet (FMH-21), but is recorded on a new form called the Forest Plot Burn Severity Data Sheet (form FMH-22). An option to record burn severity for every sample
point (100 points) along the brush/grassland transect has been added to the Brush and Grassland Plot Burn Severity Data Sheet (form FMH-24).

**Char Height (page 118 - 4.54)**
Instructions for measuring individual tree char heights and calculating the mean char height have been added. A space to record char height (a recommended variable) has been added to the Overstory Tree Postfire Assessment Data Sheet (FMH-21).

**Data and Labeling Coding Guidelines (Appendix C)**
An alternative, abbreviated plot identification tag is described. Instructions for labeling slides has been added.

**Equipment Checklist for Index Plots (Appendix E)**
The checklist has been refined.

**TEXT CLARIFICATIONS AND CORRECTIONS**

**CHAPTER 1**

**Policy Considerations (page 8 - 1.8)**
Text for "prescribed natural fires" was rewritten to reflect changes in national policy.

**CHAPTER 3**

**Monitoring Type Variables (page 49 - 3.8)**
Text was added on choosing a plot technique (sampling method) for overlapping monitoring types or ecotones.

**Dealing with Burning Problems (page 58 - 3.12)**
Text was added on what to do about partially burned plots and plots burned when the prescribed burn unit treatment is incomplete.

**CHAPTER 4**

**Specific Methods (page 90 - 4.27)**
Figure 2 on page 90 has been improved. The length of the hypotenuse of the triangle in Figure 2B has been corrected.

A new form (FMH-22) has been developed to record forest plot burn severity. The old forms FMH-22, 23, 24, and 25 have been renumbered to FMH-23, 24, 25, and 26, respectively.
Acknowledgments

Many have worked towards the development of this handbook. While it is impossible to acknowledge all contributors, it is appropriate to recognize individuals who were critical to this effort.

Prescribed and Natural Fire Monitoring Task Force, 1989

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Summary

Fire management decisions for the National Parks require information on fire behavior and on the effects of fire on park resources. This fire monitoring program allows the National Park Service to document basic information, to detect trends, and to ensure that fire and resource management objectives are met. From identified trends, park staff can articulate concerns, develop hypotheses, and initiate specific research projects to develop solutions to problems.

National Park Service fire management guidelines require that parks with prescribed fire programs monitor fires, but do not specify how this is to be done. This Western Region Fire Monitoring Handbook is intended to insure compliance with these guidelines by facilitating and standardizing monitoring for the Region. Information gained will help to guide management decisions, and serve scientific and educational purposes as well.

Park superintendents are responsible for implementation of the fire monitoring system prescribed in the Handbook. Fire management officers, natural resource managers, and fire behavior weather specialists will use the Handbook. Research scientists will assist in the monitoring process by acting as consultants.

The Handbook is organized around fire management strategies which are outcomes of fire management goals. Each management strategy requires a minimum amount of monitoring, or Minimum Acceptable Standard level. Levels of monitoring activity are established and defined. At each successive level, monitoring is more extensive and complex. Level 1 covers reporting of all fires, and levels 2, 3, and 4 call for monitoring of fire conditions, short-term effects, and long-term change, respectively. Monitoring levels are applied cumulatively; at level 4, for example, all procedures of levels 1 through 3 are carried out, as well as those specific to level 4. Monitoring at all four levels is required for prescribed burns.

All fire management programs require monitoring at level 1, Reconnaissance. Variables monitored include fire cause, location and size, vegetation type, fire behavior and weather, smoke conditions, and resource or safety constraints. The monitoring schedule is limited to the fire period itself. Data is recorded on the Individual Fire Report and sometimes on the Fire Situation Analysis.

Level 2, Fire Conditions, is required for prescribed natural fires and prescribed burns. It adds to the variables monitored an array of specifics descriptive of such
conditions as topography and weather, fire characteristics, and smoke characteristics. Monitoring frequency depends on fuel type and phase of fire spread. Data is recorded on the Fire Situation Analysis and on forms included in the Handbook.

Level 3, Immediate Postfire Effects, and Level 4, Long-term Change, are required for all prescribed burns. Monitoring at level 3 provides information on fuel reduction and vegetative change in a specific vegetation and fuel complex (monitoring type), and on other variables dependent on management objectives. Vegetation and fuels monitoring is accomplished primarily through sampling of index plots in representative areas, and covers such items as percent non-native species, density, fuel load, and relative cover by species. Monitoring is carried out at varying frequencies preburn, during the burn, and postburn. Data is collected within one to five years after the burn.

Level 4, Long-term Change, is also required for prescribed burns, and may call for monitoring of the same variables as in level 3, over a longer period. It is also concerned, however, with identification of significant trends over time that can serve as guides to management decisions. Some trends may not be statistically valid, but are nevertheless useful. Variables serving to reveal trends, or primary indicators, may be monitoring type, or objective-dependent, or may be non-standard. Monitoring frequency is based on an initial sequence of 1, 2, 5, and 10 years after the burn; then plots are monitored every 10 years.

The Handbook provides detailed instructions for defining a monitoring type, for establishing index plots, and for monitoring variables that are Minimum Acceptable Standard. Index plots are designed to yield statistically valid results for detecting change in the environmental variables of interest. References describing methods for monitoring non-standard variables are provided. Variables dependent on prescribed burn objectives, as well as some primary indicators of long-term change, may require specific monitoring designs not covered in this Handbook. Aids such as random-number tables and data coding instructions are also provided. Data is recorded on forms included in the Handbook.

Minimum Acceptable Standards (MAS) for fire monitoring within the Western Region of the National Park Service, as established in this Handbook, will not answer all questions about the effects of park fire management programs on ecosystems. Many parks will still require research programs to study specific problems and to describe fire regimes. Parks are encouraged to expand long-term monitoring to include any additional physical or biotic ecosystems elements important to management but not covered by the MAS.
1 Essentials of the Program

Fire monitoring and evaluation are critical management activities to enhance and protect our park resources. Without these activities, a fire manager has no way of assessing the impact of fire, or its suppression.

If fire monitoring is so essential, why aren't we, as fire managers, all doing it? The fact is that monitoring requires a commitment of time and money. It is rarely straightforward. It does not always accomplish what is needed, because there may be procedural or system design flaws.

To complicate matters, the public (with good reason) is holding us increasingly accountable for everything we do, especially in the area of fire management. Federal and state agencies are instituting progressively more stringent guidelines for burning, monitoring, and evaluation. The impetus behind this effort, and the purpose of this Handbook, is to provide guidance that can prevent fire management problems from developing, limit possible legal actions against the agency, and insure that objectives are being met.

THE RATIONALE FOR FIRE MONITORING

When the National Park Service (NPS) was created by the 1916 Organic Act (16 USC 1), conventional thought was that fire was bad. The NPS, therefore, attempted to suppress all fires. In 1963, the Leopold Committee was convened by Congress to study the state of the parks' wildlife, and reported that fire was a process critical to the health of many ecosystems. By 1968, NPS policies officially recognized fire's role in many of its park ecosystems and an active program of fire management was born. Parks began igniting fires to accomplish specific goals, and even allowed fires ignited by natural means (commonly lightning) to burn.

Initially, fire managers concentrated solely on keeping the fires within controllable limits and made no attempt to document the effects of the fires on park resources. In 1978, however, responding to enactment of the National Environmental Policy Act (see below, Fire Monitoring Policy), some parks such as Yosemite, Sequoia, and Kings Canyon, began extensive monitoring programs. In Yosemite, fire effects monitoring plots were installed in nearly every burn block. After a decade of installing plots, the park had more than 350 plots to revisit each year and more were being installed as burn units were added to the program. The situation was
becoming unmanageable. To make matters worse, monitoring techniques differed significantly between parks in the Region, and many parks were not monitoring at all. The need to reduce the monitoring burden in some parks, to bring other parks up to some minimal acceptable standards, and to develop standardized procedures for collecting data was obvious.

Action was ultimately taken following questions about the justification for NFS burns conducted in giant sequoia (Sequoiadendron giganteum) forests of Yosemite, Sequoia, and Kings Canyon National Parks. An outside review panel (Christensen et al. 1987) was convened to evaluate these parks’ prescribed burn programs; a strong recommendation was made to develop a monitoring program which would heighten the NPS awareness of past burn results.

This Handbook is a direct response to the growing recognition, by fire managers in general, that a feedback mechanism is needed to provide park managers with information that will enable them to affirm that park objectives are being met and to identify and correct deficiencies. The objectives of the program described here are to

- Document basic information for all fires, regardless of management strategy
- Predict fire behavior and take appropriate action on all fires that (1) have the potential to threaten resource values or (2) are being managed under specific constraints, such as a prescribed burn
- Document immediate postfire effects of prescribed burns
- Follow trends in plant communities where literature exists or research has already been done to establish fire effects in the community
- Identify problem areas where research needs to be initiated
- Facilitate the sharing of fire-related information by standardizing data collection and analysis techniques

There are many benefits that can be expected as these objectives are met. One of these will be that when the monitoring database is complete, fewer prescribed burn units will require monitoring plots, and costs will be lowered.

FIRE MONITORING POLICY

National Park Service fire management policies are outlined in the Management Policies (1988) and are expanded in the Wildland Fire Management Guideline, NPS-18 (1990). The rationale, purpose and justification of individual park fire management programs are documented in their Natural Resource Management and
Fire Management Plans. NPS-18 directs parks with prescribed fire programs to monitor those fires to ensure that fire behavior is assessed and resource management objectives are met. It does not say how the monitoring is to be done. This Handbook provides that guidance.

The monitoring procedures set forth here are intended to complement, not supersede, established policy pertaining to the use of the NPS Fire Situation Analysis (FSA) (see Appendix G) and the Prescribed Burn Unit Plan in NPS-18 (1990).

Fire monitoring directives to support implementation of this Handbook are as follows:

Provisions of NEPA

The National Environmental Policy Act (42 USC 4321-4347), NEPA (enacted in 1969), as amended, mandates that monitoring and evaluation be conducted to mitigate human actions that alter landscapes or environments. The Code of Federal Regulations (CFR) provides the following legal directives:

40 CFR Sec. 1505.03
"Agencies may provide for monitoring to assure that their decisions are carried out and should do so in important cases."

40 CFR Sec. 1505.2(cl)
"A monitoring and enforcement program shall be adopted and summarized when applicable for any mitigation."

NPS-18 Guidelines

NPS-18, Wildland Fire Management Guideline (1990) directs that all prescribed burns and prescribed natural fires be monitored. These guidelines are contained within section III, Chapter 5.

Monitoring goals (summarized here from NPS-18) are to

- **Determine** burning conditions, perimeter expansion, and smoke impacts throughout the duration of a prescribed natural fire
- **Verify** that fire weather and fire behavior were within prescription
- **Quantitatively document** fire effects and compare with stated burn objectives
- **Insure** that fire and park management objectives are being met
Directives for the NPS, Western Region

Fire monitoring directives for the NPS, Western Region, as defined in this Handbook, are designed to insure conformance with NPS-18 and to take full advantage of the monitoring and evaluation process. The objectives are to

- Insure that all park units meet minimum standards for fire behavior and effects monitoring
- Standardize data collection and analysis techniques, to facilitate the sharing of fire behavior and effects information with other fire managers
- Provide adequate information on fire behavior and effects to validate or refine management objectives and to guide decisions on alternative management strategies
- Document effects of fire management policies for scientific, economic, legal and ethical purposes, and to develop interpretive and educational materials

MINIMUM ACCEPTABLE STANDARDS

Minimum Acceptable Standards (MAS) for fire monitoring within the Western Region of the National Park Service, as established in this Handbook, will not answer all questions about the effects of park fire management programs on ecosystems. Many parks will still require research programs to study specific problems and to describe fire regimes. Parks are encouraged to expand long-term monitoring to include any additional physical or biotic ecosystems elements important to management but not covered by the MAS.

Elimination of elements categorized as minimum without Western Regional Office approval is unacceptable. For example, park managers cannot throw out the vegetation transects in a forest plot because they do not want to spend the time doing it or prefer another method. They may, however, add another vegetation sampling method, which will of course increase costs.

The significance of the data collected will ultimately depend on how closely the Handbook is adhered to during the entire monitoring process. Standardization of these procedures should help managers make long-term program adjustments. Many of these adjustments will be based upon examination of trends. These trends, and the variation caused by processes other than fire (such as climate and
pathogens), may be difficult to validate statistically. It is reasonable to expect, however, that the baseline data collected, though gross, will justify investigating a trend through detailed research, or making minor adjustments to insure that the fire management program will accomplish desired objectives.

SOME WARNINGS TO NOTE

Implementation of this Handbook relies heavily upon knowledgeable fire and resource management staff. Evaluation of information obtained requires the combined efforts of field technicians, fire and resource management staff, and park or regional scientists.

This monitoring program is to be applied only in parks where fire effects are highly predictable and management is comfortable with expected results. If these criteria are not met, Western Region fire ecologists should conduct research to validate the role of fire in the park and develop prescriptions capable of meeting park management objectives. The park must delay implementation of its prescribed fire management program until these issues are resolved. It is possible that the monitoring methodology presented in this Handbook, with minor modifications, may be wholly or partially transferable to a research design.

Sampling design and intensity as described in this Handbook are not intended to test hypotheses. The Handbook does not define the degree of acceptable change before a research project is initiated. Management judgement based on local knowledge of fire ecology must be used to make this transition.

This fire monitoring program may detect changes not solely attributable to fire. Appropriate studies, beyond the scope of this Handbook, may be necessary to support an understanding of cause-and-effect relationships. Each park area must evaluate its own need for such additional information.

Establishment of control plots is optional. However, control plots must be installed when it is critical to isolate the effects of fire from other environmental or human influences, or to meet the specific requirements of a prescribed burn plan. Control plot sampling design will necessarily be specific to site and problem, and will require the assistance and approval of regional and park ecologists.
USE OF THE HANDBOOK

The Handbook presents detailed instructions that cover a variety of situations. To make these instructions accessible, they have been organized around the management strategies frequently used to accomplish specific goals. Monitoring levels have been defined, and on a cumulative basis, one or more have been identified as providing a minimum standard of conformity to the NPS-18 guidelines.

At each level, the monitoring process calls for gathering data, processing it, and documenting and evaluating results. Instructions for each level are primarily addressed to data gathering, but where necessary, comments on processing, documentation, and evaluation are included.

The Handbook examines the monitoring levels first in broad outlines, and then in specific detail. It is important for all users to review the material as a whole, but it is expected that a particular situation will call for use of only a limited number of procedures.

In the two chapters that follow this overview of program essentials, detailed information is provided on the MAS variables and the procedures and monitoring schedule associated with each level. Procedures related to index plots for monitoring prescribed burns (at levels 3 and 4) are treated in a fourth chapter which covers both Forest/Woodland and Grassland/Brush vegetation types. Reference materials, aids to data collection, and data record forms are provided in the appendix.

This Handbook should be placed in a binder to make it easy to use and update; chapters and appendices are removable, and instructions for the applicable monitoring level required for a fire can be detached from the Handbook and carried into the field for reference.

Most publications referenced in this Handbook are available for check out from the WRO-RNR library located at the National Park Service - Western Regional Office, San Francisco, California. References should be requested through the Regional Prescribed Fire Specialist and may be kept in the park for no more than 5 weeks. When requesting documents special reference should be made to this Fire Monitoring Handbook. If this library is not abused, critical reference materials will be made available to all participating parks at no cost to the parks.
FIRE MANAGEMENT GOALS AND STRATEGIES

Goals

This Handbook is organized around fire management strategies which are outcomes of fire management goals. Each management strategy requires a minimum amount of monitoring, or MAS monitoring level.

Although fire management goals vary from park to park and fire to fire, each park will have one or several of the following fire management goals

♦ To prevent or eliminate the negative consequences of wildfires
♦ To maintain natural conditions in native ecosystems
♦ To cause fuels and vegetation to change in order to reduce fire hazard or to achieve goals related to restoration of a natural ecosystem or historic scene
♦ To expand knowledge of fire ecology

Strategies and Monitoring Levels

The goal of minimizing the negative consequences of wildfires usually leads to fire suppression (although reclassifying the wildfire as a prescribed natural fire is an option). A fire suppression operation has well-established and standardized monitoring needs based on the goal of preventing or eliminating the negative consequences of wildfires. For most wildfires, monitoring means recording data on fire cause and origin, discovery, size, cost, and location. This is Reconnaissance, level 1 monitoring.

Programs whose goal is to maintain natural conditions in native ecosystems generally call for simple management strategies and have simple monitoring needs. Often only prescribed natural fire with a simple prescription is used. For example, the prescription may provide that fires must be confined within a designated zone and can burn in a relatively large window of weather and fuel moisture conditions. The MAS for such programs will be satisfied by a simplified version of the Fire Situation Analysis, part I (Appendix G) in which general fire characteristics such as cause, location, size, fuel type, general fire behavior and weather conditions, and threats or program constraints are recorded. This is Fire Conditions, level 2 monitoring.

Under certain conditions, simulated natural fire (a class of prescribed burn) may be included in the strategy for maintaining natural conditions. Then all levels of monitoring will be required, as explained below.
Table 1. Fire management strategies and Minimum Acceptable Standard (MAS) monitoring levels

<table>
<thead>
<tr>
<th>Management Strategy</th>
<th>MAS Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppression fire: unplanned or natural fire that must be suppressed</td>
<td>1. Reconnaissance</td>
</tr>
<tr>
<td>Prescribed natural fire (PNF): natural fire burning within prescription</td>
<td>1. Reconnaissance, 2. Fire conditions</td>
</tr>
<tr>
<td>Simulated natural fire: fire set within a prescription window to simulate a lost natural ignition. (One class of prescribed burn.)</td>
<td>1. Reconnaissance, 2. Fire conditions, 3. Immediate postfire effects, 4. Long-term change</td>
</tr>
<tr>
<td>Prescribed burn: fire set to reduce fuel, modify vegetative structure, or for any management purpose. (Burn is constrained by a prescription window.)</td>
<td>1. Reconnaissance, 2. Fire conditions, 3. Immediate postfire effects, 4. Long-term change</td>
</tr>
</tbody>
</table>

Prescribed burning to restore natural ecosystems or restore historic scenes by changing fuels and vegetation requires a much more complex monitoring system. The MAS here includes a hierarchy of monitoring levels from simple reconnaissance to the complex monitoring of prescriptions, immediate postfire effects, and ultimately the long-term and often subtle changes in vegetation community structure and succession. The effectiveness of prescribed burning for natural ecosystem restoration may take decades to assess.

The goal of expanding knowledge of fire ecology is expressed in the strategy of the research burn, a fire set within defined limits to test hypotheses. This is another class of prescribed burns. Its requirements are established in specific research designs which are part of management planning. Monitoring requirements for research burns must be individually developed, and are not covered in this Handbook.

Table 1 outlines monitoring levels required for fire management strategies. These levels are minimums; parks are encouraged to add levels to their monitoring program if warranted.

Policy Considerations

The goal of minimizing the negative effects of wildfire has important policy implications. Management strategies and monitoring levels are not clear cut. Although wildfires and prescribed natural fires are understood to be exempt from monitoring of immediate postfire effects (level 3) and long-term change (level 4), higher levels of monitoring are sometimes required.
Suppression Fires

Monitoring the effect of wildfires on vegetation or other area-specific variables of special concern may produce valuable information on ecosystem fire ecology, identify significant threats to park resources, or permit adjustments of prescriptions. This may be especially important in parks managed under a program of total fire suppression.

More information about the effects of wildfire may be needed to develop appropriate fire management strategies or to plan research. For example, wildfire may result in the establishment of unacceptable frequencies of non-native vegetation, or the loss of naturally recurring fire may cause a fire-dependent plant and animal community to disappear. In an area where prescribed burning is not provided for, monitoring data from wildfires may be the only source of information about how fire affects vegetation, fuels, and other resources.

Often, change in vegetation and fuels resulting from wildfire must be assessed. However, it is unlikely that plots can be established and read in a timely manner prior to a wildfire, even in fire-prone areas. A more practical design is to establish monitoring plots after a wildfire. An additional advantage to this design is that firelines often bisect a particular habitat, a factor prerequisite to establishing control plots. Thus, monitoring plots can be established near the edge of a burn and control plots just outside the burn.

Prescribed Natural Fires

Fire conditions monitoring is required for prescribed natural fires only if there is a "resource value at risk" (see Glossary).

Since free-burning natural fires should be allowed only in areas in which fuels and vegetation have not been significantly altered by human activities, there is less need to quantify fire behavior and effects in these areas. Although managerial information needs are easily satisfied in this situation, information on natural fire regime characteristics may be inadequate for the park's prescribed burn program. If this is true, further investigations of the natural fire behavior and effects relationship are encouraged, but not mandated.

Recent directives in the NPS-18 Wildland Fire Management Guideline (NPS-18 1990), have expanded the set of conditions that mandate suppression of naturally ignited fires within Prescribed Natural Fire Management Zones. Under the new guideline, prescribed natural fires (PNF) must not violate prescription elements of time, place, weather, fire behavior, funding, staffing, and resource availability. In addition, the prescription must include at least one indicator of drought. Once a PNF starts, its maximum allowable extent should be defined and approved in the Fire Situation Analysis Part II (Appendix G, pages 5 to 9). Approved PNFs may be further constrained by legal limitations (air quality regulations, contingency
plans, etc.). For example, a National Preparedness Level of IV mandates the suppression of all new PNFs, "except those of no significant risk".

It is important to track the influences of this new policy. Because of the additional program constraints, parks can expect fewer PNFs and new effects in their Prescribed Natural Fire Management Zones. Parks should seriously consider establishing primary indicators of long-term change (level 4) monitoring plots in areas where their PNFs are routinely altered. Where naturally-occurring fires are suppressed on a regular basis (full suppression policy), it is also recommended that the primary indicators of long-term change be monitored.

PROGRAM RESPONSIBILITIES OF NPS PERSONNEL

This Handbook will be used jointly by fire management officers, natural resource managers, fire behavior/weather specialists, and biological technicians in direct support of ongoing fire programs. The National Park Service science community will assist park managers using the Handbook to monitor and evaluate ecosystem change.

The level of knowledge required of individuals conducting this monitoring program is substantial. Knowledge and skills needed by the field monitors are specifically defined, and detailed training, experience, and performance requirements are described in the appropriate NPS job task books. The fire management officers and natural resource managers must possess a knowledge of ecological principles and basic statistics. They must also be skilled in the application of fire management strategies.

Fire Behavior/Weather Specialists (FBWS-II) under the guidance of the Fire Management Officer (FMO), Resource Management Specialist (RMS) and/or Prescribed Burn Boss (PBB) are responsible for monitoring reconnaissance (level 1) and fire conditions (level 2) status. Portions of these monitoring duties (such as weather monitoring) can be delegated to persons who have been trained and certified by a qualified FBWS-I or -II.

The Fire Behavior/Weather Specialists (FBWS-I) are responsible for all types of fire monitoring, including identification of monitoring types and rejection criteria, index plot installation, and data interpretation. Detailed training, experience, and performance requirements are described in the appropriate NPS Fire Behavior/Weather Specialist job task book (NPS, BIA 1990).

Biological technicians (plants) are responsible for collecting and processing plot data. These individuals must be skilled botanists.
Resource management specialists are responsible for the within-park program coordination and evaluation. They help coordinate prescribed burning, fire suppression, and monitoring activities with fire management staff and all other park staff. They are chiefly responsible for quality control and quality assurance of the monitoring program as it relates to park fire management and other ongoing resource management activities. They must assure that results and information are transferred in a timely fashion to park staff and regional personnel and that those results are reflected in refinements of the Fire Management Plan.

The FMO is responsible for seeing that management fires do not violate basic prescription objectives, the Fire Management Plan, or NPS-18. Evaluation of immediate postfire effects (level 3) and long-term change (level 4) are the responsibility of the FBWS, FMO, and RMS. Formal evaluation of these monitoring levels must occur on a annual basis.

At any time during implementation of the monitoring program, park or regional (CPSU, WRO) science staff, statisticians familiar with the Handbook, or other resources management specialists can act as consultants. Consultants may be particularly valuable in stratifying monitoring types, selecting index plot locations, determining the appropriate numbers of sample plots, evaluating preliminary and long-term results, and preparing reports. Park and regional scientists should assure that research needs identified by monitoring efforts are evaluated, prioritized, designed, and incorporated into the park's Resource Management Plan. They should assist, when needed, in the sampling procedures designed to determine whether short-term objectives are met, and in the analysis of immediate postfire effects and long-term change monitoring data. They should work with resource management staff to fully evaluate important ecological results and facilitate publication of pertinent information. These efforts should validate the monitoring program. Research scientists should also serve on advisory committees to smaller park units undertaking the monitoring effort and on program review boards.

Superintendents will facilitate the coordination of fire management, resource management, and associated research within their parks. They may also play an active role on program review boards established to assess if monitoring objectives are being met, and that information gained by the monitoring effort is addressing key park issues.

The Western Regional Office will insure that time, money, and staff are available to meet program objectives. They will assign a Regional Prescribed Fire Specialist to insure (1) consistency in Handbook application; (2) regional quality control and quality assurance of the program; (3) timely data processing and report writing; and (4) coordination of periodic program review by NPS and other scientists and resource managers.
The roles and responsibilities of the above individuals will be detailed as performance standards elements.

FIRE MONITORING LEVELS

As stated earlier, the Handbook is organized around the monitoring levels that will provide a minimum acceptable standard (MAS) of conformance with NPS-18 guidelines. The four monitoring levels in ascending order of complexity are reconnaissance, fire conditions, immediate postfire effects, and long-term change. These four levels are cumulative; that is, implementing a higher level will usually require that lower levels of complexity also be implemented. For example, monitoring of immediate postfire effects and long-term change is of little value unless information is available on the type of fire behavior that produced the observed results.

Level 1: Reconnaissance

Reconnaissance monitoring, which provides a basic overview of the fire event, is essential to all types of fire.

The following information will be collected to satisfy reconnaissance MAS:

1. Fire cause, location, and size
2. Fuel and vegetation type
3. Relative fire activity
4. Potential for further spread
5. Current and forecasted weather
6. Resource or safety threats and constraints
7. Smoke volume and movement

Level 2: Fire Conditions

Fire conditions will be documented for all fires that, based on a reconnaissance, have the potential to threaten resource values at risk, or that are being managed under specific constraints, such as a prescribed burn. Routine monitoring of fire conditions calls for data on ambient conditions and fire and smoke characteristics. This data is coupled with information gathered during reconnaissance monitoring to predict fire behavior and to identify potential problems.
The following information will be monitored to satisfy fire conditions MAS:

Fire Monitoring Period
1. Fire number and name
2. Observation date and time
3. Monitors' names

Ambient Conditions
Topographic Variables:
1. Percent slope
2. Aspect of terrain

Fire Weather Variables:
3. Air temperature
4. Relative humidity
5. Wind speed
6. Wind direction
7. Percent shading
8. 10-; 1-, 100-h, 1000-h time-lag fuel moisture
9. Live fuel moisture
10. Drought index by fuel model

Fuel Model
1. 13 Fire Behavior Prediction System fuel models or customized model

Fire Characteristics
1. Linear rate of spread
2. Perimeter and area growth
3. Flame length
4. Fire spread direction

---

1Live fuel moisture depends on required inputs for fire behavior prediction in primary fuel models affected.

2Ex.: Energy Release Component (ERC), Burning Index (BI), 1000-hour TLFM.

Chapter 1: Essentials of the Program 13
Smoke Characteristics

1. Visibility
2. Particulates\(^1\)
3. Carbon monoxide
4. Total smoke production\(^1\)
5. Mixing heights
6. Transport and surface wind speeds and direction
7. Documented complaints from downwind areas

Level 2: Fire Conditions (Recommended Variables)

1. Duff moisture
2. Flame zone depth

Level 3: Immediate Postfire Effects

Immediate postfire effects monitoring requires collecting information on fuel reduction, vegetative change, or other objective-dependent variables within 1 to 5 years after a fire. Level 3 monitoring permits a quantitative evaluation of whether a stated objective was achieved, such as to reduce dead and downed fuels by 60 percent; to disrupt the understory tree ladder; or to remove 95 percent of the invading young trees from a specified meadow.

At level 3, conditions before, during, and after a burn are monitored primarily through sampling on relatively small portions of the burn area. These index plots are usually set up well ahead of a prescribed burn and are monitored for varying periods of time after it. In monitoring these plots, fire ecologists and other specialists must be consulted.

Variables at this level fall into two groups: monitoring type and objective-dependent. The first group focuses on the components of a monitoring type—an association of fuels and vegetation. They serve to represent (by frequency and cover) plant species present in a plant community, and may include the dead and downed fuel array; they describe the basic structure and composition of the vegetation and fuels burned under a particular prescription. Objective-dependent variables are directly linked to specific burn objectives and are identified in fire management plans or prescribed burn unit plans. They may be the same as the monitoring type variables.

\(^1\)Required only when standards have been established in the park’s fire management plan or other pertinent management plans, or as a stipulation in a burn permit from a state or county air pollution control district.
The MAS monitoring type variables for forest and woodland types are as follows:

Tree Layer
1. Density by species
2. Diameter by species

Dead and Downed Fuel Loads
3. Fuel load by size class
4. Total fuel load
5. Duff depth
6. Litter depth

Brush and Herbaceous Layer
7. Number of transect hits by species
8. Relative cover by species
9. Number and percent of non-native species
10. Number and percent of native species
11. Brush density by species
12. Brush age by species

Postburn Conditions
13. Average scorch height
14. Percent of crown scorched
15. Burn severity (substrate and vegetation)

The recommended and optional monitoring type variables are as follows:

Overstory Trees
1. Crown position
2. Tree damage
3. Average char height
4. Mortality

Pole-size and Seedling Trees
5. Height

Brush And Herbaceous Layer
6. Brush and herbaceous layer height
7. Herbaceous layer species density (optional)
8. Crown intercept (optional)
9. Fuel load (optional)
Dead and Downed Fuel Loads
10. Tons/acre duff
11. Tons/acre litter
12. Aerial fuel load (optional)
13. Fuel continuity (optional)

Grasslands and Brush

The MAS monitoring type variables for grasslands and brush types are as follows:

1. Number of transect hits by species
2. Relative cover by species
3. Number of non-native species
4. Number of native species
5. Burn severity (substrate and vegetation)
6. Brush density by species (Brush types only)
7. Brush age by species (Brush types only)

The recommended and optional monitoring type variables are as follows:

1. Vegetation height
2. Herbaceous layer density (optional)
3. Crown intercept (optional)
4. Fuel load (optional)

Level 4: Long-term Change

Long-term change monitoring requires collecting information on trends, that is, change over time, in a managed ecosystem. Once a trend is detected, a research program and appropriate management response can be implemented. An example of where this type of monitoring would have helped is in the effects of the National Park Service's total fire suppression policy until 1968. Unknown and undesired effects were not formally recognized for about 90 years and only after considerable and often irreversible damage had been done. If a systematic process of monitoring and evaluation had been present during this time, the full suppression period may have been short-lived. Current fire management strategies also have potential to cause undesired change. For this reason, long-term change monitoring should be strongly considered for all types of fire management strategies, including fire suppression.

The existence of a trend is revealed by continued monitoring of the level 3 monitoring type variables and by monitoring of certain variables, called the primary indicators of long-term change. The indicators serve as flag-waver or
watch-out variables that should make the park manager aware of potential misapplication of fire. This monitoring system does not specify the most appropriate indicators of long-term change, but indicators will be selected by the park. To accomplish this, park management will have to examine (1) fire management goals and objectives, (2) their biota's sensitivity to fire induced change, and (3) special management concerns. These indicators may be drawn from the monitoring type variables just described under "Level 3: Immediate Postfire Effects".

Cautionary Note

Monitoring data produces only a snapshot in time. The manager must realize that any data collected in a dynamic system must be static. Carefully designed research studies, for very specific concerns, may reduce the potential for anomalous data, but are also subject to inaccuracies.

Selection of index variables that can characterize population dynamics or ecosystem "health" is difficult. Even with careful planning, pilot studies, and past research studies, there is a danger that the chosen index variables may prove inadequate. The MAS immediate postfire effects (level 3) and long-term change (level 4) monitoring variables outlined in this Handbook are the current best estimate; they may be altered (with Western Regional Office approval) through experience and information gained from implementing this monitoring system.

The total number of MAS level 3 and 4 monitoring variables will vary according to the monitoring types present, the burn unit objectives, and the primary indicators of long-term change.

Ultimately, fire management program success rests on the primary indicators of long-term change. Changes usually occur gradually and may not be apparent for years.

DATA AND PROGRAM EVALUATION

The success of this fire monitoring program is strongly dependent on the fulfillment of clearly defined responsibilities at all stages, particularly during data analysis and program evaluation. The specific roles played by management staff have been reviewed earlier under "Program Responsibilities". Here the nature of these responsibilities as it pertains to data manipulation and interpretation is discussed in more detail.
The procedures called for include gathering and processing data, and evaluating its significance. Throughout both these stages of monitoring, documentation is vital. Finally, the program as a whole must be evaluated.

Gathering and Processing Data

Reconnaissance (level 1) data processing requires that the appropriate forms be accurately filled out and the information transferred to appropriate personnel for action and final reporting. No statistics are required.

Data entry, editing and storage are major components of immediate postfire effects and long-term change monitoring (levels 3 and 4). Approximately 10 to 25 percent of the field monitor's time will be needed for levels 3 and 4 data processing.

Data processing software has been developed for analyzing prefire, immediate postfire effects, and long-term change data. The software and a manual (called the Western Region Fire Monitoring Handbook Software Manual) is available from the publisher of this Handbook.

Evaluating Results

Evaluation is the process by which monitoring becomes more than an exercise in data collection. It requires the coordinated efforts of fire management, resource management, and research staffs. At reconnaissance and fire conditions monitoring levels, the data is needed to guide decisions on ongoing fires and to document the fire and its conditions. At the immediate postfire effects and long-term change levels, careful and prompt evaluation will provide much of the information necessary to detect fire management program problems. Evaluation of data at these levels, however, is much more complex and time-consuming than at levels 1 and 2.

Evaluating long-term change is even more complex than evaluating immediate postfire effects. Yet, this is the true basis for measuring attainment of goals and success of a fire management program. Although the index plots are designed to quantify the extent of change from prefire conditions, the complex interaction of ecological processes (fire, plant mortality and establishment, herbivory, competition, climate change, etc.) makes long-term change difficult to interpret. Therefore, the data analysis, interpretation, and response associated with long-term trends requires special attention.
Analyzing and Interpreting Trend Data

The evaluation process begins with the computation and summarization of information from the MAS variables in search of trends. This Handbook cannot define the generic dimensions of a trend. Management judgment, based on broad review and in-depth knowledge of local fire ecology, are essential for identifying significant trends. Trends may be easy to recognize (influx of non-native plants, high mortality of one species) or complex and subtle (change in stand structure, altering wildlife habitat, or categorizing insect or disease infestations).

Generally, significant trends are unidirectional, though they may appear as a pulse following fires separated by several years; they may be ecological occurrences or species "behavior" unreported in the literature; or they may be unparalleled in forests experiencing a natural (unaffected) fire regime. It is essential that the manager remain familiar with the character of the monitoring type throughout the burn units (and possibly its range) in order to maintain sufficient breadth of context for informal interpretation. Joint review of data by fire, research and resource personnel will help define and identify trends.

After the trend has been recognized, its significance must be determined. Park management must decide if the trend is unacceptable. They must ask themselves if the trend will affect untreated areas; will it threaten the integrity of the system; will it shift balances within the system? Most importantly, management must ask "What are the ecosystem and management trade-offs if the trend is ignored?" For example, is it acceptable to maintain seral chamise in a buffer zone, or to convert brush to grassland? Is it acceptable to lose a plant community type such as pinyon-juniper forest because the natural fire regime threatens human values? Fire-induced ecosystem alterations can have far-reaching implications.

Responding to an Identified Trend

Management response to a recognized trend must be based on informed projections and further evaluation of the trend. Scientific input, from the broadest spectrum possible, is strongly encouraged at this point. Once a trend is recognized, the following steps should be taken:

1. Determine the cause of the trend and the mechanism by which it is manifested. While the monitoring procedures and methods prescribed in this Handbook do not permit hypothesis testing, changes may be so overt that they should signal immediate alteration of management programs (Ex.: non-native thistle infestation of meadows). Proper action may include further research or modification of program protocols. Continued burning must be informed. On the other hand, trends may be quite subtle and require researching testable hypotheses to determine (1) if the trend is real, and (2) its correlation with the burning program. If the trend has potential to become significant, and the trade-offs are unacceptable, the burn program should be modified.
2. Identify appropriate burn program modifications: If significant and unacceptable trends are occurring, the burn program should be suspended until research provides mitigating management options.

Long-term change monitoring is essential for detecting undesired effects of management activities. In the end, a fire monitoring program's success will depend upon the fire manager's ability to select, monitor, and evaluate key indicators of change.

Documenting Results

Documentation, at a minimum, includes completing the required monitoring forms as specified in the procedures for the four levels of monitoring. It may also include reporting on a more in-depth investigation, analysis, and synthesis of information including the integration of results with other ongoing research and resource management programs in the park, and surrounding lands.

Evaluation documents will provide an important historical reference—a description of the relationships among prescriptions, firing techniques, fuel reduction and ecological change. The exact format of the documents (including output tables) resulting from immediate postfire effects monitoring will depend on the vegetation and fuel type, monitoring type-variables selected, the precision and accuracy selected for those variables, and specific burn objectives. Nevertheless, such documents must each contain full descriptions of pre- and postburn conditions (based on all monitoring type-variables), fire behavior, maps and photographs of the burn area and index plots, a narrative of methods that even slightly deviated from this Handbook, and an interpretation of results.

Evaluating the Program

The effectiveness of this fire monitoring program must be periodically reviewed at all levels (park, region, service-wide) and by various people (such as field technicians, park staff, regional staff and outside scientists). The program will be evaluated periodically by a regional committee containing, at least, one superintendent, two resource management specialists, two fire management officers, two scientists, and the regional fire management program coordinator. An independent review of the program (by interagency scientists and resource managers, and outside scientists and fire ecologists) may also occur as determined by NPS-BIFC or WRO.

The purpose of the above program evaluations is to evaluate progress to date; and to review and revise, if necessary, the goals and objectives of the program, the levels of accuracy and precision required, field methods and data processing.
procedures, and reports and publications. A written evaluation will be distributed to all interested persons.

REFERENCES


2 Monitoring Levels 1 and 2:
Reconnaissance and Fire Conditions

The first two monitoring levels, as indicated earlier in Table 1 (chapter 1, page 7), are usually sufficient to deal with fire management strategies calling for suppression of wildfires or prescribed natural fires. They also provide a base for monitoring prescribed burns at levels 3 and 4. It is the responsibility of those in authority (PFM, FMO, or PBB) to analyze and act upon the reconnaissance and fire conditions data. Fire conditions analysis outputs are recorded on page 4 of the FSA-part I (Appendix G) for prescribed natural fires. The FSA-part II (Appendix G) must be completed by the PFM, FMO, or PBB to select, or get approval to change, a strategy for every prescribed natural fire.

RECONNAISSANCE MONITORING

Reconnaissance monitoring data provides a basic overview of the fire event. Data on the following variables will be collected on all fires. On wildfires this may be the only data collected.

1. Fire cause (origin), location, and size
2. Fuels and vegetation type
3. Relative fire activity
4. Potential for further spread
5. Current and forecasted weather
6. Resource or safety threats and constraints
7. Smoke volume and movement

PROCEDURES AND TECHNIQUES

Data is collected from aerial or ground reconnaissance and recorded on the Individual Fire Report (DI-1202) (Appendix F). Sometimes the information may be initially recorded on the Fire Situation Analysis (FSA-part I (Appendix G)).
Fire Cause, Location, and Size

Determine ignition source, origin, and current fire size. Describe the type of material ignited, such as red fir snag. Fire size is documented through growth maps that include acreage estimates. Fire location reports must include a labeled and dated fire map.

Fuel and Vegetation Type

Describe the fuel array, composition, and dominant vegetation. If possible, determine primary fuel models: Fire Behavior Prediction System fuel models #1-13 (Anderson 1982) or custom models using BEHAVE (Burgan and Rothermel 1984).

Relative Fire Activity

Assess relative fire activity using adjective classes: smoldering, creeping, running, torching, or crowning.

Potential for Further Spread

Assess potential for further spread based on surrounding fuel types, forecasted weather, fuel moisture, and natural or artificial barriers. Record the directions of fastest rates of spread at present on a fire map; and predict for the next burn period.

Current and Forecasted Weather

Measure and document weather throughout the course of the fire. (Use of page 4 of the FSA-part I is optional but recommended.) Obtain forecasted weather reports and attach to reconnaissance record forms and maps.

Resource or Safety Threats and Constraints

Evaluate existing or potential resource or safety threats and constraints. Consider the potential for a fire to leave a designated management zone, annoy adjacent landowners, endanger human safety or property, or threaten cultural resources, or threatened or endangered species.
Smoke Volume and Movement

Assess smoke volume using at minimum these terms: light, moderate, or heavy. Calculate and record predicted concentrations in downwind areas.

MONITORING SCHEDULE

Reconnaissance monitoring must be done during all phases of the fire, but not all variables must be included in each phase. Minimum acceptable standards are given here.

Discovery or Initial Attack Phase

Monitor fire cause, location, and size; fuels; fire spread potential; weather; and smoke. Note particularly threats and constraints regarding safety, cultural resources, and threatened or endangered species, relative to the suppression effort (esp. fireline construction).

During-fire or Mop-up Phase

Monitor fire location and size, spread potential, weather, smoke, and threats or constraints.

Postfire Phase

Evaluate monitoring data and post reports. Assess, implement, and monitor rehabilitation activities.
FIRE CONDITIONS MONITORING

Fire conditions monitoring data provides information on fire weather, fire behavior, and resource values at risk. Data on the following variables will be collected for all prescribed natural fires and prescribed burns. Wildfire management may also require the collection of some or all of this information.

- Fire monitoring period
- Ambient conditions
- Fuel model
- Fire characteristics
- Smoke characteristics

PROCEDURES AND TECHNIQUES

Data is collected from aerial or ground reconnaissance and recorded on the Fire Situation Analysis-part I (Appendix G). These procedures also require the use of forms FMH-1, -2, and -3 (Appendix A). Ambient conditions inputs and fire behavior prediction outputs must follow standard formats for the Fire Behavior Prediction System (Albini 1976, Rothermel 1983).

Fire Monitoring Period

Provide this data (MAS):

1. Fire number and name
2. Observation date and time
3. Monitor’s name

Fire name and number should be automatically assigned by the Park Dispatcher or Fire Management Officer. Be very careful to record observation date and time for the data collection period; a common mistake is to record the date and time at which the monitor is filling out the final report. The monitor’s name is needed so that when the data is evaluated the manager has a source of information.

Ambient Conditions

Ambient conditions include Topographic Variables and Fire Weather Variables. Ambient weather observations may be made with (1) a Remote Automatic Weather Station (RAWS), (2) a standard prescription weather station with a recording hygrothermograph, or (3) an onsite belt weather kit. The RAWS or the standard
weather station, however, must be erected in a location that represents the existing and potential burn area. Fuel moisture may be measured with a drying oven (recommended), COMPUTRAC or moisture probe, or may be calculated using the Fire Behavior Prediction System or BEHAVE (Burgan and Rothermel 1984). Onsite fire weather observations are made as specified in the Fire-Weather Observers' Handbook (Fischer and Hardy 1976) and are recorded on the Onsite Weather Data Sheet (form FMH-1) and the Fire Behavior/Weather Data Sheet (form FMH-2) in Appendix A.

Collect data as follows (MAS):

Topographic Variables:
1. Slope (%)
2. Aspect

Fire Weather Variables:
3. Dry bulb temperature (°F)
4. Relative humidity (%)
5. Wind speed (mph)
6. Wind direction (8 cardinal points)
7. Shading and cloud cover (%)
8. Time-lag fuel moisture (10-; 1-, 100-, 1000-h) (%)
9. Live fuel moisture (%)
10. Drought index (varies by fuel model and park)

**Slope (%)**

Measure percent slope using a clinometer. A common mistake is to measure slope in degrees and then forget to convert to percent; a 45° angle is equal to a 100% slope—the relationship is roughly 1° = 2% slope.

**Aspect**

Determine aspect if required for fuel moisture calculations.

**Dry Bulb Temperature**

Read from a thermometer (belt weather kit) or hygrothermograph (standard prescription weather station) out of the influence of the fire, including smoke generated from the fire. Record in degrees Fahrenheit.

**Relative Humidity**

Use a sling psychrometer or hygrothermograph from a standard prescription weather station, out of the influence of the fire. Record in percent.
**Wind Speed**

Measure at midflame height as the fire burns across the preestablished rate of spread (ROS) interval. (See "Fire Characteristics, Linear Rate of Spread" below.) Fire weather monitoring requires, at a minimum, monitoring of 20-ft wind speed at standard fire weather stations.

**Wind Direction**

Determine the wind direction as the fire moves across the preestablished ROS interval. Record by cardinal point (that is N, NE, E, SE, S, SW, W, NW). Wind direction may be recorded by azimuth and relative to topography (ex.: 90° and across slope, 180° and upslope).

**Shading and Cloud Cover**

Determine the combined cloud and canopy cover as the fire moves across the preestablished ROS interval. Record in percent.

**Time-Lag Fuel Moisture (10-h)**

Weigh 10-h time-lag fuel moisture (TLFM) sticks at a standard prescription weather station or onsite within 1 hour of the time that the fire spreads across the ROS interval. If fuel sticks are unavailable, calculate the 10-h TLFM from the 1-h TLFM which is calculated from dry bulb temperature, relative humidity, and shading. Record in percent.

**1-, 100-, 1000-h**

Measure if required for fire behavior prediction in the primary fuel models affected.

**Live Fuel Moisture**

Measure woody or herbaceous fuel moisture if required for fire behavior prediction in the primary fuel models affected.

**Drought Index**

Calculate the drought index identified for the park. This variable will be established by the Boise Interagency Fire Center or park staff, and will usually be related to the fire danger rating (for example, the Energy Release Component (ERC) or the Burning Index (BI)).

**Duff Moisture (recommended)**

Monitor duff moisture when there is a management concern about burn severity and root or cambial mortality. Duff moisture affects the depth of the burn, the duration of heating and smoke production. Measure the duff moisture by drying and weighing the duff.
Fuel Model

Determine the primary fuel models that have burned and will burn if the fire continues to spread. Use the Fire Behavior Prediction System fuel models #1-13 (Anderson 1982) or create custom models using BEHAVE (Burgan and Rothermel 1984).

Fire Characteristics

Collect data on fire behavior as follows (MAS):

1. Linear rate of spread
2. Perimeter or area growth
3. Flame length
4. Fire spread direction

Linear Rate of Spread

Measure the rate of spread (ROS). ROS describes the relative activity of a fire extending its horizontal dimensions; that is, the time it takes the leading edge of the flaming front to travel a known distance, the ROS interval. ROS is expressed as chains/hour in this Handbook. ROS can also be expressed as the rate of increase of the fire perimeter or as a rate of increase in area (perimeter or area growth). Linear rate of spread is the distance between markers divided by the time required for the fire to spread from one marker to the next.

Perimeter or Area Growth

Measure or calculate the perimeter or area growth depending upon situational needs. Generally, growth is mapped or calculated once daily soon after the active fire period. A growth map with an accompanying acres-by-date legend is generally the best way to record this information.

Flame Length

Measure the flame length (FL). FL is the distance from the ground (not necessarily the base of the flame) to flame tip. Flame length is generally described as an average. Measure to the nearest inch if length is less than 2 ft, the nearest half foot if between 2 to 4 ft, the nearest foot if between 4 to 15 ft, and the nearest 5 ft if over 15 ft long.
Fire Spread Direction

Determine the fire spread direction (FSD). The FSD is the spread direction of that portion of the fire under observation or being projected; that is, the fire front is described as a head (H), backing (B), or flanking (F) fire.

Flame Zone Depth (recommended)

Monitor flame zone depth (FZD) when there is a management interest in the residence time of the flaming front. Measure the depth of the flaming zone with a rule or by ocular estimation as the fire spreads across the ROS interval.

Smoke Characteristics

Smoke management is a rapidly evolving and highly technical field. Much of the technology that will enable a fire manager to effectively model and predict plume rise, smoke dissipation and movement is currently being developed; this technology will eventually be transferred from the scientific community to field managers. This section of the text and the MAS specified will be revised periodically as managers better understand and implement state-of-the-art smoke monitoring techniques. In the interim, there are several smoke management parameters which can be monitored at levels 1 and 2. A detailed discussion and justification for the establishment of such parameters can be found in the RX-95 Training Manual (1987).

All Western Region prescribed burn plans (NPS-18 1990) should contain specific and measurable smoke management objectives. Monitoring should be tailored to document the extent to which the objectives are met. Burn plan objectives should reflect minimum standard smoke monitoring variables.

Record the following smoke and visibility monitoring variables on the "Smoke Monitoring Data Sheet" (form FMH-3) in Appendix A. These MAS smoke monitoring variables are accompanied by "recommended thresholds" for change in operations following periods of smoke exposure (Table 2). THESE THRESHOLDS ARE NOT ABSOLUTES AND ARE PROVIDED ONLY AS GUIDELINES.

1. Visibility
2. Particulates
3. Carbon monoxide (CO)
4. Total smoke production
5. Mixing heights
6. Transport and surface wind speeds and directions
7. Documented complaints from downwind areas
Visibility must be monitored either in general, that is, as the visual range in miles or kilometers, or specifically by a measured change in visual clarity of an identified target. Particulates and total smoke production must be measured, if required in a park's Fire Management Plan, other park management plans, or by the local air pollution control district to comply with federal, state, or county regulations. The current fine particulate diameter monitoring standard is "PM-10", this is, suspended atmospheric particulates less than 10 microns.
Table 2. Smoke monitoring variables (MAS) with techniques, frequencies, and recommended thresholds

<table>
<thead>
<tr>
<th>Variable</th>
<th>Location</th>
<th>Technique</th>
<th>Frequency</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of fireline</td>
<td>Fireline</td>
<td>Ocular estimate</td>
<td>½ h</td>
<td>Exposure of burn crew-members to areas of &lt;100 ft visibility not to exceed 2 h</td>
</tr>
<tr>
<td>Duration of fireline</td>
<td>Vicinity of fire</td>
<td>Ocular estimate</td>
<td>½ h</td>
<td>Exposure dependent on Min. Acceptable Visibility (MAV) standards (see chapter 2, page 36)</td>
</tr>
<tr>
<td>Duration of downwind</td>
<td>Downwind</td>
<td>Ocular estimates;</td>
<td>2 h</td>
<td>Minimum distance Pop. (miles)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use known milestones or photographic standards</td>
<td></td>
<td>1K-5K 3-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;5K-50K 5-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;50K 7-9</td>
</tr>
<tr>
<td>Particulates:</td>
<td>Population centers and critical areas</td>
<td>PM-10 sampler; Established state and NPS monitoring programs</td>
<td>weekly 24-h cycle or as directed by state</td>
<td>Levels established by EPA and state</td>
</tr>
<tr>
<td>PM-10; amount and duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO Exposure:</td>
<td>Fireline</td>
<td>Badge sampler or correlation with visibility</td>
<td>½ h</td>
<td>Exposure of burn crew-members to areas of &lt;100 ft visibility not to exceed 2 h. If exceeded, 24-h detoxification required before crew-members can return to line duty</td>
</tr>
</tbody>
</table>

1PM-10 monitoring will be a mandatory requirement only if a major concession or population center of 20,000 or more or a critical target (different from sensitive target) exists within park boundaries or within 5 miles of a park boundary and may be impacted by smoke of unknown quantities. The state may provide a PM-10 monitor in the surrounding area under any circumstances; the key is that the state has the ultimate authority for determining when PM-10 standards are violated and when land managers must take appropriate actions to comply with established state and federal standards.

Chapter 2: Monitoring Levels 1 and 2: Reconnaissance and Fire Conditions 33
Smoke monitoring variables (MAS) with techniques, frequencies, and recommended thresholds (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Location</th>
<th>Technique</th>
<th>Frequency</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Smoke Production:</td>
<td>Burn site or office</td>
<td>• Calculated from total fuel consumed;</td>
<td>Preburn</td>
<td>May be determined by state</td>
</tr>
<tr>
<td>Tons/unit time</td>
<td></td>
<td>• Intensity estimates;</td>
<td>estimate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Smoke particle size/intensity</td>
<td>followed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>equations</td>
<td>by</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>postburn</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>reaffir-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mation</td>
<td></td>
</tr>
<tr>
<td>Mixing Height:</td>
<td>Ground</td>
<td>• Spot weather forecast;</td>
<td>1 h</td>
<td>1500 ft above burn elevation; do not violate for</td>
</tr>
<tr>
<td>Height - temperature</td>
<td></td>
<td>• Mobile weather unit;</td>
<td></td>
<td>more than 3 h or past 1500 h</td>
</tr>
<tr>
<td>gradient</td>
<td></td>
<td>• On site soundings;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ocular estimates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport Winds:</td>
<td>Ground</td>
<td>• Spot weather forecast;</td>
<td>1 h</td>
<td>5 to 7 mph at 1500 ft above burn elevation; do not</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td>• Mobile weather unit;</td>
<td></td>
<td>violate for more than 3 h or past 1500 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• On site soundings;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Winds:</td>
<td>Ground</td>
<td>• Wind gauge held at breast height</td>
<td>1 to 6 h</td>
<td>1 to 3 mph day (depending on threat to safety, as</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
<td></td>
<td>near roads)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complaints:</td>
<td>Received at headquarters</td>
<td>• Written</td>
<td>NA</td>
<td>The maximum allowable number of &quot;recordable&quot;</td>
</tr>
<tr>
<td>Number</td>
<td>from air quality resource</td>
<td>• Verbal</td>
<td></td>
<td>complaints per treatment, as defined by the Air</td>
</tr>
<tr>
<td>district</td>
<td></td>
<td></td>
<td></td>
<td>Quality Control District.</td>
</tr>
</tbody>
</table>

Chapter 2: Monitoring Levels 1 and 2: Reconnaissance and Fire Conditions
Use of the Smoke Monitoring Data Sheet (FMH-3)

The Smoke Monitoring Data Sheet (form FMH-3 in Appendix A) is intended for use on both prescribed natural fires and prescribed burns. The minimum acceptable monitoring frequencies are displayed along the top of each line. Data collected during each time interval is entered under the appropriate frequency. For example: the following visibility readings in feet were collected along a road being monitored by Fire Behavior/Weather Specialist-1Is:

<table>
<thead>
<tr>
<th>Post-Ignition Time (hr)</th>
<th>Visibility (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>1 ½</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
</tr>
<tr>
<td>2 ½</td>
<td>85</td>
</tr>
</tbody>
</table>

These visibility values in feet are recorded horizontally across the form for carbon monoxide (CO) exposure. Since a visibility of less than 100 feet was recorded for a period of more than 2 hours (see recommended threshold), the fire monitor (FBWS) would need to leave the site for a 24-hour CO detoxification period.

When this form is used, it is important to note the following:

Formulas for determining appropriate highway visibilities can be found in the RX-95 Training Manual (1987) and on the next page.

The number of public complaints (monitoring variable #4 on the form) is monitored by time interval (2 to 4 hours post ignition), rather than at any specific time. "Recordable complaints" can be monitored via the local air quality district and are considered to be complaints when they are formally documented in writing by the affected citizen.

The MAS monitoring frequency for ground winds must be determined by each park since this parameter is a frequent and critical source of data collection. At a minimum, however, these data should be collected once every 24 hours. Values recorded should represent averages taken at the time interval specified by the FBWS. Monitoring frequencies should be recorded on the form together with subsequent wind speed in miles per hour (mph).

The formula for computing total emissions production (TEP) is found on the back of the FMH-3 form. Emission factors included in this formula are derived from factors available in the RX-95 training manual. TEP, in tons/acre is recorded under "OTHER," line 1.
**Monitoring Highway Visibility**

The steps required to meet the MAS for highway visibility are to monitor and record smoke density or sight distance along the travel route and then apply a "reduced visibility braking factor" similar to that required for braking in a foggy environment. This minimum acceptable visibility adjustment factor (AF) is 1.75 (California Highway Patrol, 1984). It is multiplied by the normal braking distance required for a vehicle to stop if traveling at a posted speed limit, given dry and clear (ideal) conditions.

**Minimum Acceptable Visibility (MAV)** is calculated using the California Highway Patrol formula:

\[
MAV = (EB + FB) \times (AF)
\]

Where:

- MAV = Minimum acceptable visibility at posted speed
- EB = Eye-to-brain reaction distance under clear conditions
- FB = Foot-to-brake reaction distance under clear conditions
- EB + FB = Total distance traveled while braking under ideal conditions
- AF = 1.75 (constant)

<table>
<thead>
<tr>
<th>Posted Speed Limit (mph)</th>
<th>(EB)</th>
<th>(FB)</th>
<th>(AF)</th>
<th>MAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10.5</td>
<td>5.6</td>
<td>1.75</td>
<td>28</td>
</tr>
<tr>
<td>15</td>
<td>16.0</td>
<td>12.5</td>
<td>1.75</td>
<td>50</td>
</tr>
<tr>
<td>20</td>
<td>21.5</td>
<td>22.2</td>
<td>1.75</td>
<td>76</td>
</tr>
<tr>
<td>25</td>
<td>27.0</td>
<td>34.7</td>
<td>1.75</td>
<td>108</td>
</tr>
<tr>
<td>30</td>
<td>32.5</td>
<td>50.0</td>
<td>1.75</td>
<td>144</td>
</tr>
<tr>
<td>35</td>
<td>38.0</td>
<td>68.0</td>
<td>1.75</td>
<td>185</td>
</tr>
<tr>
<td>40</td>
<td>43.5</td>
<td>88.9</td>
<td>1.75</td>
<td>232</td>
</tr>
<tr>
<td>45</td>
<td>49.0</td>
<td>112.5</td>
<td>1.75</td>
<td>283</td>
</tr>
<tr>
<td>50</td>
<td>54.5</td>
<td>138.9</td>
<td>1.75</td>
<td>338</td>
</tr>
<tr>
<td>55</td>
<td>60.0</td>
<td>168.0</td>
<td>1.75</td>
<td>399</td>
</tr>
<tr>
<td>60</td>
<td>65.5</td>
<td>200.0</td>
<td>1.75</td>
<td>465</td>
</tr>
<tr>
<td>65</td>
<td>71.0</td>
<td>234.7</td>
<td>1.75</td>
<td>535</td>
</tr>
</tbody>
</table>

Note: The MAV must be doubled if smoke is present along the road at night. The MAV must also be doubled when the road is a simple divided highway, because there is an increased chance of head-on collisions. The visibility adjustment factor does not take into account a head-on encounter of two vehicles traveling in opposite directions.
Mitigating Reduced Visibility Situations (MAS)

Take the following steps to mitigate for reduced visibility when a paved road is affected by smoke. These actions are presented in order of decreasing visibility; implementation of step 3, for example, means that steps 1 and 2 have been taken.

1. Post "Smoke on Road" signs when visibility is twice the MAV value or less: for example, the sight distance is reduced to 220 ft and the posted rate of speed is 25 mph (MAV = 108 ft).

2. Reduce posted speed limit when visibility is at MAV value, or less: for example, sight distance is 110 ft and the posted speed is 45 mph (MAV = 283 ft); therefore, the posted speed limit must be reduced to 25 mph or less.

3. Unless a lead car is on scene, stop traffic by closing the road to travel when the ratio of actual visibility to MAV is \( \frac{x}{i} \) or less: for example, the sight distance is 50 ft and the posted speed limit is 25 mph (MAV = 108 ft).

4. When the ratio of actual visibility to MAV is less than \( \frac{1}{5} \), close the road to all but administrative use.

MONITORING SCHEDULE

Levels 1 and 2 monitoring frequencies vary according to fire management strategy.

Prescribed Natural Fire Scenarios

Minimum acceptable monitoring levels and monitoring frequencies for prescribed natural fires are dependent on the "value of the resource at risk" (determined by each park) and the estimated distance (number of days) until fire arrival at that resource at risk. Table 3 gives minimum monitoring frequencies for these fires.

Examples of potential high value resources at risk include major threats to human safety and property (for example, a wilderness trail used by 100 parties per day), combustible cultural resources, some threatened and endangered species, giant sequoia trees and other unusual natural features, and extremely important vistas. When a fire is predicted to cross a prescribed natural fire unit boundary and threaten resources outside the unit, the risk category becomes HIGH. An example of a potential LOW value resource at risk is a minor threat to human safety posed by fire burning across a remote wilderness trail used by fewer than five parties per day.
Table 3. Monitoring frequency for prescribed natural fires (MAS) by fire distance from resource at risk and value of resource at risk (Level 1 = Reconnaissance, Level 2 = Fire Conditions)

<table>
<thead>
<tr>
<th>Fire distance from resource at risk</th>
<th>Monitoring frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High value resource</td>
</tr>
<tr>
<td>20+ days</td>
<td>Level 1 once per day every 14th day</td>
</tr>
<tr>
<td>8 to 20 days</td>
<td>Level 1 once per day every 7th day</td>
</tr>
<tr>
<td>4 to 7 days</td>
<td>Level 2 once per day every 3rd day</td>
</tr>
<tr>
<td>2 to 3 days</td>
<td>Level 2 once per day during peak burning conditions</td>
</tr>
<tr>
<td>1 day</td>
<td>Monitor variables onsite at level 2, at the same frequency as for a prescribed burn (see Table 5)</td>
</tr>
</tbody>
</table>

A prescribed natural fire must be monitored before it reaches the resource with a HIGH value at risk. Each monitoring session will determine the estimated time for the fire, or sometimes the smoke from the fire, to threaten the value at risk, based on existing and forecasted burning conditions. The estimated time to the resource value at risk is never considered to be static. Monitoring frequency must be adjusted based on updated evaluations of time to the value at risk.

Table 4 represents a simplified set of scenarios which can be used as a model for managing prescribed natural fire (PNF) decisions. The sequences of events which occur under scenarios Day 3, A to C, are typical and conform with established National Park Service policy for managing such incidents (National Park Service (NPS)-18 1990). Nevertheless, the actual sequence during the life of a PNF may include several complex "loops" of scenarios between Day 2 or Day 3 (A or B), and may extend over a much longer period of time, perhaps a month or more. Regardless of these variations, strict conformance with the minimum acceptable standards (MAS) for monitoring and staffing requirements (described here and in the Wildland Fire Management Guideline, NPS-18) and the FSA/Decision Record protocols (National Park Service (NPS)-18 1990) must be adhered to. Failure to do so constitutes a violation of established NPS policies, and may result in immediate termination of a prescribed natural fire (PNF) declaration following regional or national intervention.
Table 4. Prescribed natural fire scenarios

<table>
<thead>
<tr>
<th>Time</th>
<th>Events at fire</th>
<th>Time</th>
<th>Events at headquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1345</td>
<td>Lightning strike occurs in Prescribed Natural Fire Zone.</td>
<td>1400</td>
<td>Dispatch notifies the FMO/PFM.</td>
</tr>
<tr>
<td>1500</td>
<td>First FBWS team arrives on site. Collection of monitoring data begins.</td>
<td>1415</td>
<td>FBWS team called out by FMO/PFM.</td>
</tr>
<tr>
<td>1745</td>
<td>FSA-part I summarized by FBWS team. Data relayed to park dispatch (hand-carried or via radio).</td>
<td>1800</td>
<td>FSA-part I information reviewed by responsible official (PFM/FMO).</td>
</tr>
<tr>
<td>1900</td>
<td>Onsite monitoring continues; data placed on the FSA-part I and the Smoke Monitoring Form (FMH-3).</td>
<td>1830</td>
<td>Suppression resource assessment completed by FMO.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>FSA-part II completed by responsible official (PFM/FMO) with help from FBWS team. Complexity Analysis (NPS-18) completed by responsible official (PFM/FMO); number of PBBs and FBWS-lls in team determined. Responsible official recommends that the fire be managed as a PNF.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2100</td>
<td>FSA-parts I and II reviewed by appropriate park staff and approved by Superintendent. PNF Decision Record signed by the Superintendent.</td>
</tr>
</tbody>
</table>

**PRESCRIBED NATURAL FIRE DECLARED.**
Table 4. Prescribed natural fire scenarios (continued)

<table>
<thead>
<tr>
<th>Day 2</th>
<th>Time</th>
<th>Events at fire</th>
<th>Time</th>
<th>Events at headquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0001...</td>
<td>Data collection by FBWS team continues.</td>
<td>0600</td>
<td>Additional PNF personnel arrive, receive briefing packages and sent to fire.</td>
</tr>
<tr>
<td></td>
<td>0800</td>
<td>Additional personnel arrive at the fire</td>
<td>1400</td>
<td>Dispatch provides weather forecast to FBWS team and FMO/PFM/PBB.</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>Summarized FSA-part I reported to park dispatch.</td>
<td>1630</td>
<td>FSA-part I summary reviewed by responsible official (PFM/FMO/PBB); fire determined to be IN prescription.</td>
</tr>
<tr>
<td></td>
<td>1700</td>
<td>Onsite monitoring continues; data placed on the FSA-part I and the Smoke Monitoring Form (FMH-3). FSA-part I delivered to PFM/FMO/PBB.</td>
<td>1800</td>
<td>Resource assessment completed; PFM/FMO recommends that the fire be managed as a PNF into the next burning period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Superintendent approves the recommendation via NPS PNF Decision Record.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>PRESCRIBED NATURAL FIRE DECLARATION REAFFIRMED.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Events on Day 2 are repeated for succeeding days until (A) the PNF goes out naturally, (B) a change in management strategy is indicated, or (C) the fire is declared a wildfire. These options are covered in the Day 3 portions of this Table.</td>
</tr>
</tbody>
</table>
### Table 4. Prescribed natural fire scenarios (continued)

**DAY 3**  
**(OPTION A - NATURAL OUT)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Events at fire</th>
<th>Time</th>
<th>Events at headquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001...</td>
<td>Monitoring continues in compliance with this Handbook.</td>
<td>1400</td>
<td>Dispatch provides weather forecast to FBWS team and FMO/PFM/PBB.</td>
</tr>
<tr>
<td>1600</td>
<td>Summarized FSA-part I reported to park dispatch.</td>
<td>1600</td>
<td>FBWS predicts rapidly decreasing fire activity due to frontal passage (rain or snow), lack of fuels, natural barriers, etc.</td>
</tr>
<tr>
<td>1800</td>
<td>Heavy rains over the fire area, or fire out of fuels. Onsite monitoring continues; data placed on the FSA-part I and the Smoke Monitoring Form (FMH-3). FSA-part I delivered to PFM/FMO/PBB.</td>
<td>1830</td>
<td>FSA-part I reviewed and signed by responsible official (PFM/FMO/PBB); fire situation and resources assessed.</td>
</tr>
<tr>
<td></td>
<td>1900 PFM/FMO recommends that the fire be declared a Natural Out to Superintendent via NPS daily PNF Decision Record. Recommendation accepted by the Superintendent and Decision Record signed.</td>
<td>1900</td>
<td>PFM/FMO recommends that the fire be declared a Natural Out to Superintendent via NPS daily PNF Decision Record. Recommendation accepted by the Superintendent and Decision Record signed.</td>
</tr>
<tr>
<td>2200</td>
<td>Fire goes out on its own due to a lack of fuels, precipitation, or physical barriers previously identified in an approved fire management plan.</td>
<td>2300</td>
<td>Postburn reporting (DI-1202, post-burn narrative, etc.) completed by responsible official (PFM/FMO/PBB).</td>
</tr>
</tbody>
</table>

**PRESCRIBED NATURAL FIRE IS DECLARED A NATURAL OUT.**
Table 4. Prescribed natural fire scenarios (continued)

**DAY 3**
**(OPTION B - CHANGE IN MANAGEMENT STRATEGY)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Events at fire</th>
<th>Time</th>
<th>Events at headquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001...</td>
<td>Monitoring continues in compliance with this Handbook.</td>
<td>1400</td>
<td>Dispatch provides weather forecast to FBWS team and FMO/PFM/PBB.</td>
</tr>
<tr>
<td>1600</td>
<td>Summarized FSA-part I reported to park dispatch. FBWS team registers concerns in Sections 8a-8e of part I, FSA.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1615</td>
<td>Onsite monitoring continues; data placed on the FSA-part I and the Smoke Monitoring Form (FMH-3).</td>
<td>1615</td>
<td>FSA-part I summary reviewed and signed by responsible official (PFM/FMO/PBB); fire determined to be IN prescription but with recognized threat.</td>
</tr>
<tr>
<td>1730</td>
<td>FSA-part I delivered to PFM/FMO/PBB.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1830</td>
<td>FSA-part II completed by responsible official (PFM/FMO/PBB) to address concerns in 8a-8e, part I FSA. Holding actions and alternative management strategies are evaluated and a preferred alternative is developed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1845</td>
<td>New FSA-part II reviewed by appropriate park staff. Superintendent approves change in PNF management strategy and the preferred alternative.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1930</td>
<td>FSA-part II and the PNF Decision Record signed by Superintendent.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FIRE IS MANAGED AS PRESCRIBED NATURAL FIRE UNDER NEW STRATEGY INTO NEXT BURNING PERIOD. ADDITIONAL PNF RESOURCES ARE DISPATCHED OR HOLDING ACTIONS INITIATED ACCORDING TO NEW STRATEGY.</td>
</tr>
</tbody>
</table>
### Table 4. Prescribed natural fire scenarios (continued)

**DAY 3**  
(OPTION C - WILDFIRE)

<table>
<thead>
<tr>
<th>Time</th>
<th>Events at fire</th>
<th>Time</th>
<th>Events at headquarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001...</td>
<td>Monitoring continues in compliance with this Handbook.</td>
<td>1000</td>
<td>Dispatch provides weather forecast to FBWS team and to FMO/PFM/PBB.</td>
</tr>
<tr>
<td>1400</td>
<td>Summarized FSA-part I reported to park dispatch. FBWS team registers concerns in Sections 8a-8e of part I FSA.</td>
<td>1430</td>
<td>FSA-part I summary reviewed and signed by responsible official (PFM/FMO/PBB); fire determined to be OUT of prescription (in accordance with park FMP or Regional contingency plan).</td>
</tr>
<tr>
<td>1500</td>
<td>Onsite monitoring continues; data placed on the FSA-part I and the Smoke Monitoring Form (FMH-3).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td>FSA-part I delivered to PFM/FMO/PBB.</td>
<td>1830</td>
<td>FSA-part II completed by responsible official (PFM/FMO/PBB) to address concerns in 8a-8e, part I FSA. Holding actions and alternative management strategies are evaluated and a preferred alternative is developed.</td>
</tr>
<tr>
<td>1845</td>
<td>FSA-parts I and II reviewed and signed by the Superintendent who declares the fire a wildfire.</td>
<td>1900</td>
<td>NPS PNF decision record signed by Superintendent.</td>
</tr>
<tr>
<td>1915</td>
<td>Incident Commander notified; EFSA prepared.</td>
<td>1900</td>
<td>Suppression alternative implemented.</td>
</tr>
<tr>
<td>2000</td>
<td>Suppression actions initiated (CONTAIN, CONFINE or CONTROL).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Incident management continues via ICS system.

**FIRE IS EVENTUALLY DECLARED OUT AS A RESULT OF SUPPRESSION ACTIONS.**
Table 5. Monitoring frequency for prescribed burns (MAS) during three phases\(^1\), by fuel type (level 1 = Reconnaissance, 2 = Fire Conditions)

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Monitoring Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>Active Fire Spread (level 2)</td>
</tr>
<tr>
<td></td>
<td>Low Fire Spread (level 2)</td>
</tr>
<tr>
<td></td>
<td>Residual Burning (level 1)</td>
</tr>
<tr>
<td>Brush</td>
<td>Once every 30 minutes</td>
</tr>
<tr>
<td>Forest</td>
<td>Once every 2 hours</td>
</tr>
</tbody>
</table>

\(^1\)Fire Phases

Active Fire Spread: Fire front is actively flaming and continuous along most of its length. Fire front is spreading into unburned fuels. The fire perimeter is not secure.

Low Fire Spread: Fire is smoldering or going out along much of its perimeter, or if flaming areas exist they are not continuous and the fire advances sporadically rather than advancing along a broad front. Torching and short runs may occur. Unit contains areas of unburned fuel. Fire perimeter is not fully secured. Fire danger is low and not predicted to increase within the next 4 to 6 hours.

Residual Burning: Minimal risk from spotting exists AND the perimeter is secured as follows: EITHER (1) fine or live fuels (as appropriate) are burned out at the fire perimeter or control area of concern, OR (2) fine or live fuels cannot sustain a flaming front.

Prescribed Burns

Monitoring frequency on prescribed burns is dependent upon the vegetation and fuel type and upon fire activity. Table 5 specifies MAS monitoring frequencies for prescribed burns.

Monitor weather at specified time intervals each day (Table 5) using either a belt weather kit and rain gauge, a RAWS station, or a dummy AFFIRMS weather station. If the prescription includes 100- or 1000-hour time-lag fuel moisture, a full prescription weather station (containing a hygrothermograph, fuel moisture sticks, rain gauge and anemometer) must be established at least two weeks prior to the planned ignition date.
Conduct supplemental prescription monitoring at various points along the fire perimeter to be determined by the Prescribed Fire Manager or Resources Management Specialist and relayed to the Prescribed Burn Boss. If only residual burning is occurring near the base prescription site, but active or low spread phases continue in other areas, conduct level 2 monitoring in those areas at the frequencies listed in Table 5.

REFERENCES


3 Monitoring Levels 3 and 4: Immediate Postfire Effects and Long-term Change

Monitoring levels 3 (immediate postfire effects) and 4 (long-term change), as indicated in Table 1, (chapter 1, page 7) are always required when the fire management strategy is prescribed burning. These higher levels of monitoring are often appropriate for wildfires and prescribed natural fires as well. Reconnaissance (level 1) and fire conditions (level 2) data are always collected in conjunction with levels 3 and 4 data so that observations and results can be correlated with the conditions of the burn.

Levels 3 and 4 are similar with respect to the variables monitored, but differ in the emphasis given to some variables, in the timing of data collection, and in the interpretation of data. At level 3, conditions before, during, and after a burn are monitored primarily through sampling on relatively small portions of the burn area. These index plots are usually set up well ahead of a prescribed burn and are monitored for a period of time after it. Fire ecologists and other specialists are usually required as consultants for the choice of variables at either level, and for the interpretation of results.

Monitoring type variables identified for level 3 will continued to be monitored through the long-term (level 4). Some of the monitoring type variables, or others not previously monitored, may be found to have particular value in revealing change in conditions sampled. These are the primary indicators of change which reveal trends that management should address.

In this chapter we first examine the kinds of MAS variables to be monitored at both levels, and then we look at the sampling design and procedures in broad outline. (Detailed procedures are provided in chapter 4).
Table 6. Monitoring type variables (MAS) for level 3

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Variables</th>
</tr>
</thead>
</table>
| Grassland (includes prairies and sedge meadows) | 1. Number of transect hits by species  
2. Relative cover by species  
3. Number of non-native species  
4. Number of native species  
5. Burn severity  
6. Brush density by species  
7. Brush age by species  |
| Brush | 1., 2., 3., 4., and 5. as above  
6. Brush density by species  
7. Brush age by species  |
| Forest or Woodland | 1. Tree density by species  
2. Tree diameter by species  
3. Fuel load by size class  
4. Total fuel load  
5. Duff depth  
6. Litter depth  
7. Number of transect hits by species  
8. Relative cover by species  
9. Number and percent of non-native species  
10. Number and percent of native species  
11. Brush density by species  
12. Brush age by species  
13. Average scorch height  
14. Percent of crown scorched  
15. Burn severity |

LEVEL 3 VARIABLES

Monitoring data on immediate postfire effects provides detailed descriptive information on fuel loading, and vegetation structure and composition. This information is only broadly determined at level 1, reconnaissance. Data on level 3 variables will be collected for all monitoring types (including those burned by simulated natural fires). Wildfire and prescribed natural fire management may also require the collection of some or all of this data.

The MAS for level 3 monitoring are the variables listed in Table 6 (monitoring type variables). In addition, all the variables that may be listed as objectives of a burn plan must be monitored (objective-dependent variables). At least one monitoring type variable must be statistically valid. All objective-dependent variables must be statistically valid if a high degree of certainty is required.

The park natural resource specialist or ecologist is responsible for identifying and defining the monitoring type and for choosing which variables will be sampled for...
statistical validity. If this person is not qualified to make these decisions, the park should seek outside assistance.

A monitoring program can be customized to address specific park needs, however any modifications must be approved by the parks resource management specialist, fire management officer, and scientist or local CPSU research scientist. These proposed changes should then be sent to the Western Regional Office for approval.

**Monitoring Type Variables**

Monitoring type variables describe the basic fuel and vegetation components of a relatively homogeneous fuel and vegetation complex. (See chapter 4 for a discussion on defining and stratifying monitoring types.) They represent (by frequency and cover) plant species present in a plant community, and sometimes the dead and downed fuel array; they describe the basic structure and composition of the vegetation and dead fuels burned under a particular prescription.

Ex. 1: A yellow pine forest with an understory composed of young yellow pine and white fir. The dead and down fuels are mostly 1 to 8 inches in diameter and are relatively uniform. (Variables are underlined).

Ex. 2: A brush/grassland dominated by rabbitbrush (40% cover) and needlegrass (20% cover). More than 20% of the ground is barren. (Variables are underlined).

Table 6 lays out the minimum acceptable monitoring type variables for monitoring immediate postfire effects in three vegetation types. All of the variables on Table 6 will be monitored, but not necessarily to a statistically valid level. A statistically valid sample (see Glossary for definition) is required, however, for at least one (1) monitoring type variable for each monitoring type. For example:

If your primary concern is to increase the number of plants of a suppressed brush species, you might choose only the number of transect hits or relative cover of that species for statistical significance, even though it is not the dominant species in the preburn environment. Only this variable would then be used to calculate your sample size.

Although only one monitoring type variable need be statistically valid, it is strongly suggested that at least one variable in each layer of the monitoring type be monitored to a statistically valid level. A dominant species (or fuel element) that represents each layer of a monitoring type should also be strongly considered for selection. For example:
If your primary concern is giant sequoia reproduction and survival over time, you might choose duff depth (fuel layer), density of giant sequoia seedlings (understory layer), and density of the most dominant overstory tree (overstory layer). These four variables would then be used to calculate your sample size.

The choice of variables is extremely important and will generally require consultation with a fire ecologist or subject matter expert.

It is possible that the ecotonal or successional/transitional vegetation may not fall neatly under the three vegetation types listed in Table 6. The monitoring system described in this Handbook is designed to look at changes in a vegetation type not in a community boundary. However, the techniques described can be modified to fit almost any situation if the variables of concern are defined in advance. The rule of thumb is to select the most intensive sampling technique (usually a forest type plot). Listed below are three examples where choices were made based on variables of interest and vegetation structure.

Ex. 1: A park has savannas and woodlands with scattered junipers and oaks invading grasslands. Recruitment of trees (the key variable) in these areas is a concern. Fire's presence could dramatically alter this recruitment. The grassland plot technique described in this Handbook does not assess recruitment of trees. If brush density belt transects were added, the sample size would be inadequate to describe woodland or savanna conditions where tree density is very low. A forest plot of at least 20m by 50m would probably be the method of choice to detect tree recruitment as well as grassland condition.

Ex. 2: A park has a brushfield populated by scattered mixed shrubs and trees. Park managers hypothesize that the presence of trees is indicative of the absence of fire. The standard brush plot is too small to sample trees. The park could choose to widen the brush density transect and include trees in the dataset or it could install forest plots.

Ex. 3: A park has several meadow areas being encroached upon by trees. Park managers want to know what effect the burns are having on the edges of the meadow. They choose to call the ecotone a unique monitoring type and install forest plots to detect recruitment/mortality of trees into the meadow.
Objective-dependent Variables

The second kind of variable is called objective-dependent; that is, it is specified by a burn plan objective. Minimum Acceptable Standards for monitoring of objective-dependent variables cannot be given in this Handbook. By their very nature, these variables are specific to the goals of the burn and are identified in the Fire Management Plan or in the burn unit plan. This Handbook only requires that a statistically valid sample be collected for objective-dependent variables if the park manager must be relatively certain that subtle results are attributable to the burn. Evidence of overt change, such as a reduction in fuel load, may not need to be statistically valid for management to be satisfied with the results.

Objective-dependent variables are very often the same as the monitoring type variables, for example:

A burn plan objectives are to reduce fine fuels by 60% and reduce 3 to 8 inch fuels by 40%, maintain current density and species composition of overstory trees, and thin white fir understory trees by 80%, while retaining 90% of the yellow pine understory trees. (Variables are underlined.)

In this example, the burn plan objectives are specific and the variables clearly defined. These variables also happen to be monitoring type variables.

In other situations the burn plan may specify objectives that dictate variables dissimilar to the monitoring type variables, for example:

Increase raptors in the area (requires altering tree structure and composition, and prey species). (Variables are underlined.)

In this example, the raptor population may be limited by prey species (such as deer mice), or by suitable tree roosts. The fire could have an impact on cover and forage for deer mice, and could alter tree roosts. The number of mice or raptors is an objective-dependent variable that will require a unique sampling design. The monitoring type variable—overstory trees—will provide information on tree composition and size, but suitable roost trees may need to be counted based on castings at the base of trees. A roost tree is, therefore, an objective-dependent variable requiring a burn-specific monitoring design.

Refer to Appendix H for suggested sampling method references for organisms of special management concern (forest "pests", birds, reptiles, and mammals). Customized monitoring systems for these variables should be designed with subject expert assistance and are beyond the scope of this Handbook.
LEVEL 4 VARIABLES

The MAS for level 4 is to continue monitoring all the monitoring type variables described in Table 6 over an extended period of time and to monitor one or more statistically valid "primary indicators of long-term change" as described below.

Monitoring Type Variables

Monitoring type variables track both short and long-term change in the vegetation and fuel components of the ecosystem. When monitoring type variables are followed over the long term, even though only a few will be statistically valid, subjective deductions can be made from most of them. For example:

In a sugar pine (Pinus lambertiana) monitoring type the statistically valid variables are the density of sugar pine in the overstory and total fuel load. Data has been collected for five years and the fire manager notices that the number of transect hits of Ribes sp. is 80 times more than before the fire. The manager suspects that the fire has caused this increase and is concerned since Ribes sp. is an alternate host for the non-native white pine blister rust, which kills sugar pines.

In this example, the manager recognized a trend based on a non-statistically valid variable (Ribes sp.). The manager now must determine whether the increase in Ribes sp. is due to fire or is a generalized phenomenon taking place in the region. Plots installed outside of the burned area, but within the monitoring type should now be installed (control plots) to address the specific issue.

Primary Indicators of Change

Primary indicators of long-term change are those variables most sensitive to change in the environment as a result of fire. The primary indicators are chosen by the fire manager or ecologist after evaluating what plants, animals and fuel variables will best detect trends. Change in these primary indicators will usually occur gradually and may not be fully apparent for years.

Primary indicators of long-term change are linked to the ultimate accomplishment of program goals. Selection of these indicators is based on their ecological significance, information content, and indexing capabilities relative to ecosystem components of special management concern. The most sensitive indicator could be an animal population, for which a customized sampling design would have to be developed.
The primary indicators may be selected from the monitoring type variables (usually) or may be completely different. The following examples of primary indicators of change provide guidelines for selection:

**Monitoring Type Indicators**

- **Grasslands/Brush**: Number of transect hits for each of the three dominant species; percent non-native species; density of brush species.
- **Forest/Woodland**: Density of three most dominant overstory trees; density of two dominant understory trees; and total fuel load.

To detect trends, the values of the two or three most dominant species could be combined to form an average value or the manager could select the species requiring the greatest number of plots. There are advantages and disadvantages to either choice depending upon the situation. An ecologist should assist the manager making this decision.

**Other Indicators**

- **Biological Diversity**: All organisms present on the plot and their relationships through time.
- **Animal Population Dynamics**: Select species populations are followed through time. (Channel Island uses this method.)
- **Plant Mortality and Recruitment**: Death and birth rates of selected plants. These variables could be very important in attempts to encourage or discourage particular species.
- **Rare Species Occurrence**: Occurrence of a rare species through time. This variable will be very important if you are trying to enhance the habitat of a rare species by burning; ex.: Kirkland warbler.

If park management chooses primary indicators of long-term change that are not monitoring type variables, appropriate sampling methods, not covered in this Handbook, will need to be developed. Appendix H lists several monitoring references for other than MAS variables. These references are limited, but should serve as a useful guide. Customized monitoring or research systems should be designed with the assistance of subject-matter expertise. The local Cooperative Park Studies Unit (CPSU) will help identify sources of this expertise.

The primary indicators chosen will determine the sample size and, therefore, labor costs for the monitoring program. Where there is a great deal of variability between plots, an infrequent variable, or need for a high level of precision or confidence in the results, the number of plots will be very high. (See chapter 4, page 79, "Adjust Sample Sizes").
MONITORING DESIGN

The MAS variables are monitored by sampling according to a standardized design. Index plots form a representative area for each monitoring type, with or without control plots. Customized methods may also be needed for special concerns, however all customized methods and form modifications must be approved by the Western Regional Office.

Index Plots

Immediate postfire and long-term change monitoring is accomplished through the use of index plots -- plots established before prescribed burning on which fire behavior and effects will be measured. Index plots are designed to yield statistically valid results for detecting change in the environmental variables of interest. Index plots will be randomly distributed throughout each monitoring type occurring within the burn units which are scheduled for burning within the next five years. Additional plots should be established in areas of special concern, such as a minor but very flammable fuel type occurring along a burn unit boundary.

Representative Area

The collective aggregation of all index plots for a particular monitoring type constitutes a representative area (RA). An example of a representative area layout is shown in Figure 1. All index plots within a given representative area must be treated as a single data set for analysis purposes. Representative areas thus comprise a stratified random sample of monitoring types contained within areas proposed for prescribed burning within the next 5 years.

A representative area database should not be used for quantitative assessments of immediate postfire effects or long-term change until all index plots comprising the RA have been treated. Treatment consists of burning all the prescribed burn units in which the index plots are located. It could take up to 5 years to complete the immediate postfire effects databases because of the burn schedule. At that time the databases will represent the immediate postfire effects and some of the long-term changes expected for all prescribed burns conducted under the same prescription and within the same monitoring type.

If the representative area database exists, postfire narratives and reports for individual prescribed burns must refer to the relevant RA database. Significant fire behavior and effects outside the bounds documented in the RA must be addressed qualitatively in narrative form.
A systematic assessment of the extent to which specific burn plan objectives are met must be accomplished during the interim period prior to establishment of the Representative Area. Do not rely wholly on data from one or two within-the-burn-block index plots for this assessment.

There is only so much that can be physically monitored. We simply cannot put a statistically valid number of plots in for every fire, nor can we obtain statistical validation for all MAS variables. The "representative area" concept was specifically designed to negate the need to put plots in for every prescribed burn; this body of data should represent a large number of burns and thus lessen data collection overload.

**Areas of Special Concerns or Constraints**

Quantitative immediate postfire effects monitoring before the representative area database is complete is always required for those prescribed burns subject to special concerns or constraints. Examples are char height or mortality on giant sequoia trees or impacts on threatened and endangered species. Customized monitoring methods must be developed for these situations and the methods outlined in this Handbook may be insufficient.

The following monitoring options may be considered until the RA database is complete:

- Use existing data from previous prescribed burns conducted in the same or similar type under the same prescription.

![Figure 1. A representative area layout, showing monitoring type and burn units.](image)
• Use photo series for fuel reduction assessments.
• Use data from the index plots contained within a particular prescribed burn unit even though these plots are not yet part of a statistically valid database for a completed RA. These data will usually have to be combined with other data.
• Use existing literature that discusses relationships between fire behavior, intensity, or severity and fire effects for specific vegetation types.
• Use visual or other qualitative estimation techniques.

Small Areas

Some monitoring types may occupy small areas or the remaining unburned monitoring type area is small. To meet the requirements of this Handbook, it will be necessary to delay burning these areas until the representative area is complete. Recently burned units cannot be designated as untreated areas within a monitoring type since management-induced changes due to prescribed burning have already occurred. Continued burning before implementation of this monitoring system could diminish the usefulness of the representative area database since a large percentage of the monitoring type will be unavailable for sampling.

Control Plots

Installation of control plots is optional, but control plots are often necessary to evaluate whether specific burn plan objectives are met. In fact, it is essential not to confine all causal observations to burned areas. (See chapter 4, page 79, for details on installing control plots.)

Frequently, the need for control plots may not have been anticipated until postfire observations indicate otherwise. It is often appropriate to establish control plots after the burn when a specific question needs to be addressed.

When control plots are established to measure specific variables, they should be parallel in design and precision levels to their preburn counterparts. The choice of when and how to install control plots will require fire ecologist or subject specialist assistance. Implementation of a formal research project may be more appropriate in many cases.

In deciding not to include control plots the park manager recognizes that either an adequate fire effects information base is available to start or continue a burn program, or there are ongoing research programs adequate to address management concerns.
**Immediate Postfire Effects Control Plots**

Control plots are often important to determine if the prescribed burn caused a particular short-term effect. For example:

A burn block area has been invaded to a small extent by non-native species. Non-native species have been increasing throughout the region for the last 20 years and the park manager does not want to worsen the problem by prescribed burning. In fact, one of the burn plan objectives is to reduce non-native species frequency by 20% or more.

Fire is known to have played a very important ecological role in your burn block and the park manager is also anxious to see its force restored to the ecosystem. You know that your prescription can meet your burn objectives, but you suspect that the slow and incessant march of non-native plants could be accelerated by the prescribed burn.

In this example, and in many situations involving non-native species, it is important to set up control plots to test whether the result observed (a change in non-native species frequency) in the prescribed burn area is attributable to fire or to another force, such as climatic change, moisture regimes, or grazing.

It is important to recognize that immediate postfire effects control plots are non-treatment, that is, unburned plots that have value for a limited time. Generally, these plots will be valid for only a few years (1 to 10 depending on the variables, vegetation type, and environmental influences).

**Long-term Change Control Plots**

Establishing control plots for evaluating long-term change is limited to testing specific hypotheses comparing nontreatment effects (unburned) with treatment or treatment-plus-time effects. These controls are not generally sensitive to evaluating deviations from a "natural" state. For example:

A brush stand is burned every 20 years to reduce fuel hazard. The natural fire return interval is estimated to be 50 years. After 100 years of fuels treatment by fire, it is hypothesized that a difference in composition and density exists between those stands that have been burned every 20 years and the unmanaged stand.

In this example, and in most situations, control plots to evaluate long-term change will be installed long after the fire event. A competent research scientist or fire ecologist will be used to insure adequate research design and execution.
PROCEDURES AND TECHNIQUES

Procedures for monitoring levels 3 and 4 are similar but differ in timing and emphasis. As has been explained, the level 3 monitoring type variables continue to be monitored on the index plots in level 4, and any of these, or any of the objective-dependent variables, as appropriate, may become primary indicators.

Collecting and Analyzing Data

The MAS variables listed should be monitored according to the monitoring schedule (see page 59). Monitoring methods and procedures for index plots are described in chapter 4.

Burning the Prescribed Burn Units

All index plots within a representative area must be burned under the same prescription (but not necessarily at the same time or same year), and burn units with index plots must be treated the same as units without index plots. If a burn unit is ignited but the index plots contained within it do not burn, data on those index plots are still a valid part of the RA database. However, every effort should be made to burn each plot.

Dealing with Burning Problems

Plot Burning Off-Schedule

Index plots may reburn because of unplanned ignitions (natural or human-caused) or short burn prescription intervals. Other plots may be burned at some time other than the majority of the unit. The questions of when to eliminate such plots from the representative area, and whether or not to reinitialize the monitoring regime on that plot are addressed here.

Unplanned Ignitions. Unplanned ignitions that are permitted to burn because they meet the prescription criteria of a managed fire regime (and essentially replace a prescribed ignition) will be treated as a component of the managed fire regime. Monitoring schedules for the plot will not be altered. However, it is recognized that considerable variation may enter the system and affect index parameters if many index plots burn more frequently than prescribed. Managers will have to keep this in mind and make evaluation adjustments when examining results. In any case, it is essential to record the data collected from any unplanned ignition in appropriate plot database files. Fire behavior and weather data should also be included.
Plot Burns at Different Time Than the Burn Unit. Occasionally a plot may be placed such that it burns before or after the majority of the burn unit. Is the data from this plot still valid? It depends. If the plot is burned within prescription using the same ignition techniques typical of the vegetation type, it should contain valid data. However, the plot should not be allowed to burn off-schedule (e.g. protect the burned plot if the burn unit is reignited after an earlier attempt to avoid reburning of the plot).

Short Fire Intervals. If the intervals between prescribed burns are very short (2 to 5 years), resulting in frequent burn repetitions, in relation to the required monitoring frequency (years 0, 1, 2, 5, 10, etc.), year 0 (within 2 months postburn) and postburn year 1 monitoring will be conducted on the first and subsequent burns until responses are predictable. Usually, monitoring responses from a prescribed fire regime rather than the effects of a single fire will be desired. Losing track of change caused by a single fire is probably not important in this situation.

Partially Burned Plots

Fire rarely spreads uniformly across a fuel bed. Unburned patches are frequently part of the fire regime and should not be of concern as long as the plot was burned similarly to the remainder of the burn unit. A partially burned plot, if burned within prescription, should be considered part of the database.

Plot Burned Out-of-Prescription

Index plots burned by unplanned fires that exceed the ecological parameters of the management prescription must be eliminated from the representative area database. This does not preclude the option of continued monitoring of the plots.

MONITORING SCHEDULE

All index plots and representative areas for all monitoring types must be established in the first phase of this program (1990 to 1994) or in those burn units scheduled for burning in the next 5 years.

Preburn Frequency

Establish a minimum of 10 index plots for each monitoring type in the same year and increase the number if needed to obtain the desired level of precision. Sample size must be adjusted before all of the units are burned in a particular monitoring type. The final number of index plots will usually be 10 to 50 per monitoring type!
Index plot data must be read within 2 years of actual burning, and preferably within 1 year preburn. If a longer period has passed since plot establishment, the plot must be remonitored before prescribed burning. Since many plots will probably not be burned within the first or second year of plot installation, subsequent preburn remonitoring visits should be expected.

**During-burn Frequency**

Fire conditions MAS variables must be monitored and recorded during the burn as described in chapters 2 and 4.

**Postburn Frequency**

All index plot variables must be reread within 2 months after the burn. Vegetation parameters must be remonitored during the growing season at postburn intervals 1, 2, 5, and 10 years. Thereafter, monitoring will be at 10 year intervals until each unit is either placed within a prescribed natural fire zone or the area is burned again, in which event the monitoring cycle starts over again.

More frequent postburn monitoring visits may be made (ex.: 6 months postburn or 18 months postburn) depending on the specific informational needs of the park. These additional visits, however, may require adjustments in data processing if the standardized software provided with this Handbook is used.
4 Methods for Monitoring Forest, Brush, and Grassland Index Plots

As indicated in chapter 3, for levels 3 and 4, the MAS variables are monitored by means of sampling according to a standardized design. Index plots form a representative area for each monitoring type, with or without control plots. Customized methods are needed for special concerns. This chapter details variables and procedures for establishing index plots and for collecting and recording data from them. Techniques for determining the success or failure of a prescribed burn in attaining specific objectives, as well as the postfire response patterns, are described.

Many of the same procedures may be used for forest, brush, and grassland monitoring type variables; these procedures are outlined in the main discussion. Some methods, however, are specific to the vegetation type. For convenience (easily removed for field application), forest methods and grassland/brush methods for plot layout and preburn, during-burn, and postburn monitoring of vegetation, fuel, and fire characteristics are presented here in separate sections, after the main discussion.

The procedures described for monitoring MAS variables require the use of standardized forms to record data; these are provided in Appendix A. Methods and data collection forms are also provided for most of the recommended monitoring variables and for some of the optional variables. Many of the recommended variables require very little additional data collection effort. The most time-consuming monitoring activities are locating and installing the plots, not collecting the data. Since most of the recommended variables can provide a significant amount of useful information, they should be monitored whenever possible. Other useful information are given in the Appendices, as noted in the discussion.

Elimination of variables and prescribed methods categorized as MAS in this Handbook is unacceptable. For example, park managers cannot throw out the brush and herbaceous layer transects in a forest plot because they do not want to spend the time doing it or prefer another method. They may, however, add another vegetation sampling method, which will of course increase costs.
INDEX PLOT VARIABLES

As stated in chapter 1 and Table 6 (chapter 3, page 48), MAS variables have been established for grassland, brush, and forest monitoring types. These requirements are given here in greater detail.

FOREST PLOTS

Forest index plots are designed to measure the amount of dead and downed fuels consumed, density of overstory and understory trees, and change in cover of the associated brush and herbaceous layers. Index plot postfire assessments (MAS) will include a survey of tree scorch heights, percent crown scorched, char height (recommended), and burn severity.

MAS Variables

Tree Layer
1. Density and
2. diameter (dbh) by species for
   Overstory trees
   Pole-size trees and
   Seedling tree

Dead and Downed Fuel Loads
3. Fuel load by size class: tons/acre of woody fuels by time-lag fuel moisture size class: 10-h; (1-, 100-, 1000-h)
4. Total fuel load
5. Duff depth
6. Litter depth

Brush and Herbaceous Layer
7. Number of transect hits by species
8. Relative cover by species
9. Number and percent of non-native species (derived)
10. Number and percent of native species (derived)
11. Brush density by species
12. Brush age by species

11-, 100-, and 1000+ hour fuels must be monitored if present; or calculated if required by the fuel model, otherwise they are optional variables.
Postburn Conditions
13. Average scorch height
14. Percent of crown scorched
15. Burn severity (substrate and vegetation)

Recommended and Optional Variables

Overstory Trees
1. Crown position
2. Tree damage
3. Average char height
4. Mortality

Pole-size and Seedling Trees
5. Height

Brush and Herbaceous Layer
6. Brush and herbaceous layer height
7. Herbaceous layer species density (optional)
8. Crown intercept (optional)
9. Fuel load (optional)

Dead and Downed Fuel Loads
10. Tons/acre duff
11. Tons/acre litter
12. Aerial fuel load (optional)
13. Vertical and horizontal fuel continuity (optional)

GRASSLAND AND BRUSH PLOTS

For grassland and brush variables, a point line-intercept method (Veirs and Goforth 1988) will be used to monitor change in relative cover by species over time. Sampling will occur during the season in which the plants can most easily be identified and when biomass is greatest, usually in late spring or early summer. Postburn remonitoring should occur at the same phenological stage. The collection of voucher specimens is strongly recommended.

Procedures call for establishing two-dimensional "index transects" rather than three-dimensional index plots. The term index plot, however, will be used throughout the text since brush density measures add a third dimension.
MAS Variables

1. Number of transect hits by species
2. Relative cover by species (derived)
3. Number of non-native species (derived)
4. Number of native species (derived)
5. Burn severity
6. Brush density by species (Brush plots only)
7. Brush age by species (Brush plots only)

Recommended and Optional Variables

1. Vegetation height
2. Herbaceous layer density (optional)
3. Crown intercept (optional)
4. Fuel load (optional)

GENERAL METHODS

The first stage of this process is to select and define monitoring types, the second is to select and install plots, and the third is to collect data. Data collection steps are (1) monitor preburn conditions, (2) monitor fire conditions, and (3) monitor postburn conditions. Data evaluation and program review is the last and most important stage of the monitoring process.

Selecting and defining monitoring types is the Resources Management Specialist's (RMS) or Fire Behavior/Weather Specialist-I's (FBWS-I) responsibility. Biological technicians (BT) verify site suitability and collect index plot data. The RMS, FBWS-I, and ecological scientists evaluate the data. The Superintendent and Western Regional Office are responsible for program reviews.

SELECT AND DEFINE MONITORING TYPES

Monitoring type variables, as explained in chapter 3, represent vegetation and vegetation-related ecosystem components. Their primary purpose is to provide a quantitative picture of a plant community being influenced by fire. The predicted fire behavior or prescription is also part of that picture.

Definition of a monitoring type requires considerable judgment. It should be done after careful field reconnaissance and in consultation with a vegetation or fire ecologist. The process calls for stratifying the monitoring types by selecting
appropriate defining and rejecting criteria. Guidelines for stratification are as follows:

Each monitoring type must be relatively homogeneous. However, if a monitoring type includes vegetative complexes of similar composition spread across a changing landscape, then a range of stand densities, structure, fuel loading, understory, and herbaceous associates must be expected. The baseline monitoring regime must be broad enough to reflect this variation with sufficient statistical confidence to allow change to be detected.

Stratifying into strictly homogeneous monitoring types will decrease the sample size within a type, but could dramatically increase the number of plots needed to monitor the larger number of new monitoring types.

The number of designated monitoring types should be the minimum required to represent the major fire regimes within units scheduled for prescribed burning and areas of special concern. There is no need to identify all possible types. A park of moderate topographic and vegetative complexity could easily have 50 to 100 possible types using the criteria listed above, however, such designation is impractical. A compromise must be expected and should be developed with the assistance of a vegetation management specialist or fire ecologist.

Step 1: Establish Selection Criteria

It is essential to establish the specific criteria used to identify each monitoring type. By defining selection criteria, monitors can determine whether each randomly selected index plot is truly an index. Defining criteria quantitatively (ex.: > 75% cover of California black oak with < 10% ponderosa pine, or > 75% relative cover of annual cheatgrass with < 10% seedling oaks) will insure that all index plots will be located in relatively homogeneous areas (monitoring types). Defining criteria should also permit a qualitative comparison of trends or indexes between different monitoring types or similar types from different parks.

Types may be differentiated on the basis of one or a combination of the following elements:

Vegetation Composition

The limits of compositional variability must be established by a qualified resource manager or researcher. Examples of vegetative composition are lodgepole pine forest grading into a red fir forest or California chaparral grading into coastal prairies.
Vegetation Structure

Examples of vegetation structure are dense cover within a forest type, pine with brush, oak stands without reproduction, dense cover of perennial bunchgrasses, or brush with scattered bull pine.

Sensitive Species

Some biotic elements may be particularly dependent on a strict fire regime or be extremely sensitive to a type of fire. Some areas may be politically sensitive and will require a very different fire regime than the norm for that vegetation type. Examples of sensitive species are endangered plant populations or habitat, or politically or environmentally sensitive species or areas such as giant sequoia groves or vernal pools, respectively.

Physiography

Physiographic changes in slope, aspect, topographic position, or elevation, can sometimes define a monitoring type. Stratification based solely on these elements, however, is generally inappropriate, since the biological elements frequently transgress physiographic "boundaries", or occur over a broad range of conditions.

Fuel characteristics

Classic fuel models (Anderson 1982) may be subdivided into different monitoring types if the strata vary significantly. Examples are change in dead and downed loads, standing fuel density, duff loads, biomass height and continuity. Additionally, several monitoring types may be included within a single fuel model.

Prescription

Burn prescriptions define how the fire will behave, and therefore, expected burn results. Example of prescription criteria that are useful in stratifying a type are areas that will be burned at different intervals, seasons, or with different intensities.

Step 2: Describe the Monitoring Type

A detailed description of each monitoring type is essential in order to relocate index plots, monitor the biophysical elements of concern, and qualitatively compare indexes between areas or plots.
On the Monitoring Type Description Sheet (form FMH-4 in Appendix A) record the following information (see Appendix C for coding guidelines):

**Park Unit 4-Character Alpha Code**

**Monitoring Type Code**

**Monitoring Type Name**

**Prescription Criteria**

- **Burn Prescription.** Record the prescription to be used throughout the type.
- **Burn Goals.** Record the goals of burning in the type.

**Monitoring Type Variable(s)**

Although only one monitoring type variable need be statistically valid, it is strongly suggested that at least one variable in each layer of the monitoring type be monitored to a statistically valid level. For a more complete discussion of monitoring type variables see page 49.

**Biophysical Description**

Describe biological and physical elements selected in Step 1 that characterize the type. For example:

- **Physical.** Describe the range of topographic features included in the type (aspects, elevational range, gradient, landforms, etc.).
- **Biological.** Describe species that dominate or characterize the vegetation association. Indicate the acceptable range of values for the elements that define each stratum.

**Rejection Criteria**

Define when an area is not representative of the intended monitoring type. For example:

- An index plot may not be placed within 30 m of a road, trail, stream, meadow, anomalous vegetation patches, monitoring type boundary, or in a large rock outcrop or barren area.
**Plot Protocols**

Record the recommended and optional variables to be sampled, the areas in which monitoring variables are to be sampled, and all other protocols that apply to each individual monitoring type. For example:

Monitor the following preburn variables: herbaceous height, pole-size and seedling height, crown position (live only), tree damage (live only), herbaceous density, and collect voucher specimens.

Sample the following areas: brush density -- 3 m wide belt transect, overstory and pole-size trees -- all quarters, seedling trees -- Q1.

Monitor the following variables during the burn: duff moisture and flame zone depth.

Monitor the following postburn variables: char height.

**Examples of Monitoring Type Descriptions**

A monitoring type description should include the following level of effort and quantitative information:

**Forest/Woodland Types**

**Monitoring Type Code.** FABCO1D08 is the monitoring type code for a forest type (F) dominated by *Abies concolor* (ABCO1, white fir), and the prescription calls for burning in the fall when most plants are dormant (D); NFFFL fuel model 8 (08) is considered the best fit.

**Name of Type.** Montane Mixed Conifer Forest

**Burn Prescription.** Fall burns (August to November); time since last burn exceeds 25 years; average fuel loading greater than 10 tons/acre; 10-hr TLFM 7% to 15%; midflame wind speed <10 mph; average flame lengths 6 inches to 4 ft; rate of spread for head fire ≤ 1 ch/hr.

**Burn Goals.** Reduce fuel loading along boundary, stimulate pine regeneration, and encourage herbaceous components.

**Monitoring Type Variable(s).** Tons/acre 1000 hr fuels and density of overstory ponderosa pine regeneration.
Physical Description. Includes north, south, and west aspects (mostly south); gradients range from 10% to 60% (average 30%); contains midslope, upper slope and ridge top areas (mostly midslope); elevation ranges from 4,800 to 6,200 ft.

Biological Description. Incense cedar, white fir, and ponderosa pine combine for \( \geq 75\% \) of forest canopy cover; each has a minimum of 15% cover. Total canopy closure is \( >50\% \). Basal area ranges from 25 m\(^2\) to 60 m\(^2\)/hectare. Understory trees range from sparse (50 stems/hectare) individuals to thickets (3,000 stems/hectare). Hardwoods (including black oak) may or may not be present. Bear clover does not exceed 10% cover. No differentiation is based on herbaceous vegetation.

Rejection Criteria. Riparian corridors, large rock outcrops, and areas within 20 m of a paved or dirt road or a trail are excluded from this monitoring type.

Plot Protocols. Preburn protocols: Measure herbaceous height; record brush individuals using a belt width of 1 meter; use abbreviated tags; bury the origin and install all stakes except P1 and P2; collect voucher specimens; sample overstory, pole-size and seedlings in all quarters; monitor crown position (live only) and tree damage (live only); pole-size and seedling tree height; map seedlings; and tag all pole-size trees. During the burn protocols: flame zone depth. Postburn protocols: char height.

Grassland and Brush Types

Monitoring Type Code. BARTR1D05 is the monitoring type code for a brush type (B) characterized by *Artemisia tridentata* (sagebrush) (ARTR1); the prescription calls for burning in the fall when most plants are dormant (D); NFFL fuel model 5 (05) is considered the best fit.

Name of Type. Mixed Sagebrush and Cheatgrass

Burn Prescription. Spring burns (May to June); time since last burn exceeds 15 years; average biomass greater than 6 tons/acre; 1-hr TLFM 5% to 10%; 10-hr TLFM 7% to 15%; midflame wind speed <20 mph; average flame lengths 1 to 15 ft; rate of spread for a head fire 3 to 60 ch/hr.

Burn Goals. Reduce brush height by 40%, encourage wildlife habitat for Sage Grouse, and reduce overall fuel loading to protect life and property.

Monitoring Type Variable(s). Relative cover and density of *Artemisia tridentata* and the relative cover *Bromus tectorum*. 

*Chapter 4: Methods for Monitoring Forest, Brush, and Grassland Index Plots* 69
Physical Description. Includes north, east, and west aspects (mostly north); gradients range from 0% to 30% (average 5%); contains midslope, upper slope and ridge top areas, but the terrain is relatively open and gently sloping; elevation ranges from 4,000 to 6,000 ft.

Biological Description. Brush and grass community dominated by *Artemisia tridentata* and *Bromus tectorum*. Rabbitbrush (*Chrysothamnus nauseosus*) is present (< 5% cover). Native bunchgrasses are absent to occasional with squirrel-tail barley (*Sitanion hystrix*) the most common, and *Stipa* sp., *Poa* sp., and *Elymus cinereus* occasional. This community is a highly disturbed version of the *Artemisia tridentata*/native bunchgrass type.

Rejection Criteria. Cave entrances and collapse areas, seeps, large rock outcrops (> 70% barren), and areas within 20 m of a paved or dirt road or trail are excluded from this monitoring type.

Plot Protocols. Preburn protocols: Measure herbaceous height; record brush individuals using a belt width of 5 meters; install stakes at OP and 30P only; collect voucher specimens. During the burn protocols: flame zone depth. Postburn protocols: 100 point burn severity.

LOCATE INDEX PLOTS

Randomly locate 10 index plots per monitoring type throughout all units proposed for prescribed burning in the next 5 years. These 10 plots will be used to determine sample size. Ideally one or two plots will fall in most units scheduled for burning in the next 5 years.

Step 1: Randomly Locate Plots on a Map or Other Locator

Two methods are presented here for locating an index plot on a map, orthophoto (an aerial photograph that usually corresponds to the USGS 7.5 minute quad), or other locator. Both methods require very accurate base and burn unit maps before randomization or monitoring can begin. This step, along with finding the equivalent field location, can actually be the most time-consuming activity in monitoring index plots. Both methods establish a random point, called the plot location point, from which the plot origin point is randomly determined in the field.

A Geographic Information System (GIS) may be used in place of either method. The objective is to do whatever is necessary to select and record random index plot origin points in the field.
Method 1: Grid Map Method

Grid the area or areas containing each monitoring type scheduled for prescribed burning in the next 5 years into small sections roughly equivalent to the plot size (50 m x 50 m for forest types or 30 m x 30 m for brush and grassland types) on a map. Assign each grid unit within the monitoring type a unique number, and randomly select 10 index plot grid units (refer to Appendix B for random number generation instructions). The center point of the grid unit is the plot location point from which a random direction and distance are measured in the field to find the plot origin point. The plot, therefore, probably will not fall entirely within the randomly generated grid unit, but its origin point will.

Method 2: XY Coordinates Method

Prepare an XY grid. Overlay the XY grid on the map or orthophoto which contains the monitoring type. Select an origin in the lower left hand corner where X,Y = 0,0. A 30-cm clear plastic ruler or transparent grid works well for this purpose. Select pairs of random numbers to define X and Y points on the grid (see Appendix B). The intersection of the XY coordinates on the map is the plot location point from which the origin point is determined in the field from random distance and direction measurements.

Discard any index plot points or grid units which meet rejection criteria identified and recorded on form FMH-4. These rejected areas can be eliminated before gridding the monitoring type burn units if they are identified and excluded prior to gridding and randomly selecting the index plot location point or grid unit. To do this, however, requires an intimate knowledge of the burn unit area and perfect maps.

Mark the selected index plot location points or grid units on your map or other locator before going to the field.

Step 2: Field Locate Selected Plots

- Potential plot locations should be visited in the order they are randomly selected. This will eliminate the tendency to avoid plots located in difficult terrain or are otherwise operationally less desirable.

- Verify suitability by visiting each plot location point identified on the map in Step 1. Use a compass and measure (tape measure, hip chain, or pace) the distance to the plot location point. (Don’t forget to adjust your compass azimuth for the local declination.)

- Select a random compass direction (0° to 359°) using a random number generator (Appendix B).
• Select a random distance (0 to 20 m) using a random number generator.
• Check the area against the monitoring type description and rejection criteria on form FMH-4.
• Locate the plot origin point by moving the indicated direction and distance.

It may be very difficult to find plot location points in undifferentiated terrain, even from orthophotos or aerial photographs. An alternative locator method is to pinpoint the plot location point on the map and the nearest relatively easy-to-locate landmark. Determine the actual distance and bearing from the landmark to the plot location point determined in Step 1. Hike to the point using this information.

Step 3: Assess Index Plot Acceptability and Mark the Plot Origin

• If the index plot origin point and a 30-m radius from this point meet the criteria for the monitoring type, proceed to mark and establish the index plot.
• If the origin point and surrounding area meet one or more rejection criteria for the monitoring type, return to the plot location point. Orient 180° away from the previous randomly selected azimuth and move a distance of 50 m to a new plot origin point. If the second location meets one or more rejection criteria, abandon the plot location point and select a new one (return to Step 1).
• Install a REFERENCE STAKE, which is always the plot origin point (center point of the forest plot or the 0 point of a grassland or brush plot). Marking the plot is described in detail under the methods sections.

Step 4: Field Map the Index Plot for Relocation

• Map and label index plot locations by code (see step 5 for plot identification instructions) on a USGS 7.5, 15-minute topographic quad, or better map. Attach this map to the plot file.
• Map and label index plots on orthophoto quads or aerial photos, if possible. Using aerial photos should make relocation of the index plots much easier.
• Map and label index plot locations on a full park or large-scale map.

Step 5: Complete Location Data Sheet

Follow along with the completed Index Plot Location Data Sheets (FMH-5) on the following two pages as you read this step. A blank FMH-5 form is available in Appendix A.
• Assign and record the plot identification code (see Appendix C for detailed coding instructions). The index plot ID number is the 9 character monitoring type code, and a 2 digit plot number; ex.: FSEGI1T0801 or BARTR1D050L. The last two digits (plot number) should start with 01 for each monitoring type and continue sequentially within each type.

• Circle whether the index plot is to be burned or is a control (B/C). Record the burn unit name or number (or both), the date the form is being completed, who is completing the form, and the topographic map the plot is located on.

• Record longitude and latitude from LORAN unit, or UTM’s from a Global Positioning Device, if available. Record the average percent slope, and the elevation and aspect of the plot location. Record the declination used for all azimuths.

• Describe the fire history of the plot. At a minimum, include the date of the last fire, if known.

• Record the travel route used to access the index plot (also show this on a topo map).

• Record the compass bearing followed from the road or trail (or other relatively permanent reference point) to locate the index plot. Mark on the topo map where you left this well-known trail or road. (A photo of this location is optional; if a photograph is taken attach it to the datasheet).

• Describe how to get to the index plot and hand draw a route map. Remember others will have to find the plot for many years to come!

• Draw the reference stake location on the hand drawn map.

• Identify permanent or semi-permanent reference features on the site in case the reference stake is hard to find or disappears.

  The reference feature should be easy to relocate, such as an obtrusive and distinctive living tree or large boulder, peak, or cliff.

  Record the true compass bearing from the reference stake to the reference feature.

  Record the distance in meters from the reference stake to the reference feature.

  Take a photograph from the index plot reference stake toward the reference feature and also take the reverse photograph. Record the photo numbers and roll ID on form FMH-5. A plot number marker should be included in the photo to facilitate photo verification. The same kind of camera, lens (preferably 35 mm), and film should be used for original and follow-up photographs; subsequent photos should be taken at approximately the same time of day and in the same season as the original photographs. (See Appendix D for detailed instructions.)
◆ Describe the plot location, and map it as accurately and completely as possible on the field sheet (FMH-5). Remember, someone else will have to find this plot in the near and far future.

◆ Enter the Index Plot Location Data Sheet information into the computerized history of plot visits database.
Plot ID BCELE1D0612  Burn/Control (circle one) Date 7/17/87
Burn Unit BUTTE          Recorders Nelson, Rucklos
Topo Quad Caldwell Butte  Declination 17
UTM ZONE UTMN UTME
Lat 43°30'39" Long 121°31'11" Section 35 Township 45N Range 4E
Slope (%) 2  Elevation 4720 ft  Aspect N
Date of Last Known Fire 1946

Fire History of the Plot  A large wildfire swept through this area during the 1946 fire season. Fire intensity and ambient conditions were not recorded. No fires since 7/13/46.

1. Road and trail used to travel to the plot  First road on the right SE of Caldwell Butte.
2. True compass bearing at point where road/trail is left to hike to the plot: 277° degrees.
3. Mark and attach a map of the point where the road/trail is left to go cross-country to the plot.
4. Describe the route to the plot; include or attach hand drawn map.

1 mile hike SW from the Gravel Pit. Pass "hump" on south side of Caldwell Butte. Travel 75 meters to an open area at the base of the Butte. Plot is on level ground, 7 m from where the ground slopes up abruptly into the butte. Plot is ≈200 m past a linear rock out-cropping on the south side of the Butte.

5. True compass bearing from the plot reference stake to the reference feature 40°
6. Describe the reference feature 20-ft high boulder which is the high point on the linear rock out-cropping.
7. Photo # of picture from plot reference stake to reference feature 11
8. Photo # of picture from reference feature to plot reference stake 12
Lens focal length 35 mm, ASA 100 Film Ektachrome
Time photos taken 1035 , Roll ID 22
9. Distance from reference feature to reference stake 26 m
10. Describe the index plot location; include or attach hand drawn map of the plot layout (including plot reference stake) and significant features.
11. Deviations from monitoring protocols Y N (circle one)
12. If yes, describe

FMH-5; page 1 of 2
History of Site Visits

<table>
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<th>Date</th>
<th>Status</th>
<th>Purpose</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
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<td>PRE</td>
<td>monitor preburn</td>
<td></td>
</tr>
<tr>
<td>2 7/25/91</td>
<td>PRE</td>
<td>second preburn</td>
<td></td>
</tr>
<tr>
<td>3 8/1/91</td>
<td>Post</td>
<td>monitor postburn</td>
<td>presc. burned 7/27/91</td>
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<tr>
<td>4 10/22/91</td>
<td>mo2</td>
<td>monitor respouts</td>
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FMH-5
INDEX PLOT LOCATION DATA SHEET

Plot ID FPIPO1T0950  Burn/Control (circle one) Date 8/14/89
Burn Unit BUTTE  Recorders Nelson, Rucklos
Topo Quad Schconchin  Declination 17
UTM ZONE UTMN UTM E
Lat 43°32'00"  Long 121°45'15"  Section 32  Township 45N  Range 4E
Slope (%) 4  Elevation 5190 ft  Aspect W
Date of Last Known Fire 10/8/87

Fire History of the Plot  Unknown prior to 1987. In 1987 the
1,000 and 10,000 TLFM fuels were ignited to prepare for
burning of this unit.

1. Road and trail used to travel to the plot  Medicine Lake
   Road and Hidden Valley Trail.

2. True compass bearing at point where road/trail is left to
   hike to the plot: 91° degrees.
3. Mark and attach a map of the point where the road/trail is
   left to go cross-country to the plot.
4. Describe the route to the plot; include or attach hand drawn
   map.

   Hike down into Hidden Valley from Mammoth Crater parking
   area. There is a large yellow pine where the trail meets
   the valley floor. From there, hike 50 m at 330° to the
   plot. The plot is at the head of the canyon on the SW side.

5. True compass bearing from the plot reference stake to the
   reference feature 277°
6. Describe the reference feature  Head of the box canyon.
   01 and 04 are almost touching the canyon wall.
7. Photo # of picture from plot reference stake to reference
   feature 13
8. Photo # of picture from reference feature to plot reference
   stake 14
   Lens focal length 35 mm, ASA 64 Film Ektachrome
   Time photos taken 1315, 1320
9. Distance from reference feature to reference stake 25 m
10. Describe the index plot location; include or attach hand
    drawn map of the plot layout (including plot reference
    stake) and significant features.
11. Deviations from monitoring protocols Y N (circle one)
12. If yes, describe

FMH-5; page 1 of 2
Plot ID: FPIPO1T0950  B/C Burn Unit: BUTTE  Date: 8/14/89

### History of Site Visits

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<th>Date</th>
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<tbody>
<tr>
<td>8/14/89</td>
<td>PRE</td>
<td>monitor preburn</td>
<td></td>
</tr>
<tr>
<td>8/22/90</td>
<td>Post</td>
<td>immediate postburn</td>
<td>burned 8/10/90</td>
</tr>
<tr>
<td>7/28/91</td>
<td>yrl</td>
<td>monitor one year</td>
<td>incomplete brush</td>
</tr>
<tr>
<td>7/30/91</td>
<td>yrl</td>
<td>finish brush transect</td>
<td>complete</td>
</tr>
</tbody>
</table>


LAY OUT INDEX PLOTS

Once the index plot origin point has been located, the plot boundaries are defined and the actual collection of data begins. Procedures for these activities are different for forest plots than they are for grassland and brush plots; details are given in separate sections (page 91 for forest plots and page 119 for grassland and brush plots).

For all plots, however, note that laying out the plot and collecting data can devastate the variables being sampled. The monitor must exercise extreme care when approaching the plot, laying out the plot, and collecting data. It is important to follow these rules: avoid wearing shoes that tear vegetation, watch your step, keep the number of trips to the plot to a minimum, keep the number of monitors to a minimum, discourage observers, and plan to collect data on the most trampling-sensitive variables first, such as seedling trees, downed fuels, and herbaceous relative cover.

PLOT PLACEMENT PROBLEMS

Small Areas

Some monitoring types may occupy small areas or the remaining unburned monitoring type area is small. To meet the requirements of this Handbook, it will be necessary to delay burning these areas until the required number of index plots have been installed. Recently burned units cannot be designated as untreated areas within a monitoring type since management-induced changes due to prescribed burning have already occurred. Continued burning before implementation of this monitoring system could diminish the usefulness of this monitoring database since a large percentage of the monitoring type will be unavailable for sampling.

Since small areas generally have fewer plots (due to space limitations), it is important to burn, whenever possible, all the plots in the small area. The resulting (larger) database will improve the potential for meaningful analyses.

Irregular Areas

For very narrow or irregular monitoring types or burn units where it is impossible to randomly orient the plot, it is appropriate to orient the axis of the plot to fit within the narrow confines of the type or unit as long as the initial plot location points or grid units are randomly predetermined. The narrow burn unit should accommodate a range of plot axes which can then be randomly selected from.
INSTALL CONTROL PLOTS AS NEEDED

Control plots must be installed if park management desires to establish that fire caused the observed effects. (See chapter 3, page 56). When control plots are necessary they will be designed to monitor the specific variables of interest. Control plots may be installed at the same time as the burn plots, or later when a specific issue needs to be addressed.

Interpretation of the control plot data can be misleading. A major problem is that the control plot data can only be used to describe what happens in the absence of fire, not what happens in a naturally-functioning ecosystem. This Handbook does not prescribe how to install control plots. A vegetation or fire ecologist should assist in the development of control plot sampling procedures.

Generally, control plots must be installed under the same randomization rules as for the index plots. Control plots must be located outside of the areas scheduled for prescribed burns during, at least, the next 10 years. An adequate sample size for variables of interest must be collected; the number of control plots for a monitoring type may or may not be the same as for the index plots installed in the monitoring type. Data collection methods may be identical to those used for the index plots.

Control plot data sheets (Appendix A) are always marked by circling the "C". Plots to be burned are marked by circling the "B".

ADJUST SAMPLE SIZES

The initial 10 plots installed within each monitoring type do not necessarily fulfill monitoring precision requirements. These initial plots provide information for calculating the number of index plots (sample size) required, given a level of precision. If the sample size is calculated to be larger than ten, additional plots must be installed.

Objective-dependent variables not related to the vegetation in a monitoring type (such as wildlife populations) may or may not be used in determining the sample size. Variables such as scorch height and burn severity, which cannot be measured preburn, cannot be included in the determination of sample size.
Determine Levels of Precision

Statistics is the customary tool used to determine whether the differences in the means of two sample populations truly reflect differences in the underlying populations. The more variable the samples, the more uncertainty in that determination. The larger the number of samples, the greater the certainty.

The park manager must make his/her own decision about the level of uncertainty s/he can live with. The "level of significance" or Alpha is the likelihood that populations are the same when samples indicate they are different. In much of science, this has customarily been set at 0.05 (one chance in twenty of rejecting the null hypothesis when it is true, a false negative). In the resource sciences, high field variability makes an alpha of 0.05 often economically and practically unrealistic. If one can accept an uncertainty of, say 0.20, the necessary number of samples can be greatly reduced.

A second measure of uncertainty is the "power of the test," or Beta. Beta means the likelihood that samples are determined to be from the same population ("are not significantly different") when in fact they are. To put it another way, Beta reflects the likelihood that you will fail to detect actual changes in vegetation over time. Although the power of the test has often been ignored in science, in conservation it may be more important to say the sky is falling when it is okay (Beta) than to say things are fine when the sky is falling (Alpha). Unfortunately, the two measures of uncertainty are a zero-sum game. Increasing the certainty of one reduces the certainty of the other, unless you increase sample size.

Each monitoring type has a true (population) value for every variable. Measurement of all the area within the type would reveal the true value, but would be prohibitively costly. The sampling procedure outlined in this Handbook provides a method for estimating these true values using reasonably small portions of a monitoring type. The mean variable values among index plots will be used to estimate the population values. In general, such estimates have greater precision (certainty) when they are derived from larger numbers of plots. It is therefore possible to change the precision of our estimates by altering the number of index plots used. The data from the ten initial plots in each monitoring type are used to estimate the number of index plots needed to yield the chosen level of precision (certainty) in that type. The number of index plots, therefore, will vary by monitoring type.

Precision will be here represented by the width of 95% confidence intervals. A 95% confidence interval is a range of variable values which has 95% probability of including the true value. The mean value obtained from index plots will always be located in the center of this interval. The width of a confidence interval can therefore be represented by the distance from the mean to the outer edge of the range.
confidence interval. If we represent the magnitude of this distance by the letter $d$, we can say that there is a 95% probability that our sample mean will be within $d$ units of the true value for the monitoring type. The quantity $d$ is expressed in the units of the variable under consideration. Small values of $d$ therefore indicate that the sample mean is likely to be very close to the true value. The width of confidence intervals can also be represented as a percentage of the sample mean. These two representations of precision are related by the equation

$$d = x \times \frac{R}{100}$$

where $R$ represents the percentage, $d$ represents the distance from the mean to the edge of the 95% confidence interval, and $x$ is the sample mean.

**Calculate the Minimum Number of Index Plots**

1. Calculate the mean and sample standard deviation (not standard error) of one of the monitoring type variables or variables used as primary indicators of long-term change within the monitoring type. Use data from the ten initial index plots. Call the mean $x$, and the sample standard deviation $s$. (Follow the same steps for objective-dependent variables.)

2. Choose a desired level of precision by choosing a value of $R$. **This value is required to be 25 or less.** Now calculate a corresponding value for $d$ using the equation

$$d = x \times \frac{R}{100}$$

where $R$ represents the desired precision as a proportion of the mean, $x$ is the sample mean from your 10 initial index plots, and $d$ is the distance from $x$ to the outer edge of the 95% confidence interval for the critical variable.

3. Calculate the number of index plots needed to obtain the desired level of precision. The required number of index plots is given by

$$n = 4 \times \frac{s^2}{d^2}$$

4. Repeat this process for each variable selected. The largest number calculated for a variable in these repetitions will be the number of index plots required for this monitoring type.
Example 1

From a single monitoring type, the data from 10 index plots are available. For one of the monitoring type variables, the calculations are as follow:

1. The sample mean and sample standard deviation are \( x=10, \ s=3 \). 

2. The value \( R=20 \) has been chosen as a desirable level of precision.
   Therefore \[ d = 10 \times 20/100 = 2 \]

3. The required sample size is \( n = 4 \times 3^2/2^2 = 9 \).

These results indicate that, for this variable, the use of 9 index plots in this type will give a mean value which will be within 2 units of the true value with 95% probability. This is equivalent to the statement that our estimated value will be within 20% of the mean value with 95% probability. For another of the variables, the calculations are as follow:

Example 2

1. The sample mean and sample standard deviation are \( x=20, \ s=10 \).

2. The value \( R=25 \) has been chosen as a desirable level of precision.
   Therefore \[ d = 20 \times 25/100 = 5 \]

3. The required sample size is \( n = 4 \times 10^2/5^2 = 16 \).

These results indicate that, for the second critical variable, the use of 16 index plots in this monitoring type will give a mean value which will be within 25% of the mean value with 95% probability. To guarantee adequate precision for both variables considered so far, 16 index plots must be used.

Add Extra Index Plots to the Sample

After the minimum number of index plots has been calculated add at least 2 extra plots to the sample size. These extra plots are necessary since some plots are usually thrown out for a variety of reasons, such as burning out-of-prescription or not being representative of the monitoring type (often occurs in the early stages of plot installation due to monitor inexperience).
Cautionary Notes

The number of plots determined by this method should yield results of the desired precision, so long as the condition of the index plots remains similar to that measured during preburn monitoring. A drastic change in conditions, such as burning, may be accompanied by changes in precision. Although preburn adjustment of numbers of plots is sensible, it will not guarantee a similar level of postburn precision. Without further information on burn effects, better guesses cannot be made.

All index plots—the initial 10 and those generated from sample size calculations—must be randomly distributed through the same units (by monitoring type) proposed for burning in the next 5 years, and must be monitored no more than 2 years prior to burning.

Limit the number of index plots per monitoring type to twenty-five or thirty. Consult the WRO Prescribed Fire Specialist or Program Manager if minimum plot calculations exceed this limit.

MONITOR VEGETATION, FUEL, and FIRE CHARACTERISTICS

Instructions for vegetation, fuel, and fire characteristics monitoring procedures are provided separately in the forest methods (page 91) and grassland-brush methods (page 119) sections.

MONITORING SCHEDULE

The monitoring schedule for both forest and grassland-brush plots is directly related to the phases of the burn program.

Preburn

Index plots should be installed, the variables measured, and the area burned within the same year. At most, the index plot can be burned within two years of establishment. If two or more years have passed, the index plot variables must be remeasured prior to burn treatment.

Burn and Postburn

Following index plot establishment plots are revisited

- during the fire (to record fire behavior),
- immediately postfire (approximately 2 months),
and 1 year, 2 years, 5 years, 10 years, and at 10 year intervals after burning.

On forest plots, postfire measurements include all MAS variables, except overstory tree diameter, during the immediate postfire and the one year visits. Most variables are remonitored at every postburn visit. Trees which were alive prefire but have died subsequently are noted.

On grassland and brush plots, postfire measurements include all MAS variables, most of which are monitored at every postburn visit.

All index plot variables must be reread within 2 months after the burn. Vegetative parameters must be remonitored during the growing season at postburn intervals 1, 2, 5, and 10 years. Thereafter, monitoring will be at 10 year intervals until each unit is either placed within a prescribed natural fire zone or the prescribed burn objectives change.

The season in which recurrent sampling occurs is just as important as specified year. In general, sampling should be scheduled to minimize seasonal variation between visits. Index plots should be revisited when phenological states are comparable to the status of the more ephemeral species recorded in the initial survey. Some very early or late season species may be overlooked by this survey. If those species are of major concern, a multiple sampling season survey should be initiated.

Index plots should be revisited around the date of original establishment, however, adjustments due to seasonal irregularities, such as prolonged snow cover, must be made in order to minimize between-year variation. Comments on the phenological state of the plants should be made at each visit. This will help determine future sampling dates when there is uncertainty about timing of phenological events. It will also facilitate determination of differences that may be due to seasonal weather variations rather than to other variables.

DATA PROCESSING

Data will be encoded into IBM compatible personal computers from standardized data sheets using the Fire Monitoring Handbook software--FMH.EXE. The data entry and analysis program utilizes dBASE database files, but is a stand alone package which does not require any other software to run other than DOS.

The software program is available on a single 360K diskette. A software manual, called the Western Region Fire Monitoring Handbook Software Manual, is available as a companion document to this Handbook.
Data entry is designed to mimic standard data sheets. The addition of pull down menus, specific help, and extensive error checking makes FMH.EXE powerful and easy for computer novices to use. Any software which can access DBASE files (such as DBASE and FoxBASE) can be used to edit, enter, and analyze the data, but using FMH.EXE will enhance data integrity by providing validated data entry and will automate standard data analyses.

Once data have been entered, analyses routines in FMH.EXE calculate all MAS variables, and some recommended and optional variables. Minimum plots calculations also output the mean, standard deviation, standard error, and range. Data summaries should be filed with the plot data, and copies sent to the Western Regional Office.

Formulae used to calculate cover and density are described in the software manual.

A park generated floppy disk containing current database files and data summaries will be sent to WRO annually where they will be kept in subdirectories named with the four character park code (ex.: PINN for Pinnacles National Monument).

FILES MAINTENANCE

A raw data file should be established for each plot. Maps, data collection forms, slides, data analysis, and all other pertinent information should be dated and placed in this file.

Each plot file folder should be labelled with its plot identification code (Appendix C) and burn unit. All plots associated with a monitoring type should be filed sequentially within the type; for example, the first file would be labeled FSEQI1T0801, the second file would be labeled FSEQI1T0802, and so on.

REFERENCES

Vegetation


Fuels


Martin, R.E., D.W. Frewing, and J.L. McClanhan. 1981. Average biomass of four northwest shrubs by fuel size class and crown cover. USDA Forest


Sample Size


Fire Behavior


Specific Methods

Forest ................................................................. 91
Grassland and Brush .............................................. 119
Figure 2. Steps in forest plot layout: A, at origin point, bury a reference stake; at other points marked with star, place metal stakes; B, lay out 90° angles; C, place coded stakes. Key: * = ½-inch wide metal stakes; corners, origin, and centerline; × = ¼-inch wide metal stakes; fuel inventory endpoints.
LAY OUT INDEX PLOT

Refer to Figure 2 as you read this section.

Locate the Plot Origin

You have arrived at a randomly derived plot origin point (the plot center); mark this point by installing a reference stake at the "Origin" as shown in Figure 2A.

Establish the Plot Centerline

Next, select a random azimuth (Appendix B) and measure out a 50-m line from the reference stake along this azimuth. The centerline is defined by a tape measure laid-out as straight as possible. To lay out this 50-m tape, stand at the plot origin and run the 0 end of the tape toward the 0P point (along the back azimuth) and the 50m end of the tape to the 50P (Figure 2A). The azimuth of the line runs from the 0P toward the 50P point. The 25-m mark will be located at the plot origin.

Orient the Plot Quarters

The plot is divided into quarters which are assigned numbers according to the following protocol. The monitor should stand at the plot origin, with both feet on the centerline and the 0 point (0P) on their left. Quarter 1 (Q1) is to the monitor’s forward-right. Quarters 2, 3, and 4 are numbered clockwise from Q1 as shown in Figure 2A.

Establish the Plot Boundaries

Laying out the tape to define the plot boundaries requires at least two monitors—one for each end. These plots are very large and one monitor could lose sight of the other, making it difficult to "square" the plot corners (90° angles). The monitors must take the time laying out the plot to create a true rectangle. A few helpful hints to accomplish this task are provided here.
The plot centerline should be laid-out as straight as possible. The three 20-m (or 30-m) tapes that lie perpendicular to the centerline should also be laid-out as straight as possible so that the tapes intersect at right angles. To accomplish this the principle of the 3, 4, 5 triangle may be used. For every right angle, measure 3-m along the 20-m tape where it intersects the centerline; mark the measurement. Measure 4-m along the centerline; mark the measurement. The hypotenuse of the resulting triangle should be 5-m as illustrated in Figure 2B. If the hypotenuse is not 5-m, adjust the 20-m tape to achieve this length. Lay out the endline (Figure 2A) and midline tapes, making sure that they are all reading 0 on the same side of the plot.

In sparsely vegetated forest types it may be possible to triangulate using larger triangles. For example, in Figure 2B the hypotenuse of the triangle from the centerline OP to point P1 is 26.92-m.

**Mark the Plot**

Define the plot, quarters, and fuel inventory lines as shown in Figure 2C with metal stakes. Bury a ½-inch wide stake (the reference stake) at the plot center or Origin. Install ½-inch wide rebar stakes at the four corners of the 20 m x 50 m plot (Q1, Q2, Q3, and Q4) and at the starting points along the centerline for the 4 fuels inventory transects (1A, 2A, 3A, and 4A). Place a stake at either end of the center line (points 0P and 50P), and a stake at either end of the short axis midline (points P1 and P2). Define the ends points of the fuels inventory lines by installing ¼-inch mild rolled steel stakes at these points (1B, 2B, 3B, and 4B).

Stake height above the ground should be sufficient to allow easy relocation of the stakes. Stakes should be installed deep enough to provide adequate basal stability relative to the height necessary to bring the stake into view. Suggested stake lengths are: ½ m (2 ft) for forest plots. It is generally best to overestimate the stake heights needed, to compensate for snow creep and vegetation growth.

Burial of the plot reference or Origin (center) stake is recommended, especially in areas subject to vandalism or disturbance. The other key stakes (Q1, Q2, Q3, Q4, 0P, and 50P) may also be considered for burial, but only as a last choice.

Color code plot beginning and ending stakes (orange for 0P, blue for the 50P). Paints should be high temperature resistant. Repaint the stakes after the burn.

Park managers will have to determine whether plot marking standards recommended in this Handbook are appropriate for their unit. This Handbook calls for the placement of 13 ½-inch rebar stakes and four ¼-inch rolled steel stakes per plot. These markers are important for the relocation of sample areas.
and transects. In some situations, however, these metal stakes may be a hazard or may be visually or philosophically intrusive. Plastic caps placed on the top of the stakes may prevent injuries, but they can increase stake visibility. Where site vandalism is chronic or where visitation is high, plot markers may have to be severely limited. At an absolute minimum, the reference stake (O) and the four corner stakes (Q1, Q2, Q3, and Q4) must be installed. These stakes can be camouflaged by paint or by total or partial burial. Deviations from the Handbook recommendations/standards should be well documented.

Plots are distinguishable from one another through identification codes (described in detail in Appendix C) etched onto metal tags which attach to the metal stakes. These tags should be prepared and installed as described below.

- Use rectangular or oblong brass tags (Appendix E).
- The recommended format includes the index stake location code, plot purpose, plot identification code, and date on the tag. An abbreviated format may be used to reduce the amount of minting. It includes the vegetation code from the plot identification code (minus the trailing number), plot number, index stake location code, plot purpose, and date. The two formats are displayed below:

![Recommended Stake Label](image)

**Recommended Stake Label**

- stake location code*
- indicates plot purpose
- plot identification code
- date; month, day, year

![Abbreviated Stake Label](image)

**Abbreviated Stake Label**

- stake location code*
- indicates plot purpose
- dominant species code & plot number**
- date; month, day, year

* The stake location codes are identified in Figure 2C.
** The dominant species code is from the plot identification code.

**Photograph the Plot**

To minimize vegetation trampling, photograph the index plot following the "Field of View" sequence below. Write the plot identification code and each field-of-view code in large black letters on a white sheet of paper. Have someone hold the sheet so that these codes are visible in each photograph. More detailed instructions are available in Appendix D.
Field of View

<table>
<thead>
<tr>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP</td>
</tr>
<tr>
<td>Q4-Q1</td>
</tr>
<tr>
<td>P1</td>
</tr>
<tr>
<td>Q1-Q4</td>
</tr>
<tr>
<td>50P</td>
</tr>
<tr>
<td>Q2-Q3</td>
</tr>
<tr>
<td>P2</td>
</tr>
<tr>
<td>Q3-Q2</td>
</tr>
</tbody>
</table>

Record photographic information data on the Forest Plot Data Sheet (form FMH-7 in Appendix A) noting lens, film, and time of photographs. A 35 mm lens is desirable. A databack on the camera is often useful, ensuring that date and time is printed on the film. Each photo must include the appropriate identification code; these are available on FMH-7 (Appendix A) for reference. Label all slides as described in Appendix C.

A photographic record sheet for individual rolls of film is available for use in Appendix A (FMH-26). This record makes labeling of individual slides or photographs much easier.
Table 7. Forest plot specifications, by variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Plot Size or Transect Length</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overstory Trees</td>
<td>Plot: 20 m x 50 m (0.1 ha)</td>
<td>Quarters 1, 2, 3, 4</td>
</tr>
<tr>
<td>Pole-size Trees</td>
<td>Plot: 10 m x 25 m (0.025 ha)</td>
<td>Quarter 1</td>
</tr>
<tr>
<td>Seedling Trees</td>
<td>Plot: 5 m x 10 m (0.005 ha)</td>
<td>Portion of Quarter 1</td>
</tr>
<tr>
<td>Dead and Downed Fuel Array</td>
<td>Transect: four, 50 ft each (200 ft)</td>
<td>Quarters 1, 2, 3, 4</td>
</tr>
<tr>
<td>Brush and Herbaceous Layer</td>
<td>Transect: two, 50 m each (100 m)</td>
<td>Outer Portions of Quarters 1, 2, 3, 4</td>
</tr>
<tr>
<td>Brush Density</td>
<td>Plot: ten, 1 m x 1 m (100 m²)</td>
<td>Outer Portions of Quarters 1, 2, 3, 4</td>
</tr>
</tbody>
</table>

MONITOR PREBURN VEGETATION CHARACTERISTICS

Plot Specifications

Recommended plot size and sampling locations vary for each monitoring variable (see Figure 3 and Table 7).

Figure 3. Sampling areas and transects for forest plot monitoring variables. For explanation of stake codes (starred) see Figure 2C.
The plot sizes and transect lengths in Table 7 are adequate for most forest types, but revisions may be necessary to reduce the potential for excessive data collection or to increase data precision for a particular variable. These adjustments may be particularly important when a key variable is sparse.

Where variability is high, calculated sample size (number of plots) may exceed 50. There are three means of reducing variability: (1) at each index plot increase the sample points, area, or transect lengths monitored for problem variables, (2) install a large number of index plots, or (3) further stratify the monitoring types and create additional sets of index plots. Locating and installing plots is very time-consuming, therefore (1) is the preferred means of reducing variability.

Use the following sample area adjustment guidelines and/or refer to a reputable vegetation monitoring source such as Mueller-Dombois and Ellenberg (1974). **Once a sample area has been selected, however, it should not be changed.** Sample area (plot size) must be consistent between plots within a monitoring type and should be consistent for each variable. If a sampling area is enlarged, plots installed prior to the enlargement should be revisited to bring all plots up to the same level.

Occasionally, it may be necessary to deviate from the Handbook standards or protocols. If this happens, document all deviations from the standard dimensions used in this Handbook, no matter how insignificant they may appear to be. Unfortunately, sampling deviations could create data processing difficulties using the standardized software provided. Data analyses can be made manually, however, or with a commercial statistical software package.

**Overstory Trees**

The 20-m x 50-m plot size may be unnecessarily large for dense stands of overstory (dbh > 15 cm) trees. In this situation try reducing the plot to a 10-m x 25-m size. If this adjustment is made, corresponding adjustments must be made for pole-sized and seedling tree monitoring areas, and the downed fuel inventory lines must be installed at 5-, 10-, 15-, and 20-m points along the midline.

Where the overstory trees are very sparse or extremely large (such as giant sequoias) the 20-m x 50-m plot size may be doubled. Original sampling dimensions can be maintained for all other variables.

**Pole-sized Trees**

Pole-sized trees (dbh ≥ 2.5 cm and ≤ 15 cm) are sometimes so dense (≥ 50 / unit area) that the 10-m x 25-m area defined in quarter 1 (Q1) is excessive. In this situation try monitoring the medial half of Q1 (5-m x 12.5-m area). Where pole-sized trees are sparse (≤ 20 or > 10 / unit area) quarters 1 and 2 (Q2) should be monitored; the area within quarters 3 (Q3) and 4 (Q4) may be added in...
extremely sparse (≤ 10 / unit area) situations. Figure 4 graphically describes the terms "dense", "sparse", and "extremely sparse". A rule of thumb is to monitor pole-sized trees in all quarters if the vegetation type has 10 or fewer trees per 250 m² (one quarter).

Seedling Trees

Seedling trees (dbh < 2.5 cm) are monitored in a 5-m x 10-m area. In dense seedling tree situations (≥ 50 / unit area), reduce the sampling area to 2.5 m x 5 m. In sparse seedling tree areas (≤ 20 or > 10 / unit area), try monitoring seedling trees in all of Q1—a 10-m x 25-m area. Where seedling trees are extremely sparse (≤ 10 / unit area), tally seedling trees in all four quarters (20 m x 50 m). Refer to Figure 4 for a graphic impression of "dense", "sparse", and "extremely sparse".

Dead and Downed Fuels

The dead and downed fuel transects may be shortened or lengthened according to fuel density and continuity. Refer to the "Handbook for Inventorying Surface Fuels and Biomass in the Interior West" (Brown et al. 1982).

Brush and Herbaceous Layer

In most forested areas, 332 intercepts (two 50-m transects) may be barely adequate since the brush, forb, and grass elements are often sparse. Where these variables are extremely sparse (≤ 55 hits/transect) and one or several of them need to be sampled to statistical validity, add the plot midline (OP to 50P; see Figure 3) as a third transect. Where the vegetation is dense (≥ 111 hits/transect), monitor only one of the 50-m transects (monitor transect Q1 - Q4 as a minimum; see Figure 3).

Brush Density

One-half meter wide belt transects are required as a minimum (25 m²; 0.5 m x 50 m). If brush species are widely dispersed, or rare, consider widening the belt transect to 5 m (250 m²; 5 m x 50 m). Use the same data sheet (FMH-18), but record the new belt width. Once a belt width has been selected for the monitoring type it should remain consistent between plots.

Figure 4. Tree density classes.
Overstory Trees

Overstory trees are defined in this monitoring system as both living and dead trees with a diameter at breast height (dbh) of > 15 cm.

Tag and Measure all Overstory Trees in all Four Quarters

Living and dead trees are tagged with sequentially numbered brass tags nailed into the trees at dbh. Orient the tags so that each faces the plot center, except in areas, such as near trails, where the tags must be oriented to make them less visually obtrusive.

The dbh of trees on a slope shall be determined while standing at the midslope side of the tree. The dbh of a leaning tree is measured by leaning with the tree. Aluminum nails are driven so that the tag hangs down and away from the tree and several centimeters of nail remains exposed, leaving ample space for tree growth. Trees on the plot boundary line are included if their base is halfway or more inside the plot defined by the 20-m x 50-m rectangle. Start in quarter 1 and tag through quarters 2, 3, and 4 consecutively.

Nonsprouting trees forked below dbh should be considered separate trees and tagged separately. If the bole of a fallen tree is below dbh, and the individual is resprouting, the sprouting branches should be treated as individuals. Resprouting trees should be considered on a species by species basis. When it is possible to identify a parent plant, it should be tagged as one individual and measured at dbh on the largest stem. If a parent individual cannot be identified, individual stems should be tagged and measured. Clarifying comments may be included on the datasheet, especially for resprouting trees.

MAS Procedures

Record the plot identification code, whether this is a burn or control plot (B/C), the data collection date, and names of the data recorders on the Overstory Tree Data Sheet (FMH-8 in Appendix A). For all overstory trees record the quarter the tree occurs in (QTR), the tree tag # (TAG), species code (SPP) (refer to Appendix C for coding guidelines), diameter (DBH), and circle whether the tree is alive (Yes or No). Record miscellaneous overstory tree information in COMMENTS.

Map each overstory tree by tag # on the Full Plot Tree Map (form FMH-9) which covers a 1000-m² area. If overstory trees are dense, use four of the Quarter Overstory Tree Maps (FMH-10); one for each quarter.
Crown Position and Tree Damage (recommended)

Monitor the recommended variables "crown position" and "tree damage", if possible. Space is provided on the FMH-8 data sheet for these data. Procedures and forms for monitoring mortality are not given.

Crown Position. Crown position, an assessment of the canopy position of live overstory trees (Avery and Burkhart 1963), is recorded in the column marked CROWN using a numeric code, see Figure 5 (crown position of dead overstory trees is optional):

1 = Dominant: Trees with crowns extending above the general level of the crown cover, and receiving full light from above and partly from the side; these trees are larger than the average trees in the stand and have well-developed crowns, but may be somewhat crowded on the sides.

2 = Codominant: Trees with crowns forming the general level of the crown cover and receiving full light from above, but comparatively little from the sides; these trees usually have medium sized crowns, and are more or less crowded on the sides.

3 = Intermediate: Trees shorter than those in the two preceding classes, but with crowns either below or extending into the crown cover formed by codominant and dominant trees, receiving little direct light from above, and none from the sides; these trees usually have small crowns and are considerably crowded on the sides.

4 = Subcanopy: Trees with crowns below the general level of the crown cover receiving no direct light from above or from the sides.
Figure 5. Crown Position Codes: 1 = Dominant; 2 = Codominant; 3 = Intermediate; 4 = Subcanopy.

**Tree Damage.** It is often desirable to identify living overstory trees exhibiting signs of stress (loss of vigor) before the burn. By doing this you can infer that if those trees die relatively soon following the fire, their death may not be wholly attributable to the fire, but to a combination of factors.

The monitor's ability to evaluate prefire damage will determine the value of the data. A trained specialist will undoubtedly observe more. (Appendix H contains several forest pest and disease references).

The following list of structural defects and signs of disease is simplistic (certainly not all inclusive), but should serve as a useful guideline. Parks may add categories to include damage of local importance. Record this data for living
overstory trees (tree damage assessment is optional for dead trees) under DAMAGE on the FMH-8 form in Appendix A.

ABGR Abnormal growth pattern for the species of concern. This category would include a range of physical deformities not included in the remainder of the damage codes.

BIRD Bird damage such as woodpecker or sapsucker holes.

BLIG Blight is generally defined as any plant disease or injury that results in general withering and death of the plant without rotting. Blight can result from a wide variety of needle, cone, and stem rusts, and canker diseases, and are often species or genus specific. Knowledge from local plant pathologists may assist in identifying specific blight conditions.

BROK Broken top in the tree.

BROM Witches broom diseases are characterized by an abnormal cluster of small branches or twigs on a tree as a result of attack by fungi, viruses, dwarf mistletoes, or insect injury. Brooms caused by dwarf mistletoe and from yellow witches broom disease are common in the Western Region area.

BURL A hard woody, often rounded outgrowth on a tree. May be naturally occurring in some tree and shrub species, and a sign of an infection or disease in other species.

CONK The knobby fruiting body of a tree fungal infection visible on a tree bole, such as a shelf fungus.

CROK Crooked or twisted bole.

EPIC Epicormic sprouting, adventitious shoots arising from suppressed buds on the stem, often found on trees following thinning or partial girdling.

FIRE Fire scar or cambial damage due to fire.

FORK Forked top of a tree, multiple primary leaders in a tree crown.

INSE Visible insects in the tree bole or the canopy, or their sign, such as frass or pitch tubes, bark beetle galleries, or gall infections.
LEAN  Tree is leaning.
LIGT  Lightning scar or other damage to the tree caused by lightning.
MAMM  Damage caused by mammals, such as bear claw marks, porcupine or beaver chewings, and deer or elk rubbings.
MISL  Mistletoe is visible in the tree (as opposed to signs of mistletoe such as broom without visible mistletoe).
SPRT  Basal sprouting, new shoots arising from the root collar or burl.
ROOT  Large roots are exposed.
ROTT  A rot of fungus in a tree other than a conk, often associated with a wound or crack.
SPAR  Unusually sparse foliage for that species and size of tree.
TWIN  A tree which forks below DBH and has two or more boles.
UMAN  Human caused damage such as axe marks, embedded nails or fence wire, vandalism.
WOND  A wound to a tree which cannot be identified by one of the other damage codes, wounds, or cracks, of unknown cause.

Record Species Codes Used

Every time a species code is used for any plot or transect in the park the species name and code must be recorded on FMH-6. This form serves as a running list of used codes. Only one list is kept for the entire monitoring program. Monitors should always carry this sheet when they are collecting data and should refer to it every time they assign a species code (see Appendix C for coding guidelines). Use of this sheet will keep the same code from being used for two different species, and will greatly facilitate data processing.
Pole-sized Trees

Pole-sized trees are defined in this monitoring system as standing living and dead trees with a diameter at breast height (dbh) \( \geq 2.5 \text{ cm} \) and \( \leq 15 \text{ cm} \).

**Measure Density and DBH of Pole-sized Trees in Quarter 1**

Count, measure dbh, and, where it would not be visually obtrusive, tag (recommended) (by numbers that are different than for the overstory trees) all pole-sized trees within quarter 1. When the tree is too small to tag at dbh, or the tagging nail could split the trunk, place the tag at the base of the tree. Nonsprouting coniferous trees forked below dbh should be considered separate trees and tagged separately. Resprouting trees should be tagged as one individual and measured at dbh on the largest stem. If a parent individual cannot be identified, individual stems should be tagged and measured. Notes should be added in the comments column of the datasheet on resprouted trees. If trees are not individually tagged, they can be counted by species (and height class if desired). Map each tree in quarter 1 (Q1) on form FMH-12 (Appendix A) to show the distribution within quarter 1. Label each tree on the map by tag number. If pole-sized trees must be monitored in more than one quarter, use the Alternate Pole-sized Tree Map (form FMH-13 in Appendix A).

**MAS Procedures**

Record the plot identification code, whether this is a burn or control plot (B/C), the data collection date, and the names of the data recorders on FMH-11. Record the quarter the tree occurs in (QTR), the tree tag (TAG) (recommended), species code (SPP), tag number (TAG), the diameter (DBH) of each tree, and whether it is alive (LIVE).

**Record Species Codes Used**

Every time a species code is used for any plot or transect in the park the species name and code must be recorded on FMH-6. This form serves as a running list of used codes. Only one list is kept for the entire monitoring program. Monitors should always carry this sheet when they are collecting data, and should refer to it every time they assign a species code (see Appendix C for coding guidelines). Use of this sheet will keep the same code from being used for two different species, and will greatly facilitate data processing.
Measure Pole-sized Tree Height (recommended)

Measure and record pole-sized tree height (HGT) on the Pole-sized Tree Data Sheet (FMH-11) for each tree encountered. Use the following height class codes (also available for reference on form FMH-11):

<table>
<thead>
<tr>
<th>Height Class Codes (height1 in centimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  0-15</td>
</tr>
<tr>
<td>2  15.1-30</td>
</tr>
<tr>
<td>3  30.1-60</td>
</tr>
<tr>
<td>4  60.1-100</td>
</tr>
</tbody>
</table>

1Height is measured from the ground level to the highest point of growth on the tree. A bent tree can have its highest point below the growing apex.

Seedling Trees

Seedling trees are defined in this monitoring system as living (recording information on dead seedlings is optional) trees with a diameter at breast height (dbh) < 2.5 cm. Trees that are less than the height required for dbh, are treated as if they were seedlings, regardless of age. A tree cannot be pole-sized and less than the height necessary for dbh by definition. Multi-branched trees would be better measured at some other point than breast height, probably basal height.

Count Seedling Trees To Obtain Species Density

Count the number of seedling trees by species within the medial section of quarter 1 (see Figure 6 below), a 50 m² area.
**MAS Procedures**

Record the plot identification code, whether this is a burn or control plot (B/C), the data collection date, and the names of the data recorders. For all seedling trees record the number of individuals (TALLY) by species (SPP) on the Seedling Tree Data Sheet (FMH-14 in Appendix A). An optional sketch map of the seedling tree aggregates may be made on form FMH-15 (50 m² Seedling Tree Map) or form FMH-16 (250 m² Seedling Tree Map). In areas with few seedlings in the understory or where tracking individual seedlings through time is important, an optional mapping procedure is to give individual seedlings sequential map numbers (MAP#), so that data can be correlated between the Seedling Tree Data Sheet (FMH-14) and the Seedling Tree Maps (FMH-15 or -16).

**Record Species Codes Used**

Every time a species code is used for any plot or transect in the park the species name and code must be recorded on FMH-6. This form serves as a running list of used codes. Only one list is kept for the entire monitoring program. Monitors should always carry this sheet when they are collecting data, and should refer to it every time they assign a species code (see Appendix C for coding guidelines). Use of this sheet will keep the same code from being used for two different species, and will greatly facilitate data processing.

**Measure Seedling Tree Height (recommended)**

Record the number of seedling trees (TALLY) by species (SPP) in each height class (HGT) on the Seedling Tree Data Sheet (FMH-14) for each tree encountered. Use the following height class codes (also available for reference on form FMH-14):

<table>
<thead>
<tr>
<th>Height Class Codes (height in centimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0-15</td>
</tr>
<tr>
<td>2 15.1-30</td>
</tr>
<tr>
<td>3 30.1-60</td>
</tr>
<tr>
<td>4 60.1-100</td>
</tr>
<tr>
<td>5 100.1-200</td>
</tr>
<tr>
<td>6 200.1-300</td>
</tr>
<tr>
<td>7 300.1-400</td>
</tr>
<tr>
<td>8 400.1-500</td>
</tr>
<tr>
<td>9 500.1-600</td>
</tr>
<tr>
<td>10 600.1-700</td>
</tr>
<tr>
<td>11 700.1-800</td>
</tr>
<tr>
<td>12 800.1-900</td>
</tr>
<tr>
<td>13 900.1+</td>
</tr>
</tbody>
</table>

1Height is measured from the ground level to the highest point of growth on the tree. A bent tree can have its highest point below the growing apex.
Brush and Herbaceous Layer

**MAS Procedures**

Use a "point line-intercept" method (Veirs and Goforth 1988) to measure the number of transect hits (frequency of species occurrence), relative cover, and density (brush only) by species over time. Sampling should occur during the season in which the plants can most easily be identified and when the biomass is greatest, usually in late spring or early summer. Thereafter remonitoring should occur at the same phenological stage. The collection of voucher specimens is strongly recommended as discussed on page 109.

**Locate the Point Line-Intercept Transect**

The point line-intercept transect runs along both 50-m lines that delineate the outside long axis of the forest plot rectangle. The transects are called Q4-Q1, Q3-Q2 and QP-QP. The Data Sheet for 50 Meter Transects (FMH-17 in Appendix A) requires that the monitor circle which transect is being monitored. There can be up to three FMH-17 forms used for each forest plot, one for each 50-m transect.

**Collect # of Transect Hits, Relative Cover, and % of Non-native Species Data**

Start at the Q4 stake, which should be at 0 on a 50-m tape. Take a ¼-inch diameter rangepole, graduated in decimeters, and every 30 cm along the transect line, place it gently so that the pole is plumb to the ground on slopes, but not perpendicular to the ground (a rigid plumb bob). The first intercept hit is at 30 cm, not at 0 cm. The last point will be at 4,980 cm (49.8 m). There will be 166 points from 30 to 5,000 cm. At each "point-intercept" record the point (PNT), gently place the pole, and then record every species that touches the pole (SPP code). Each species is counted only once at each point-intercept even if the pole touches it more than once. It is usually easiest to count the tallest species first. Record the substrate (bare soil, rock, forest litter, ash, etc.) if the pole fails to intercept any vegetation (refer to Appendix C for definitions (and codes) of what constitutes rock, bare ground, etc.). Do not count foliage or branches intercepted for trees over 2 m tall, but count all other vegetation no matter what its height. This is because trees are sufficiently sampled using other procedures, and the target monitoring variables using the line-intercept transect are shrubs and herbs. If the plumb bob intersects the bole of a tree that is over 2 m tall, record "BOLE". Species not intercepted but seen in the "vicinity", that is within 5 m of either side of the brush and herbaceous layer transect, are recorded on the bottom of the data sheet (form FMH-17).

Repeat this process on the Q3-Q2 transect, starting at the Q3 stake.
Collect and Record Brush Density Data

The purpose of determining density is to monitor recruitment. To obtain brush density, widen the transect to a selected width in meters or fractions of meters—0.5 m minimum width (ex.: 1 m where brush is common and 3 to 10 m where it is sparse), and count all individuals having ≥ 50% of its rooted base within the belt transect (see Figure 7). If the number of individuals of one or more species regularly exceeds 50, reduce the width of the belt transect or monitor only one 50-m belt transect per plot. Once a belt width has been selected, however, it should remain constant for all plots within the monitoring type. The width of the belt will also remain constant from preburn to postburn situations.

Use the Belt Transect Data Sheet for Brush Density (form FMH-18) to record the data, including the chosen belt width. The belt transect may be divided into 5-m intervals to facilitate counts. Each 5-m interval is numbered from 1 to 10; interval 1 is from 0 to 5 m and so on. The interval is recorded under INT. Data is recorded by species (SPP), age class (AGE), number of individuals (NUM) of that species, and whether the plant is living (LIVE). Under age class, identify each plant as either a seedling/immature (S), a resprout (R), or as a mature/adult (M) (see Glossary for definitions).

Record Species Codes Used

Every time a species code is used for any plot or transect in the park the species name and code must be recorded on FMH-6. This form serves as a running list of used codes. Only one list is kept for the entire monitoring program. Monitors should always carry this sheet when they are collecting data, and should refer to it when doing so.

Figure 7. Belt transect. (See Figure 2C for stake codes.)
every time they assign a species code (see Appendix C for coding guidelines). Use of this sheet will keep the same code from being used for two different species, and will greatly facilitate data processing.

**Precisely Measure Brush Individuals (recommended)**

Density data for brush would be more meaningful if size or actual age information were included, or if individuals were tagged. Changes in stand structure could then be detected. Protocols for collecting this type of data should be developed on a case-by-case basis with the assistance of a fire or plant ecologist.

**Measure Brush and Herbaceous Layer Height (recommended)**

The height of the tallest living or dead individual by species (HGT) at every intercept in the brush and herbaceous layer is measured in meters to the nearest decimeter and recorded on FMH-17. A ¼-inch diameter rangepole graduated in decimeters should make this measurement relatively easy. A vegetation height profile along the transect can then be graphed. Height is not recorded for aerial substrate such as the leaves or stems attached to a dead and downed tree.

**Deal with Sampling Problems**

Inevitably, the plot monitor will encounter a sampling situation that is not covered by this Handbook. A few potential problems, however, are dealt with here.

**Dead Vegetation.** Dead standing vegetation may be encountered along the transects. Always record dead annual vegetation; it does not need to be recorded in a way that it can be separated from live individuals.

Record dead biennial and perennial vegetation (except dead branches of living plants) by placing a "D" at the end of the 5 character species code. This permits dead vegetation to be treated separately from live encounters. Dead perennials may not be included in species abundance indexes, but their presence may provide information for estimating fire behavior and determining mortality.

**Dead Branches.** Count dead branches of living plants as a live intercept.

**Identifying the Individual to Measure Brush Density.** Brush density must be monitored when individual plants are distinct, or when a consistent convention for identifying individuals or "subunits" can be applied.

**Ex. 1:** Ceanothus sp. individuals are generally easily distinguishable. However, if two or more individuals have grown from the same point of origin and have grafted or intertwined, they could be recorded as a single individual.
because it would be very difficult to determine distinctiveness. The "stem unit", in this case, becomes the basis for identifying an individual.

Ex. 2: Chamise stems are easy to trace to a basal burl. In most cases, this defines the individual. The "burl unit" may be an appropriate delineator of individuals, even when two or more individuals have grown together.

When an individual is hard to define, and a convention cannot be devised or is labor intensive, density should not be collected (no longer an MAS variable). For example, bear clover (Chamaebatia foliolosa) is a woody plant that forms a relatively dense ground cover. It reproduces by runners and sprouts and there is no easy, non-disturbing method of determining the individual.

If density cannot be measured, consider substituting above ground biomass as a monitoring variable.

Dramatic Changes in Brush Density. Large differences in the density of individual species may occur following a fire. For example, a Ceanothus species that reproduces by seed may produce hundreds or thousands of seedlings during the first few (1-15) post fire years though only a handful of prefire individuals were present.

It may be advantageous to establish a protocol not to count seedlings in density plots until their second or third year of survivorship. However, a qualitative estimate of their presence should be attempted in all cases, such as 10/m² or 50/m².

It may be desirable to subsample the density plot during temporary high density periods. To subsample, grid the plot and randomly select an appropriate subsample (i.e. 10%, 20%, of the plot) area. Then proceed to count the individuals in the area.

Make Voucher Collection

Plant specimens should be identified within 2 days, and vouchers collected (unless the species is threatened or endangered) if there is any doubt as to the correct identification of plant species recorded on the data forms. Prompt identification of plants measured or observed is essential for data accuracy, and saves time and money. For the initial phase of this monitoring program, collection of voucher specimens of all plants present is strongly recommended.

Collection of vouchers using the following guidelines should enable consistent, and hopefully, correct future identifications:

♦ Collect the voucher specimen off or outside of the index plot. Collect enough of the plant to enable identification. Do not collect plants that are--or are
suspected as—rare, threatened, or endangered; sketch these plants and take pictures as vouchers.

✦ Press the plant materials immediately.
✦ Record the following information on a sheet of paper that is pressed with the voucher specimen:
  - Date of collection
  - Monitoring type and plots where the plant was observed
  - Describe the plant’s habitat and major Associates
  - Collector's name
  - Habit (annual, biennial, or perennial)
  - Flower color
  - Height

✦ Keep all specimens in proper herbarium storage.

A field notebook of pressed specimens (including unknowns) is a very useful way of expediting and verifying species identifications in the field.

**Optional Monitoring Procedures**

**Herbaceous Layer Species Density.** To measure the density of forbs and grasses, place a 1-m square frame on the plot side (interior) of the brush and herbaceous layer transect (Q4-Q1) every 10 m (every 5 m if the vegetation is sparse) (see Figure 8). The lowest corner of the first frame would be the 9-m mark, therefore, the sampling frame would fall between 9 and 10 m on the tape (frame 1); the next sampling areas would be from 19 to 20 m (frame 2), 29 to 30 m (frame 3), 39 to

![Figure 8. Density sampling frames for herbaceous species on a forest index plot.](image_url)
40 m (frame 4), and 49 to 50 m (frame 5). Repeat this process on the Q3-Q2 line in frames 6, 7, 8, 9, and 10. The total area sampled using this method would be 10 m² (5 m² sampled on each transect). Record this density data on the Herbaceous Density Data Sheet (form FMH-19 in Appendix A).


Fuel Load. Refer to the "Grassland-Brush Methods" sections for grass or brush biomass estimating techniques.

MONITOR PREBURN FUEL CHARACTERISTICS

Dead and Downed Fuel Load

Dead and detached woody fuel load and duff and litter depths must be monitored on all forest index plots. These fuel inventory transects must be relocatable to evaluate postburn fuel load.

Transects extend in random directions originating from the centerline at 10, 20, 30, and 40 m. Determine a random direction from 0° to 359° by using a random number generator (Appendix B or the sweep second hand of a watch). These transects may extend beyond the boundaries of the 20-m × 50-m plot (Figure 2C on page 90).

Lay out a 50-foot tape along the random direction. Place a numbered tag at both ends of the transect (tag numbers should be as described in Appendix C). Measure the slope of the transect (from one end to the other) in percent. Note that the length of this fuel inventory plane is based on the number of intercepts (see Brown 1974, Brown et al. 1982).

MAS Procedures

Tally each particle intersected along a preselected side of the tape by size class for the distances prescribed below. Measurement of all particles is taken perpendicular to the point where the tape crosses the central axis. Count intercepts along the transect plane up to 6 ft from the ground. Count dead and down woody material except for cones, bark, needles and leaves. Do not count stems and branches attached to standing brush or trees.

Suggested lengths of transect lines to tally fuels by size class are:

- 0 - ¼" diameter = tally from 0 to 6 ft
- ¼ - 1" diameter = tally from 0 to 6 ft

Chapter 4: Methods for Monitoring Forest Index Plots
1 - 3" diameter = tally from 0 to 12 ft
≥ 3" diameter = record each individual from 0 to 50 ft

Separate particles larger than or equal to 3 inches in diameter into sound and rotten categories. Rotten wood is obviously deteriorating or punky wood. Measure particle diameter to the nearest one-half inch with a diameter tape or ruler. Ignore particles buried more than halfway into the duff at the point of intersection. Visually reconstruct rotten logs as a cylinder and estimate diameter.

75% of the dead and downed transect lines within a monitoring type should intercept a 3-inch or larger diameter log; if they do not, the standard length of the sampling plane should be increased. Conversely, if many 3+ inch intercepts are being measured, the length of the fuel inventory plane can be shortened.

Take litter and duff depth measurements at 10 points along each fuel transect—that is at 1, 5, 10, 15, 20, 25, 30, 35, 40, and 45 ft. Do not take measurements at the stake (0 point); it is an unnatural structure that traps materials. Litter is considered the top, unconsolidated, and undecomposed layer. Duff is the fibrous, consolidated, decomposed layer above mineral soil. Twigs and larger stems are not measured in the litter depth. Vertically measure the litter and duff to the nearest tenth of an inch. Refill holes created by this monitoring technique.

Duff pins may be installed to measure duff instead of digging and measuring the depth of holes. Duff pins, however, are easy to trip over or pull out, and therefore, should only be used where traffic (human or animal) is limited.

Record the above dead and downed fuel data on the Forest Index Plot Fuels Inventory Data Sheet (form FMH-20 in Appendix A).

**Deal with Sampling Problems**

Occasionally a tree trunk, stump, or log will occur at a litter or duff depth data collection points. The litter or duff depth should be recorded as zero if a tree or stump is on the point. If a log is in the middle of the litter or duff measuring point, move the data collection point 1 foot perpendicular to the sampling plane.

**Forest Downed Fuel Inventory Calculations**

Dead and downed fuel loads can be processed using software provided with this Handbook or calculated by hand using the following instructions:
Calculate fuel loading using the composite coefficients provided by Brown et al. (1982) for constants, squared average diameters ($d^2$), specific gravity ($s$), slope correction ($c$), and angle ($a$) factors. These values are shown below:

<table>
<thead>
<tr>
<th>size class</th>
<th>constant</th>
<th>$d^2$ squared diameter</th>
<th>$s$ specific gravity</th>
<th>$a$ angle factor</th>
<th>$Nl$ plane length*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-.25&quot;</td>
<td>11.64</td>
<td>0.0151</td>
<td>0.48</td>
<td>1.13</td>
<td>6</td>
</tr>
<tr>
<td>.25-1&quot;</td>
<td>11.64</td>
<td>0.289</td>
<td>0.48</td>
<td>1.13</td>
<td>6</td>
</tr>
<tr>
<td>1-3&quot;</td>
<td>11.64</td>
<td>2.76</td>
<td>0.40</td>
<td>1.13</td>
<td>12</td>
</tr>
<tr>
<td>3+sound</td>
<td>11.64</td>
<td>0.40</td>
<td>1.0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>3+rotten</td>
<td>11.64</td>
<td>0.30</td>
<td>1.0</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

* Suggested length of sampling plane

These composite coefficients were identified for Rocky Mountain species. Coefficients identified by van Wagendonk et al. (1988) for Sierra mixed-conifer fuels are also available.

The equation used to arrive at tons/acre by size class is:

$$0-3" \text{ diameter: } \frac{11.64 \times n \times d^2 \times s \times a \times c}{Nl} = \text{tons/acre}$$

$$>3" \text{ diameter: } \frac{11.64 \times \sum d^2 \times s \times a \times c}{Nl} = \text{tons/acre}$$

where: $n$ = number of intersections

$d^2$ = squared diameters

$\sum d^2$ = sum of the squared diameters

$s$ = specific gravity

$a$ = angle factor

$c$ = slope correction factor (see below)

$Nl$ = length of the sampling plane

<table>
<thead>
<tr>
<th>% slope</th>
<th>c</th>
<th>% slope</th>
<th>c</th>
<th>% slope</th>
<th>c</th>
<th>% slope</th>
<th>c</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>30</td>
<td>1.04</td>
<td>60</td>
<td>1.17</td>
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<tr>
<td>10</td>
<td>1.00</td>
<td>40</td>
<td>1.08</td>
<td>70</td>
<td>1.22</td>
<td>100</td>
<td>1.41</td>
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<tr>
<td>20</td>
<td>1.02</td>
<td>50</td>
<td>1.12</td>
<td>80</td>
<td>1.28</td>
<td>110</td>
<td>1.49</td>
</tr>
</tbody>
</table>

Chapter 4: Methods for Monitoring Forest Index Plots
Calculate Duff and Litter Fuel Loads (recommended)

Duff and litter fuel load can be derived from duff and litter depths, respectively, if fuel loads (mass) by depth relationships have been developed for the fuel type. For example, Agee (1973), developed duff load factors for ponderosa pine (Pinus ponderosa) and white fir (Abies concolor) forests based on the average depth of the duff. These values are 5 tons/acre/cm for the ponderosa pine type and 6 tons/acre/cm for the white fir type. Since duff depth is generally measured in inches (Brown et al. 1982), unit conversion is often necessary. The formula used to calculate duff load in ponderosa pine or white fir types follows.

\[
\text{tons/acre/cm} \times \text{inches duff} \times 2.54 \text{ in/cm} = \text{tons/acre duff}
\]

Duff load is often at least \( \frac{1}{2} \) of the total fuel load, and should be determined if possible. A space has been provided at the bottom of form FMH-20 to record duff fuel load and total fuel load (duff + woody). Litter load can also be calculated by the same process (mass to depth relationship established) but is usually not considered important enough to determine.

MONITOR FIRE WEATHER AND BEHAVIOR CHARACTERISTICS

Fire weather and behavior observations (ROS, FL, and FZD (recommended), and other level 2 variables described in chapter 2) are taken at eight observation intervals within each 20-m x 50-m index plot. These 8 intervals are located at the end of the 4 randomly oriented downed fuel inventory transects, and along the midline at the 10, 20, 30, and 40-m points. Note that the end of the fuel inventory line may extend outside of the 20-m x 50-m index plot area.

A 5-ft radius circle around each of the downed fuel inventory transect origin and end points defines the fire behavior observation circles (FBOCs) (refer to the "O"s in Figure 9). FBOCs are areas designated for temporary fire behavior observations. These circles should be defined by four small, flagged stakes or sticks just prior to the site being burned. It is the duty of the FBWS-II on the burn, rather than the biological technicians who installed the plot, to establish and mark the FBOCs. This delegation of responsibility is necessary since the plot may not be burned for several years after the plot is established.

Fire behavior observation circles at 1A, 2A, 3A, and 4A will always be along the midline of the index plot. FBOCs at 1B, 2B, 3B, and 4B will always be randomly located since the dead and downed fuel inventory planar transects are randomly selected.

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Chapter 4: Methods for Monitoring Forest Index Plots
A minimum of 4 fire characteristics observations will be made on each plot. These observations should be made in the FBOCs, but if they cannot be safely taken, alternate observation intervals may be established outside of the plot.

THE PLOTS MUST BURN under the same conditions and ignition techniques used to ignite the rest of the prescribed burn block. Fire monitor safety, however, must always be considered foremost. Often the best arrangement is for the lead monitor (person who set up the plot) to ignite the plot or to direct the ignition boss in lighting of the plot. The fire behavior monitors must be intimately familiar with the plot location, layout, and code for each FBOC.

Safe and effective ignition of the plot usually requires delaying ignition of the surrounding area; this delay can be relatively long and interfere with burn operations.

As the fire burns across each FBOC, monitor the minimum acceptable fire conditions variables and record observations on the Fire Behavior/Weather Data Sheet (form FMH-2 in Appendix A). The time required for the fire to travel from the edge of the circle to the center (5 ft) is recorded as the observed rate of spread. Some fires will progress very slowly across the FBOC; if monitoring of a slow ROS over the 5-ft interval is logistically unacceptable, a shorter observation interval may be established. If the fire starts to burn an FBOC before a monitor arrives, wait for the fire to reach the center point and start timing the ROS and measuring other fire behavior variables as the fire moves from the center stake to the outside of the FBOC, or another known distance.

Simultaneous observations are made every 30 seconds (plus or minus) of average flame length and flame zone depth; approximately 10 observations of flame length

![Figure 9. Fire behavior observation circles (○) on a forest index plot.](image)
and zone depth should be made per circle. Flame length and depth values should be average values noted after 10 to 30 seconds of observation.

Fire weather observations should be recorded at 30 minute intervals. More frequent sampling should be made if the monitor detects a change in wind speed or direction, or the air temperature or relative humidity seem to be changing significantly.

When safe observations are not possible using the above layout, consider one of the following options:

Rate of Spread

- Time the fire as it moves across an obvious (well marked) interval that can be easily and safely seen.
- Place timing devices or firecrackers at known intervals; time the fire as it triggers these devices.
- Where observations are not possible over or near the index plot, and mechanical techniques such as firecrackers or in-place timers are unavailable, establish alternate fire behavior monitoring areas near the burn perimeter; however, these substitute observation intervals must be burned free of side-effects caused by the ignition source or pattern.

Flame Length

Where close observations are not possible, use the height of a known object between the observer and the fire behavior observation interval to estimate average flame length.

Flame Zone Depth (recommended)

Where close observations are not possible, use the length of a known object to estimate flame zone depth.

MONITOR POSTBURN VEGETATION AND FUELS CHARACTERISTICS

After the burned plot has cooled sufficiently (generally 2 to 3 weeks), remeasure the overstory (using the Overstory Tree Postfire Assessment Data Sheet, FMH-21), pole-sized (FMH-11) and seedling trees (FMH-14), dead and downed fuels (FMH-20), and the brush and herbaceous layer variables (FMH-18; FMH-17 and 19 are optional) using the preburn monitoring techniques. Do not remeasure the diameter of overstory trees for at least one year postburn, but record whether they are alive or dead at every visit. On each form, circle the postburn status
code as "Post" (within 2 months of the burn), or "yr1", "yr2", etc., or enter the number of months postburn if other than the periods listed.

MONITOR POSTBURN CONDITIONS

Postburn conditions that characterize the amount of heat received in the type are recorded on the Overstory Tree Postfire Assessment Form (form FMH-21) and on the Burn Severity Form (FMH-22). Record the tree tag number (TAG), whether the tree is alive (L), dead (D), resprouting (R), or consumed (C) in the LIVE field, maximum scorch height (SCHGT), and the scorched proportion of the crown (SCP). Char height (CHAR), a recommended variable, may also be recorded on FMH-21. Burn severity is recorded on the Forest Plot Burn Severity Data Sheet (form FMH-22).

Scorch Height

Measure maximum scorch height on each overstory tree 2 weeks to 2 months after the fire has burned across the index plot. If the 1 year postfire visit exposes scorch patterns more definitively also measure it at that time.

Maximum scorch height is measured from ground level to the highest point in the crown where foliar death is evident (see Figure 10). Some trees will show no signs of scorch, but the surrounding fuels and vegetation will have obviously burned. In this case, estimate scorch height by examining adjacent vegetation.

Average scorch height (see Figure 10) is calculated from the maximum scorch heights and recorded on form FMH-21. It may be useful to produce a graph of scorch heights to show the variation around the average. Managers may want to correlate scorch height with the preburn locations of large dead and down fuels; these correlations usually require photographs or maps of fuel pockets.

Percent Crown Scorched

Estimate the percent of the entire crown that is scorched for each overstory tree. Average percent crown scorched may be calculated, but percent crown scorched is a better indicator of individual tree mortality.
**Burn Severity**

Visual assessments of burn severity allow managers to broadly predict fire effects on the monitoring type, from changes in the organic substrate to the survival of its plants (Ryan et al 1983).

Burn severity ratings are determined at the same points on the forest dead and downed fuel inventory transect lines where duff depth is measured: at 1, 5, 10, 15, 20, 25, 30, 35, 40, and 45 ft. There will be 40 points rated per plot. At each sample point, evaluate burn severity to the organic substrate and to above ground plants in a 4 square-decimeter area (2 dm x 2 dm) using the Burn Severity codes which follow. Where there is no organic substrate present, enter a 0 to indicate that the severity rating is not applicable. Do the same if there is no vegetation present. Then calculate the average burn severity for the index plot for the two classes of impacts.

**Burn Severity Codes**

Burn severity is rated and coded separately for organic substrate and vegetation impacts, which are distinguished by an S or V, respectively. Burn severity is rated according to the coding matrix on the next page. For example, at one of the 4 dm² burn severity data collection points these conditions are observed: the litter has been consumed, the duff deeply burned, and the understory tree foliage consumed leaving stems and branches. Burn severity would be coded as S2 (substrate impacts) and V3 (vegetation impacts) on the Forest Plot Burn Severity Data Sheet (form FMH-22).

![Figure 10. Scorch height and char height.](image)
### Burn Severity Coding Matrix

<table>
<thead>
<tr>
<th>Substrate (litter/duff) (S)</th>
<th>Unburned (5)</th>
<th>Scorched (4)</th>
<th>Lightly Burned (3)</th>
<th>Moderately Burned (2)</th>
<th>Heavily Burned (1)</th>
<th>Not Applicable (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>not burned</td>
<td>litter partially charred; duff nearly unchanged; wood/leaf structures unchanged</td>
<td>litter charred to partially consumed; upper duff layer burned; wood/leaf structures charred, but recognizable</td>
<td>litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply burned; wood/leaf structures unrecognizable</td>
<td>litter and duff consumed, leaving fine white ash; mineral soil visibly altered, often reddish</td>
<td>inorganic</td>
</tr>
<tr>
<td>Vegetation (understory/brush/herbs) (V)</td>
<td>not burned</td>
<td>foliage scorched and attached to supporting twigs</td>
<td>foliage and smaller twigs partially to completely consumed</td>
<td>foliage, twigs and small stems consumed</td>
<td>all plant parts consumed leaving some or no major stems/trunks</td>
<td>none present</td>
</tr>
</tbody>
</table>

### Char Height (recommended)

Char height is often measured simultaneously with scorch height. To obtain an average maximum char height, measure the height of the maximum point of char for each overstory tree (see Figure 10). Then calculate the mean of maximum char heights. The average maximum char height observed in every FBOC can be recorded on the bottom of the Fire Behavior/Weather Data Sheet (form FMH-2).
LAY OUT INDEX PLOT

Refer to Figure 11 as you read this section.

You have arrived at a randomly derived plot origin point; mark this point by installing a reference stake.

Next, select a random azimuth (Appendix B) and lay out a 30+ m tape from the reference stake along this azimuth. The transect line defined by the tape should be suspended above the vegetation. This may require construction of two tripod scaffolds—one for each end of the tape. The entire 30-m line and 5 m on either side of it must lie within the identified monitoring type.

Mark the Plot

Mark the transect dimensions by installing two ½-inch wide metal stakes at 0 and 30.3 m. The 30P stake is installed at 30.3 m, to minimize stake interference at the 30 meter data point. Stake height above the ground should be sufficient to allow easy relocation of the stakes. Stakes should be installed deep enough to provide adequate basal stability relative to the height necessary to bring the stake into view. Suggested stake lengths are ½ to 1 m (2 to 3 ft) for grass transects, and 2 m (6 ft) or more for brush transects. It is generally best to overestimate the stake heights needed, to compensate for snow creep and vegetation growth.

Figure 11. Brush or grass index transect. At starred points, place metal stakes, and if necessary, bury reference stake.
Burial of the reference stake (0 point) is recommended, especially in areas subject to vandalism or disturbance. A metal detector can be used later to relocate the plot if all above ground stakes are lost.

In high use areas it may be necessary to camouflage stakes, and to additionally mark beginning and end points with buried metal markers that can be relocated by a metal detector.

Color code plot beginning and ending stakes (orange for 0P, blue for the 30P). Paints should be high-temperature resistant. Repaint the stakes after the burn.

Install permanent plot identification tags on each stake described below.

♦ Use rectangular or oblong brass tags (Appendix E).
♦ The recommended format includes the index stake location code, plot purpose, plot identification code, and date on the tag. An abbreviated format may be used to reduce the amount of minting. It includes the vegetation code from the plot identification code, plot number, index stake location code, plot purpose, and date. The two formats are displayed below:

<table>
<thead>
<tr>
<th>Recommended Stake Label</th>
<th>Stake location code*</th>
<th>indicates plot purpose</th>
<th>Plot identification code</th>
<th>Date; month, day, year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rx Fire</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abbreviated Stake Label</th>
<th>Stake location code*</th>
<th>indicates plot purpose</th>
<th>Dominant species code &amp; plot number**</th>
<th>Date; month, day, year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The stake location codes are identified in Figure 11 above.
** The dominant species code is from the index plot identification code.

Photograph the Plot

Photograph the line-intercept transect from both ends. Include the end markers (0P and 30P stakes) in the photographs. Follow the procedures outlined in Appendix D; be sure to write the plot identification code and the direction of the photograph (that is 0P-30P or 30P-0P) in large black letters on a white sheet of paper and include this paper in each photograph. Record photographic data on the
Data Sheet for 30 Meter Transects (form FMH-23 in Appendix A), noting lens, type of film, and time of photographs. Label the slides as described in Appendix C.

A photographic record sheet for rolls of film is available for use in Appendix A (FMH-26). This record makes labeling of individual slides or photographs much easier.

MONITOR PREBURN VEGETATION AND FUELS CHARACTERISTICS

MAS Procedures

Use a "point line-intercept" method to measure the number of transect hits, relative cover, and density (brush only) by species over time. Sampling should occur during the season in which the plants can most easily be identified and when the biomass is greatest, usually in late spring or early summer. Thereafter, remonitoring should occur at the same phenological stage. The collection of voucher specimens is strongly recommended as discussed on page 126).

Locate the 0 Point on the Line-intercept Transect

The data collection starting point is at the OP (reference stake).

Collect # of Transect Hits, Relative Cover, and % of Non-native Species Data

Start 30 cm from the OP. Take a ¼-inch diameter pole, graduated in decimeters, and every 30 cm along the transect line, place it gently so that the pole is plumb to the ground on slopes but not perpendicular to the ground (a rigid plumb bob). There will be 100 points from 30 to 3,000 cm (the first intercept hit is at 30 cm, not at 0 cm). At each "point-intercept" record the point (PNT), gently place the pole on the ground, and then record every species that touches the pole (SPP codes). Each species is counted only once (on form FMH-23 in Appendix A) at each point-intercept even if the pole touches it more than once. It is usually easiest to count the tallest species first. Record the substrate (bare soil, rock, forest litter, ash, etc.) if the pole fails to intercept any vegetation (refer to Appendix C for definitions (and codes) of what constitutes rock, bare ground, etc.). Do not count foliage or branches intercepted for trees over 2 m tall, but count all other vegetation no matter what its height. This is because trees are better sampled using other procedures, and the target monitoring variables using the line-intercept transect are shrubs and herbs. If the plumb bob intersects the bole of a tree that is over 2 m tall, record "BOLE".

Species not intercepted but seen in the "vicinity", that is within 5 m of either side of the brush and herbaceous layer transect are recorded on the bottom of the data sheet (form FMH-23).
Collect and Record Brush Density Data

The purpose of determining density is to monitor recruitment. To obtain brush density, widen the transect to a selected width in meters or fractions of meters (0.5 m minimum width) on the uphill side of the transect (ex.: 1 m where brush is common and 3 to 10 m where it is sparse) and count all individuals having ≥ 50% of its rooted base within the belt transect. When it is not clear which side of the transect is the uphill side, use the right side of the transect when viewed from OP looking down the transect towards 30P. If the number of individuals of one or more species regularly exceeds 50, reduce the width of the belt transect. Once a belt width has been selected, however, it should remain constant for all plots within the monitoring type. This width will also remain constant from preburn to postburn situations.

Use the Belt Transect Data Sheet for Brush Density (form FMH-18) to record the data, which will include the chosen belt width. The belt transect may be divided into 5-m intervals to facilitate counts. Each 5-m interval is numbered from 1 to 6; interval 1 is from 0 to 5 m and so on. The interval is recorded under INT. Data is recorded by species (SPP), age class (AGE), number of individuals (NUM) of that species, and whether it is living (LIVE). Under age class, identify each plant as either a seedling/immature (S), a resprout (R), or as a mature/adult (M) (see Glossary for definitions).

Record Species Codes Used

Every time a species code is used for any plot or transect in the park the species name and code must be recorded on FMH-6. This form serves as a running list of used codes. Only one list is kept for the entire monitoring program. Monitors should always carry this sheet when they are collecting data, and should refer to it every time they assign a species code (see Appendix C for coding guidelines). Use of this sheet will keep the same code from being used for two different species, and will greatly facilitate data processing.

Precisely Measure Brush Individuals (recommended)

Density data for brush would be more meaningful if size or actual age information were included, or if the individuals were tagged. Changes in stand structure could then be detected. Protocols for collecting this type of data should be developed on a case-by-case basis with the assistance of a fire or plant ecologist.

Brush and Herbaceous Layer Height (recommended)

The height of the tallest living or dead individual by species (HGT) at every intercept is measured in meters to the nearest decimeter and recorded on FMH-23. A ¼-inch wide rangepole graduated in decimeters should make this measurement relatively easy. A vegetation height profile along the transect can then be
graphed. Height is not recorded for aerial substrate such as the leaves or stems attached to a dead and downed tree.

**Deal with Sampling Problems**

Inevitably, the plot monitor will encounter a sampling situation that is not covered by this Handbook. A few potential problems, however, are dealt with here.

**Dead Vegetation.** Dead standing vegetation may be encountered along the transects. Always record dead annual vegetation; it does not need to be recorded in a way that it can be separated from live individuals.

Record dead biennial and perennial vegetation (except dead branches of living plants) by placing a "D" at the end of the 5 character species code. This permits dead vegetation to be treated separately from live encounters. Dead perennials may not be included in species abundance indexes, but their presence may provide information for estimating fire behavior and determining mortality.

**Dead Branches.** Count dead branches of living plants as a live intercept.

**Identifying the Individual to Measure Brush Density.** Brush density must be monitored when individual plants are distinct, or when a consistent convention for identifying individuals or "subunits" can be applied.

Ex. 1: Ceanothus sp. individuals are generally easily distinguishable. However, if two or more individuals have grown from the same point of origin and have grafted or intertwined, they could be recorded as a single individual because it would be very difficult to determine distinctiveness. The "stem unit", in this case, becomes the basis for identifying an individual.

Ex. 2: Chamise stems are easy to trace to a basal burl. This usually defines the individual. The "burl unit" may be an appropriate delineator of individuals, even when two or more individuals have grown together.

When an individual is hard to define, and a convention cannot be devised or is labor intensive, density should not be collected (no longer an MAS variable). For example, bear clover (Chamaebatia foliolosa) is a woody plant that forms a relatively dense ground cover. It reproduces by runners and sprouts and there is no easy, non-disturbing method of determining the individual.

If density cannot be measured, consider substituting above ground biomass as a monitoring variable.
Dramatic Changes in Brush Density. Large differences in the density of individual species may occur following a fire. For example, a Ceanothus species that reproduces by seed may produce hundreds or thousands of seedlings during the first few (1-15) post fire years though only a handful of prefire individuals were present.

It may be advantageous to establish a protocol not to count seedlings in density plots until their second or third year of survivorship. However, a qualitative estimate of their presence should be attempted in all cases, such as 10/m² or 50/m².

It may be desirable to subsample the density plot during temporary high density periods. To subsample, grid the plot and randomly select an appropriate subsample (i.e. 10%, 20%, of the plot) area. Then proceed to count the individuals in the area.

Make Voucher Collection

Plant specimens should be identified within 2 days, and vouchers collected (unless the species is threatened or endangered) if there is any doubt as to the correct identification of plant species recorded in the data set. Prompt identification of plants measured or observed is essential for data accuracy, and saves time and money. For the initial phase of this monitoring program, collection of voucher specimens of all plants present is strongly recommended.

Collection of vouchers using the following guidelines should enable consistent, and hopefully, correct future identifications:

♦ Collect the voucher specimen off or outside of the index plot. Collect enough of the plant to enable identification. Do not collect plants that are--or are suspected as--rare, threatened, or endangered; sketch these plants and take pictures as vouchers.

♦ Press the plant materials immediately.

♦ Record the following information on a sheet of paper that is pressed with the voucher specimen:
  - Date of collection
  - Monitoring type and plots where the plant was observed
  - Describe the plant's habitat and major Associates
  - Collector's name
  - Habit (annual, biennial, or perennial)
  - Flower color
  - Height

♦ Keep all specimens in proper herbarium storage.
A field notebook of pressed specimens (including unknowns) is a very useful way of expediting and verifying species identifications in the field.

Optional Monitoring Procedures

Herbaceous Layer Species Density

To measure the density of forbs and grasses, place a 1-m square frame on the uphill side of the brush and herbaceous layer transect every 10 m (every 5 m if the vegetation is sparse). When it is not clear which side of the transect is the uphill side, use the right side of the transect when viewed from OP looking down the transect towards 30P. The lowest corner of the first frame would be the 9-m mark, therefore, the sampling frame would fall between 9 and 10 m on the tape (frame 1); the next sampling areas would be between 19 and 20 m (frame 2), and 29 and 30 m (frame 3) (see Figure 12). The total area sampled using this method would be 3 m².

Record this density data on the Herbaceous Density Data Sheet (form FMH-19).

Crown Intercept

Refer to Canfield (1942 and 1941) or Mueller-Dombois, D. and H. Ellenberg (1974) for crown intercept monitoring techniques.

Brush Fuel Load

Brush. Total biomass (fuel) and percent dead (live to dead ratio) may be determined in brush types with sufficient accuracy to make fire behavior predictions. Total brush biomass must also be measured, when required, for smoke management. Standard biomass estimating techniques or existing species specific estimating equations must be used to determine fuel load.

![Figure 12. Density sampling frames for herbaceous species in a grassland or brush type.](image)
Preburn Biomass

Estimate preburn biomass (tons/acre) when smoke management is a specific concern, or hazard fuel reduction is the primary burn objective. Qualitatively determine preburn brush biomass to assess and predict fire behavior by following these procedures.

1. Determine appropriate plot size (see Mueller-Dombois and Ellenberg 1974, p 48-52). Chamise chaparral plots should be 5 m x 10 m. Plot dimensions for small shrubs will probably be smaller.
2. Use standard biomass estimating techniques or existing biomass estimating equations to estimate the biomass of each shrub in the plot. Many Sierran chaparral species equations can be found in Parsons and Stohlgren (1987); California coastal chaparral species equations can be found in Wakimoto (1978) or Schlesinger and Gill (1978).
3. Count the number of dead individuals (by species) to later factor out thinning from fire-caused mortality.
4. Process the data for density, biomass, and species composition from 10 initial "index plots" (not necessarily the same transects where vegetation characteristics are being monitored).
5. Adjust sample size (refer to pages 80 through 84).

Preburn Percent Dead Brush

If a custom fuel model needs to be developed for BEHAVE or HP-71B fire behavior predictions, determine the preburn percent dead brush by following these procedures. Three techniques are available to estimate preburn percent dead brush.

1. Ocularly estimate onsite
2. Estimate based upon existing publications such as a photo series
3. Directly measure live/dead ratio using the following procedure:
   a. Randomly select a sample shrub of each brush species of concern within a 1-acre area.
   b. Remove all branches ¼ inch or less in diameter, and place in separate airtight bags depending on if they are live or dead. A sample of the shrub can be taken if the shrub is very large.
   c. Determine oven dry weight of live portion and dead portion. A subsample may be used if necessary. If a subsample is used take care to weigh sample and subsample at the same time before drying.
   d. After determining dry weights separately calculate tons per acre of live and dead.
Grasslands. Grass fuel load is sometimes required for smoke management concerns, and to develop custom fuel models using BEHAVE (Burgan and Rothermel 1984).

Preburn Biomass

Estimate preburn biomass (tons/acre) when smoke management is a specific concern, or hazard fuel reduction is the primary burn objective. Qualitatively determine preburn biomass to assess and predict fire behavior by following these procedures.

Randomly toss a rigid quadrat of known area. Do this 6 times. Each time

- Clip all the vegetation to within 1 cm of the ground
- Place the clipped vegetation into airtight containers. Each quadrat should have one container.
- Label each container with the plot identification code, the container number, and the collection date
- Weigh each container before removing the lid. Record this figure as the sample wet weight
- Determine the sample dry weight by drying the material in their containers until the weight stabilizes. The oven temperature should be 100°C
- Determine the net dry weight of each sample (dry sample) by subtracting the empty container weight from both the sample wet and dry plus container weights
- Calculate the kilograms/hectare or tons/acre for each sample using this formula if weight is measured in grams:

Formula 1

\[
\text{Biomass} = \frac{(\text{dry sample, g} - \text{container, g}) \times 10,000 \text{m}^2}{\text{area of quadrat}, \text{m}^2} \times \frac{1 \text{ kg}}{1,000 \text{ g}} = \frac{\text{kg}}{\text{ha}}
\]

To obtain tons/acre from kg/ha, use Formula 2.

Formula 2

\[
\frac{\text{kg}}{\text{ha}} \times \frac{1 \text{ lb}}{0.453 \text{ kg}} \times \frac{1 \text{ ton}}{2000 \text{ lb}} \times \frac{0.405 \text{ ha}}{1 \text{ ac}} = \frac{\text{tons}}{\text{ac}}
\]
Fuel Bed Depth

If a custom fuel model needs to be developed for BEHAVE or HP-71B fire behavior predictions, determine the fuel bed depth by following one of these procedures:

1. Ocularly estimate on site
2. Estimate based upon existing publications such as photo series, anderson 1982, Rothermel & Burgan 1984
3. Directly measure fuel bed depth at several random points and develop an average value

MONITOR FIRE WEATHER AND BEHAVIOR CHARACTERISTICS

Brush and grassland type fuels are usually flashy and unsafe to move through during a fire. The monitoring procedures presented here are ideals—in many situations they will be impossible to implement. The objective of monitoring fire characteristics on brush or grassland plots, therefore, is to do whatever is necessary to be simultaneously safe while obtaining representative fire behavior measurements (representative of the conditions and fuels under which the plot burned).

THE PLOTS MUST BURN under the same conditions and ignition techniques used to ignite the rest of the prescribed burn block. Fire monitor safety, however, must always be considered foremost. Often the best arrangement is for the lead monitor (person who set up the plot) to ignite the plot or to direct the ignition boss in lighting of the plot. The fire behavior monitors must be intimately familiar with the plot location, layout, and code for each fire behavior observation interval (FBOI).

Safe and effective ignition of the plot usually requires delaying ignition of the surrounding area; this delay can be relatively long and interfere with burn operations.

Where safe observations can be made, place stakes or other identifiable objects in the vicinity of the index plots. A minimum of 4 premeasured fire behavior observation intervals must be established per index plot. Rate of spread (ROS) markers are placed at least 5 m apart for grass plots, and at least 10 m apart for dense brush plots, on both sides of the transect line. Figure 13 shows several ROS interval options. Note that the intervals given in the figure are examples of possible scenarios, and are not required data collection intervals.
Rate of spread can be measured from several directions with this set-up. If the
fire moves along the transect line, perpendicular to the line, or diagonally, the
ROS can be calculated since several intervals of known length are available (see
Figure 13). A possible problem with using these metric ROS intervals, is that the
monitor may forget to convert the metric into english units to get a standard linear
expression for ROS, which is chains per hour or feet per minute. To avoid
potential errors, it may be better to pre-measure and mark the ROS intervals in
feet. Markers along the transect line should be colored differently from those
parallel to the line to facilitate distinguishing them from a safe distance.

Estimate flame length and flame zone depth (recommended) at 30 second intervals
or more frequently if the fire is moving rapidly, as the flaming front moves across
the ROS observation interval. Use the Fire Behavior/Weather Data Sheet (FMH-2
in Appendix A) to record data. If possible, make 5 to 10 measurements of ROS,
FL, and FZD per interval. A minimum of 2 observations of each variable is
required per index plot.

When safe observations are not possible using the above layout, consider one of
the following options:

Rate of Spread

- Time the fire as it moves across an obvious (well marked) interval that can be
easily and safely seen.

- Place timing devices or firecrackers at known intervals; time the fire as it
triggers these devices.

Figure 13. Examples of fire behavior observation intervals on a brush or grassland index
plot.
Where observations are not possible over or near the index plot, and mechanical techniques such as firecrackers or in-place timers are unavailable, establish alternate fire behavior monitoring areas near the burn perimeter; however, these substitute observation intervals must be burned free of side-effects caused by the ignition source or pattern.

Flame Length

Where close observations are not possible, use the height of a known object between the observer and the fire behavior observation interval to estimate average flame length.

Flame Zone Depth (recommended)

Flame zone depth may be difficult to measure on brush head fires. Observations will usually need to be made from above.

MONITOR POSTBURN VEGETATION AND FUELS CHARACTERISTICS

After the burned plot has cooled sufficiently (generally 2 to 3 weeks), remeasure the MAS variables (FMH-19 and 23 are optional) and other objective-dependent variables using the same forms used to record preburn data. On each form, circle the status as "Post" (within 2 months of the burn), or "yr1", "yr2", etc., or the number of months postburn if other than those periods listed.

MONITOR POSTBURN CONDITIONS

Burn Severity

Visual assessments of burn severity allow managers to broadly predict fire effects on the monitoring type—from changes in the organic substrate to the survival of its plants (Ryan et al 1983).

Burn severity ratings are made every 5 m, starting at the OP and ending at the 30P. At a minimum, there should be 7 areas rated per plot. Burn severity, however, can be rated for every point sampled (100 data points) along the transect. The additional effort may be minimal since vegetation data is being collected for each of these points anyway. Space has been provided on form FMH-24 for this option.

At each sample point, evaluate burn severity to the organic substrate and to the above ground plant parts in a 4 square-decimeter area (2 dm x 2 dm) and record
the value on form FMH-24. Use the burn severity coding matrix (which follows) to determine the severity ratings. Where there is no organic substrate present, enter a 0 to indicate that the severity rating is not applicable. Do the same if there is no vegetation present. Then calculate the average burn severity for the index plot for the two classes of impacts.

**Burn Severity Codes**

Burn severity is rated and coded separately for organic substrate and vegetation impacts, which are distinguished by an S or V, respectively. Burn severity is rated according to the coding matrix on the next page. For example, at one of the 4 dm² burn severity data collection points these conditions are observed: the litter has been consumed, the duff deeply burned, and the brush foliage consumed leaving stems and branches. Burn severity would be coded as S2 (substrate impacts) and V3 (vegetation impacts) on the Forest Plot Burn Severity Data Sheet (form FMH-24).

<table>
<thead>
<tr>
<th>Substrate (litter/duff) (S)</th>
<th>Unburned (S)</th>
<th>Scorched (4)</th>
<th>Lightly Burned (3)</th>
<th>Moderately Burned (2)</th>
<th>Heavily Burned (1)</th>
<th>Not Applicable (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>not burned</td>
<td>litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged</td>
<td>litter charred to partially consumed; upper duff layer burned; wood/leaf structures charred, but recognizable</td>
<td>litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply burned; wood/leaf structures unrecognizable</td>
<td>litter and duff consumed, leaving fine white ash; mineral soil visibly altered, often reddish</td>
<td>inorganic</td>
<td></td>
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</tbody>
</table>

| Vegetation (understory/brush/herbs) (V) | not burned | foliage scorched and attached to supporting twigs | foliage and smaller twigs partially to completely consumed | foliage, twigs and small stems consumed | all plant parts consumed leaving some or no major stems/trunks | none present |

**Postburn Brush Fuel Load (Optional)**

The following steps may be used to monitor postburn fuel reduction in brush types.
Caliper 30 randomly selected terminal branches in each plot as an index of fire intensity (immediate postburn). A go-no-go template may be used to quickly separate stems into size classes. The template can be cut out of lightweight aluminum siding using the dimensions given in Figure 14.
One year after the fire, examine the percent mortality by species (by counting the number of resprouts and relating to the number of preburn live shrubs), and count the number of seedlings by species (estimate if more than 100 per plot).

Evaluate mortality rates to see if they exceed typical levels (20 to 40% for chamise) or if seedling establishment rates are too low to replace dead individuals.

Ten and 20 years after the fire, re-measure fuel characteristics to evaluate long-term changes in community structure.

Record the data on the Brush Stem Data Sheet (form FMH-25 in Appendix A).

Figure 14. Go-no-go template for brush stems.
Appendices

A. Monitoring Forms
B. Random Number Generators
C. Data and Label Coding Guidelines
D. Guidelines for Establishing Photopoints
E. Equipment Checklist for Index Plots
F. Individual Fire Report (DI-1202)
G. Fire Situation Analysis (FSA), parts I and II
H. Methods for Nonstandard Variables
I. Glossary
J. Compiled References

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Monitoring Forms

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FMH-2 FIRE BEHAVIOR/WEATHER DATA SHEET  
FMH-3 SMOKE MONITORING DATA SHEET  
FMH-4 MONITORING TYPE DESCRIPTION SHEET  
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FMH-6 SPECIES CODE LIST  
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FMH-12 QUARTER 1 POLE-SIZED TREE MAP  
FMH-13 ALTERNATE POLE-SIZED TREE MAP  
FMH-14 SEEDLING TREE DATA SHEET  
FMH-15 50M² SEEDLING TREE MAP  
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FMH-21 OVERSTORY TREE POSTFIRE ASSESSMENT DATA SHEET  
FMH-22 FOREST PLOT BURN SEVERITY DATA SHEET  
FMH-23 30 METER TRANSECT DATA SHEET  
FMH-24 BRUSH AND GRASSLAND PLOT BURN SEVERITY DATA SHEET  
FMH-25 BRUSH STEM AND BIOMASS DATA SHEET  
FMH-26 PHOTOGRAPHIC RECORD SHEET
### ONSITE WEATHER DATA SHEET

<table>
<thead>
<tr>
<th>Plot ID</th>
<th>B / C (circle one)</th>
<th>Date</th>
<th>Wind Speed</th>
<th>Wind Dir.</th>
<th>D.B. (°F)</th>
<th>R.H. (%)</th>
<th>Location / Comments</th>
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**FIRE BEHAVIOR/WEATHER DATA SHEET**

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<th>Burn Unit</th>
<th>Recorders</th>
<th>Date_ /_ /</th>
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<td>Location</td>
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<td>Fuel Model</td>
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<tr>
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<tr>
<td>Observation Time</td>
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<tr>
<td>Aspect (azimuth)*</td>
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</tr>
<tr>
<td>Air Temperature (°F)</td>
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<tr>
<td>Relative Humidity (%)</td>
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<tr>
<td>Wind Speed (mph)</td>
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<tr>
<td>Wind Direction</td>
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<td>1-hr TLFM*</td>
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<tr>
<td>10-hr TLFM</td>
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<tr>
<td>Shading &amp; Cloud Cover (%)</td>
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<tr>
<td>Slope of Hill (%)*</td>
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<tr>
<td>Slope Direction of Fire Spread (%)</td>
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<tr>
<td>Fire Spread Direction B/H/F</td>
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<tr>
<td>interval</td>
<td>ft. or in.</td>
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<td>ROS</td>
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<tr>
<td>time</td>
<td>min. or sec.</td>
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<tr>
<td>Flame Length (in or ft)</td>
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<tr>
<td>Flame Zone Depth (in or ft)</td>
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</tr>
<tr>
<td>Scorch Height (ft)*</td>
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<tr>
<td>Char Height (ft)*</td>
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</table>

* These can be measured postfire or calculated: scorch and char heights are only measured postburn.
## SMOKE MONITORING DATA SHEET

**Plot Id** [ ]  
**Burn Unit** [ ]  
**Date** / /  
**FBWS** / /  

### Monitoring Variables

<table>
<thead>
<tr>
<th>(MAS) Monitoring Variable</th>
<th>Monitoring Frequency (MAS) - Time (Post Ignition) - Hours</th>
<th>Recommended Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fireline Visibility/CO (Feet)</td>
<td>0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5</td>
<td>Visibility &lt; 100' Exposure NTE 2 hours</td>
</tr>
<tr>
<td>Visibility Highways (Feet)</td>
<td>0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5</td>
<td>See MAV in this Handbook, page 2.14</td>
</tr>
<tr>
<td>Visibility Downwind (Miles)</td>
<td>2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46</td>
<td>Pop. Min. Dist. 0-5K 3-5 miles 5K-50K 5-7 miles &gt;50K 7-9 miles</td>
</tr>
<tr>
<td>Complaints (Number)</td>
<td>0.2 2.4 4.6 6.8 8.10 10.12 12.14 14.16 16.18 18.20 20.22 22.24 24.26 26.28 28.30 30.32 32.34 34.36 36.38 38.40 40.42 42.44 44.46</td>
<td>Consult local Air Quality Control District Regs. Do Not exceed 5/treatment</td>
</tr>
<tr>
<td>Visibility Sensitive Areas (Feet)</td>
<td>0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5</td>
<td>Discretion of PBB. Refer to park FMP or PBP.</td>
</tr>
<tr>
<td>Mixing Height (Feet)</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23</td>
<td>Maintain 1500'. Do not violate for more than 3 hours or past 3:00 pm</td>
</tr>
<tr>
<td>Transport Winds (Speed-MPH)</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23</td>
<td>5-7 mph at mixing height. Do not violate for more than 3 hrs or past 3:00 pm.</td>
</tr>
<tr>
<td>Ground Winds (Speed-MPH) (Specify Frequency)</td>
<td>MAJ = 1 reading/6 hours</td>
<td>1-3 mph-Day 3-5 mph-Night No violations over 1 hour.</td>
</tr>
</tbody>
</table>

### OTHER

1. **Total Emissions Production (Tons/Acre):**  
2. **Loading Reduction (Total):**  
3. **Preburn Loading Estimate (See PBP):**  
4. **Postburn Loading Calculation:**

### KEY

- Given Frequency (MAS)  
- Actual Recorded Data

---

**FMH-3**  
**MAS = Minimum Acceptable Standard**
1. List all FUELBED COMPONENTS in (a).
2. Estimate preburn LOADING in (b).
3. Estimate percent CONSUMPTION of components in (c).
4. Multiply LOADING (b) by percent CONSUMPTION (c) to get CONSUMPTION, TONS PER ACRE (d).
5. Sum column (d) and place result in (e), TOTAL CONSUMPTION.
6. Find EMISSION FACTOR in TABLE below for PM10 (or other pollutant of choice). Place result in (f).
7. Multiply TOTAL CONSUMPTION (e) by EMISSION FACTOR (f) to get EMISSIONS. Multiply by acres burned if you want total.

<table>
<thead>
<tr>
<th>Fuelbed Components</th>
<th>(b) Loading, Tons/Acre</th>
<th>(c) Consumption, Percent</th>
<th>=</th>
<th>(d) Consumption, Tons/Acre</th>
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</thead>
<tbody>
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</table>

<table>
<thead>
<tr>
<th>Fuel Component</th>
<th>Emission Factors (Pounds/Ton)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PM2.5</td>
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<tr>
<td>Hardwood</td>
<td>22</td>
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<tr>
<td>Chaparral</td>
<td>16</td>
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<tr>
<td>Sagebrush</td>
<td>18</td>
</tr>
<tr>
<td>Long-needled conifers</td>
<td>60</td>
</tr>
<tr>
<td>Short-needled conifers</td>
<td>26</td>
</tr>
<tr>
<td>Grassland</td>
<td>20</td>
</tr>
<tr>
<td>Palmetto-gallberry</td>
<td>30</td>
</tr>
</tbody>
</table>

FMH-3
MONITORING TYPE DESCRIPTION SHEET

Monitoring Type Code* _________ Date Described / / 

Monitoring Type Name:______________________________________________

Preparer (FBWS/RMS/FMO):__________________________________________

Burn Prescription:__________________________________________________

Burn Goals:________________________________________________________

Monitoring Type Variable (s):________________________________________

Physical Description:______________________________________________

Biological Description:____________________________________________

Rejection Criteria:__________________________________________________

* Assign unique 9 character code as described below:
  - Plot Type (F=forest, B=brush, G=grass)
  - Dominant Species Alpha Code (see Appendix C)
  - Burn Period Phenology (phenological stage of key plants affected
    by and/or carrying the fire):
    G=green-up (period of active plant growth)
    T=transition (plants setting and dispersing seed)
    D=dormant (plants cured, dormant; deciduous trees lost
      leaves)
  - Fuel Model (#1-13 or custom model 10)
# PLOT PROTOCOLS

## GENERAL PROTOCOLS

<table>
<thead>
<tr>
<th>Preburn</th>
<th>YES</th>
<th>NO</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Plots/Opt</td>
<td>Herb Height/Rec</td>
<td></td>
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<tr>
<td>Herbaceous Density/Opt</td>
<td>Belt Transect Width</td>
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<tr>
<td>OP/Origin Buried</td>
<td>Abbreviated Tags</td>
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<tr>
<td>Voucher Specimens/Rec</td>
<td>Stakes Installed</td>
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<tr>
<td>Stereo Photography/Opt</td>
<td>Crown Intercept/Opt</td>
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<tr>
<td>Brush Individuals/Rec</td>
<td>Herb. Fuel Load/Opt</td>
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</tbody>
</table>

Herbaceous Data Collected at: Q4-Q1 • Q3-Q2 • 0P-50P • 0P-30P

## Burn and Postburn

<table>
<thead>
<tr>
<th>Duff Moisture/Rec</th>
<th>Flame Zone Depth/Rec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbaceous Data/Opt</td>
<td>FMH - 17/19/23 Herbs. Fuel Load/Opt</td>
</tr>
</tbody>
</table>

100 Pt. Burn Severity/Opt

## FOREST PLOT PROTOCOLS

<table>
<thead>
<tr>
<th>Overstory</th>
<th>YES</th>
<th>NO</th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>Area sampled</td>
<td>Quarters Sampled</td>
<td></td>
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<tr>
<td>Tree Damage/Rec</td>
<td>Crown Position/Rec</td>
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<tr>
<td>Dead Tree Damage/Opt</td>
<td>Dead Crown Position/Opt</td>
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</table>

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<thead>
<tr>
<th>Pole-size</th>
<th>Area Sampled</th>
<th>Quarters Sampled</th>
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</thead>
<tbody>
<tr>
<td>Height/Rec</td>
<td>Poles Tagged/Rec</td>
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</table>

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<thead>
<tr>
<th>Seedling</th>
<th>Area Sampled</th>
<th>Quarters Sampled</th>
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</thead>
<tbody>
<tr>
<td>Height/Rec</td>
<td>Seedlings Mapped/Opt</td>
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</table>

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<thead>
<tr>
<th>Fuel Load</th>
<th>Sampling Plane Length</th>
<th>Fuel Continuity/Opt</th>
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</thead>
<tbody>
<tr>
<td>Aerial Fuel Load/Opt</td>
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</table>

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<thead>
<tr>
<th>Postburn</th>
<th>Char Height/Rec</th>
<th>Mortality/Rec</th>
</tr>
</thead>
</table>

Rec = Recommended  Opt = Optional
Plot ID_________________ Burn/Control (circle one) Date__/__/ 
Burn Unit_________________ Recorders_________________
Topo Quad________________ Transect Azimuth_____
Declination____ UTM ZONE_ UTMN____ UTM E_____
Lat____ Long____ Section____ Township____ Range_____
Slope (%)____ Elevation____ Aspect____
Date of Last Known Fire____

Fire History of the Plot________________

1. Road and trail used to travel to the plot _______________________

2. True compass bearing at point where road/trail is left to 
hike to the plot: _______ degrees.
3. Mark and attach a map of the point where the road/trail is 
left to go cross-country to the plot.
4. Describe the route to the plot; include or attach hand drawn 
map.

5. True compass bearing from the plot reference stake to the 
reference feature: _______ degrees.
6. Describe the reference feature ______________________

7. Photo # of picture from plot reference stake to reference 
feature ________
8. Photo # of picture from reference feature to plot reference 
stake ______
   Lens focal length ______ mm, ASA_______ Film____________
   Time photos taken ______________, Roll ID_____
9. Distance from reference feature to plot reference stake____m
10. Describe the index plot location; include or attach hand 
drawn map of the plot layout (including plot reference 
stake) and significant features.
11. Deviations from monitoring protocols Y N (circle one)
12. If yes, describe________________________
<table>
<thead>
<tr>
<th>Date</th>
<th>Status</th>
<th>Purpose</th>
<th>Comments</th>
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<tr>
<td>Species Code</td>
<td>Genus / species (spell out full name)</td>
<td>Native (circle one)</td>
<td>Annual Biennial Perennial</td>
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<td>Yes</td>
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</tbody>
</table>

Use this form to avoid duplications of species codes.
**FOREST PLOT DATA SHEET**

Plot ID ____________________ B / C (circle one) Date ___ / ___ / ___

Burn Unit __________________ Recorders __________________

Burn Status: PRE Post mo _____ yr1 yr2 yr5 yr10 yr20 (circle one)

Random Azimuth for 50-m centerline from OP to 50P: ____________

*place metal stakes; bury reference (origin) stake.*

**Plot Photographs**

Camera Lens ____ mm Film ______ ASA_______ Roll ID _______

<table>
<thead>
<tr>
<th>Field of View</th>
<th>Photo ID Code</th>
<th>Photo ID Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. OP to origin:</td>
<td>Photo # ...</td>
<td>Time ...</td>
</tr>
<tr>
<td>2. Q4 to Q1:</td>
<td>Photo # ...</td>
<td>Time ...</td>
</tr>
<tr>
<td>3. P1 to origin:</td>
<td>Photo # ...</td>
<td>Time ...</td>
</tr>
<tr>
<td>4. Q1 to Q4:</td>
<td>Photo # ...</td>
<td>Time ...</td>
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<tr>
<td>5. 50P to origin:</td>
<td>Photo # ...</td>
<td>Time ...</td>
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<tr>
<td>6. Q2 to Q3:</td>
<td>Photo # ...</td>
<td>Time ...</td>
</tr>
<tr>
<td>7. P2 to origin:</td>
<td>Photo # ...</td>
<td>Time ...</td>
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<tr>
<td>8. Q3 to Q2:</td>
<td>Photo # ...</td>
<td>Time ...</td>
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</tbody>
</table>
**FMH-8 OVERSTORY TAGGED TREE DATA SHEET**

<table>
<thead>
<tr>
<th>Plot ID</th>
<th>Burn Unit</th>
<th>B / C (circle one)</th>
<th>Burn Recorders</th>
<th>Date / /</th>
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</thead>
<tbody>
<tr>
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</table>

**Burn Status:** PRE Post mo___ yr1 yr2 yr5 yr10 yr20 (circle one)

<table>
<thead>
<tr>
<th>QTR</th>
<th>TAG</th>
<th>SPP</th>
<th>DBH, cm</th>
<th>LIVE CROWN</th>
<th>DAMAGE (codes below)</th>
<th>COMMENTS</th>
</tr>
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<tbody>
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**Crown Position Codes:**

1 = Dominant  2 = Codominant  3 = Intermediate  4 = Subcanopy

- ABGR = abnormal growth pattern
- BIRD = bird; (woodpecker holes)
- BLIG = blight
- BROK = broken top
- BROM = witches broom
- BURL = burl
- CONK = conk; large shelf fungus
- CROK = crooked or twisted bole
- EPIC = sprouting from bole or limbs
- FIRE = fire scar or cambial damage
- FORK = forked top
- INSE = insects or their sign
- LEAN = tree is leaning
- LIGHT = lightning scar
- MAMM = mammal-caused damage
- MISL = mistletoe present
- ROOT = large roots exposed
- ROTT = rot, fungus other than conk
- SPAR = unusually sparse foliage
- SPRT = sprouting from base
- TWIN = twinned tree—below dbh
- UMAN = human-caused damage
- WOND = wound—cracks, etc.

**FMH-8**
**FULL PLOT TREE MAP**

<table>
<thead>
<tr>
<th>Tree Class</th>
<th>0m</th>
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(click one of the above)

**Plot ID**

**B / C (circle one)**

**Burn Status:** PRE Post mo____ yr1 yr2 yr5 yr10 yr20 (circle one)
Plot ID: ____________________ B / C (circle one) _____________ Date ______ / ______ / ______

Burn Unit: ____________________ Recorders: ____________________

Burn Status: PRE Post mo____ yr1 yr2 yr5 yr10 yr20 (circle one)

Record: quarter (if other than Q1), species by code, TAG # (recommended), DBH in centimeters, alive (LIVE), and height by code (HGT, recommended).

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<th>DBH</th>
<th>LIVE</th>
<th>HGT</th>
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Height Class Codes (height in centimeters):

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1Height is measured from the ground level to the highest point of growth on the tree. A bent tree can have its highest point below the growing apex.

FMH-11
FMH-13

ALTERNATE POLE-SIZED TREE MAP

Plot ID ___________________ B / C (circle one) Date __ / __ / ___

Burn Unit ___________________ Recorders

Burn Status: PRE Post mo___ yr1 yr2 yr5 yr10 yr20 (circle one)

Quarter #

or Area Dimensions

___ m x ___ m

___ m

___ m

___ m

___ m

___ m

___ m

FMH-13
**SEEDLING TREE DATA SHEET**

**Plot ID**

**Burn Unit**

**Burn Status:** PRE Post mo, _yr_1 yr2 yr5 yr10 yr20 (circle one)

**Recorders**

**Height Class Codes (height[^1] in centimeters)**

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<th>Height</th>
<th>Code</th>
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[^1]: Height is measured from the ground level to the highest point of growth on the tree. A bent tree can have its highest point below the growing apex.
Plot ID
Burn Unit
Burn Status: PRE Post mo

B / C (circle one) Date
Recorders

yr1 yr2 yr5 yr10 yr20 (circle one)

0m

2.5m

5m

7.5m

(Origin) 10m
FMH-16

QUARTER 1 (250M²) SEEDLING TREE MAP

Plot ID __________________________ B / C (circle one) Date __/__/____
Burn Unit __________________________ Recorders
Burn Status: PRE Post mo___ yr1 yr2 yr5 yr10 yr20 (circle one)

(Origin) 25m

30m

35m

40m

45m

50m
## 50 Meter Transect Data Sheet

**Plot ID**: B / C  
**Burn Unit**: Recorders  
**Burn Status**: PRE Post mo  
**Transect Azimuth**: Q4-Q1 Q3-Q2  
**Tape, PNT m HGT, m SPP; Species or Substrate Codes (tallest to lowest)**

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Species observed within 5m of either side of the transect but not intercepted:

FMH-17; Page 4 of 4
FMH-18  
BELT TRANSECT DATA SHEET FOR BRUSH DENSITY  

Plot ID__________________________________  B / C (circle one)  Date__/__/____  
Burn Unit_________________________  Recorders______________________  
Burn Status: PRE Post mo___ yrl yr2 yr5 yr10 yr20 (circle one)  
Transect Azimuth:____________________  Transect: Q4-Q1  Q3-Q2  0P-50P (circle one)  

For living and dead plants within the transect, count all individuals having ≥50% of its rooted base in the belt. The optional interval field (INT) can be used to subdivide the belt into subunits to facilitate species counts. Record AGE code (see below).

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AGE codes:  S Seedling/immature  R Resprout  M Mature/adult
**BELT TRANSECT DATA SHEET FOR BRUSH DENSITY**

Plot ID________________________ B / C (circle one) Date________/____/____

Burn Unit_______________________ Recorders________________________

Burn Status: PRE Post mo yr1 yr2 yr5 yr10 yr20 (circle one)

Transect Azimuth:_________ Transect: Q4-Q1 Q3-Q2 0P-50P (circle one)

For living and dead plants within the transect, count all individuals having ≥ 50% of its rooted base in the belt. The optional interval field (INT) can be used to subdivide the belt into subunits to facilitate species counts. Record AGE code (see below).

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AGE codes:  S=Seedling/immature  R=Resprout  M= Mature/adult
HERBACEOUS DENSITY DATA SHEET

Plot ID: B / C (circle one) Date: / / 
Burn Unit Recorders: 
Burn Status: PRE Post mo____ yrl1 yrl2 yrl5 yrl10 yrl20 (circle one)

Frame Size: m² Side of the Transect Monitored(facing 30P)____

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Herbaceous density frame

FMH-19
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## OVERSTORY TREE POSTFIRE ASSESSMENT DATA SHEET

### Variables
- **Plot ID**
- **Burn Unit**
- **Date**
- **Recorders**
- **Burn Status:** PRE Post mo yr1 yr2 yr5 yr10 yr20 (circle one)

### Instructions
For each tagged overstory tree record: TAG #, tree status (LIVE- alive (L), dead (D), resprouting (R), or completely consumed (C)), maximum scorch height (SCHGT), % crown scorched (SCPERS), and char height (CHAR) (recommended).

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<th>CHAR, m</th>
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- alive(L) 
- dead(D)
- resprouting(R)
- consumed(C)

**Total # all trees**

For scorched trees, compute average scorch height, (sum of maximum scorch heights/number of trees). Average scorch height:

To compute average maximum char height, add all char height values and divide by number of trees. Average char height:
Postfire burn severity ratings are made at Brown transects duff measurement points using the Coding Matrix at the bottom of this form. Each observation is from a 4dm² area.

**ORGANIC SUBSTRATE**

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Average Organic Substrate Burn Severity

**VEGETATION**

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Average Vegetation Burn Severity

**Burn Severity Coding Matrix**

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<th>Substrate (litter/duff)</th>
<th>Unburned (S)</th>
<th>Scorched (4)</th>
<th>Lightly Burned (3)</th>
<th>Moderately Burned (2)</th>
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<tr>
<td></td>
<td>not burned</td>
<td>litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged</td>
<td>litter charred to partially consumed; upper duff layer burned; wood/leaf structures charred, but recognizable</td>
<td>litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply burned; wood/leaf structures unrecognizable</td>
<td>litter and duff consumed, leaving fine white ash; mineral soil visibly altered, often reddish</td>
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<td>Vegetation (understory/brush/herbs)</td>
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<td>foliage scorched and attached to supporting twigs</td>
<td>foliage and smaller twigs partially to completely consumed</td>
<td>foliage, twigs and small stems consumed</td>
<td>all plant parts consumed leaving some or no major stems/trunks</td>
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</table>

Species observed within 5m of either side of the transect but not intercepted:

FMH-23; page 2 of 2
FMH-24 BRUSH AND GRASSLAND PLOT BURN SEVERITY DATA SHEET

Each observation is from a 4dm² area every 5 meters. Rating codes and descriptions are listed below in the Coding Matrix. An optional form which will allow rating at all 100 points can be found on the back of this data sheet.

ORGANIC SUBSTRATE

<table>
<thead>
<tr>
<th>Sample Point</th>
<th>0m</th>
<th>5m</th>
<th>10m</th>
<th>15m</th>
<th>20m</th>
<th>25m</th>
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<tbody>
<tr>
<td>S</td>
<td>S</td>
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Average Organic Substrate Burn Severity_____

VEGETATION

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<th>0m</th>
<th>5m</th>
<th>10m</th>
<th>15m</th>
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<th>25m</th>
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</thead>
<tbody>
<tr>
<td>V</td>
<td>V</td>
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Average Vegetation Burn Severity_____

Burn Severity Coding Matrix

<table>
<thead>
<tr>
<th></th>
<th>Unburned (5)</th>
<th>Scorched (4)</th>
<th>Lightly Burned (3)</th>
<th>Moderately Burned (2)</th>
<th>Heavily Burned (1)</th>
<th>Not Applicable (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate (litter/duff) (S)</td>
<td>not burned</td>
<td>litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged</td>
<td>litter charred to partially consumed; upper duff layer burned; wood/leaf structures charred, but recognizable</td>
<td>litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply burned; wood/leaf structures unrecognizable</td>
<td>litter and duff consumed, leaving fine white ash; mineral soil visibly altered, often reddish</td>
<td>inorganic</td>
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<tr>
<td>Vegetation (understory/brush/herbs) (V)</td>
<td>not burned</td>
<td>foliage scorched and attached to supporting twigs</td>
<td>foliage and smaller twigs partially to completely consumed</td>
<td>foliage, twigs and small stems consumed</td>
<td>all plant parts consumed leaving some or no major stems/trunks</td>
<td>none present</td>
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page 1 of 2; FMH-24
<table>
<thead>
<tr>
<th>Substrate</th>
<th>Vegetation</th>
<th>Burn Severity at Every Point (optional)</th>
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<td>100 S V</td>
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**Burn Severity Coding Matrix**

<table>
<thead>
<tr>
<th>Unburned (S)</th>
<th>Scorched (4)</th>
<th>Lightly Burned (3)</th>
<th>Moderately Burned (2)</th>
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</tr>
</tbody>
</table>

FMH-24; page 2 of 2
FMH-25  
BRUSH STEM AND BIOMASS DATA SHEET

Plot ID________________ B / C (circle one) Date_____/_____/_____
Burn Unit________________ Recorders__________________________
Burn Status: PRE Post mo___ yr1 yr2 yr5 yr10 yr20 (circle one)
Shrub #________________ Spp.__________________________

Basal Stem Diameter_____________(mm)

Date Collected_____/_____/______ Date Weighed_____/_____/______

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</table>

Total Sample Weight --->

All measurements are in grams unless otherwise noted.

Total gross weight: field weights are from a kitchen scale, lab weights from a triple-beam scale or (when measuring foliage with 0-5mm components) by conversion of field measurements using a subsample ratio.

Average all measurements if two or more subsamples are gathered.

WATER WT = WET WT - DRY WT
NET WET WT = WET WT - CAN WT
MOIST. FRAC. = WATER WT / NET WET WT
TOT. NET DRY WT = TOTAL GROSS WT - (TOTAL GROSS WT x MOIST. FRAC.)
% BY SIZE = (TOT. NET DRY WT / TOTAL SAMPLE WT) x 100%
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<th>PLOT ID</th>
<th>SUBJECT</th>
<th>AZMTH</th>
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</table>
Random numbers are used to lay out index plots and for other purposes. They can be obtained from a table or by using a computer.

**USING A TABLE**

For each use of the random number table, page B.3, choose an arbitrary starting point within the table, a reading direction, and a rule for continuing the reading of numbers if the edge of the table is reached. Number sequences may be read in any arbitrary direction (forwards horizontal, downwards vertical, diagonal, etc.) from the starting point, as long as this direction is chosen without reference to placement of numbers in the table. Various rules for continuation of reading can be used; the easiest rules use the initial reading direction, but give a new starting point for further reading. The continuation rule should indicate a new starting position relative to the table edge which has been reached and should change that portion of the table used for continuation reading. Suggested continuation rules follow:

- Start at the opposite end of the table and move to the next line (up or down)
- Start at the center of the next row above and move in the opposite direction

A unique starting point should be chosen for each new use of the table. It is, therefore, best to mark those sequences of numbers which have already been read from. If the chosen starting point and reading direction have been previously used, select another point-direction combination.

To generate short sequences, such as groups of 3 digits to obtain azimuths, divide long sequences into groups of 3 segments. Reject values that are out of range (> 359° for azimuth) and continue the process until an adequate number of valid values are obtained.

**Example:**

Say we need 5 random azimuths. We choose without reference to the table to use the 7th digit of the 10th row as a starting point. We also choose to read digits horizontally to the right from the starting point. We also decide in advance that we will move down one line if we reach the end of the 10th row. We check to insure that this group of numbers has not been previously used. If this starting point and reading direction have been used previously, we choose another reading...
direction and starting point; otherwise we proceed. Let's say that the 10th row of our table is as follows:

29246 15978 24697 15784 44265 19954 15612 22478 18496 01523 04051

This means that our 3-digit values for azimuth will be 597 824 697 157 844 426 159 954 156 122 247 818 496 015 230 405 .... Our first 5 valid azimuths will be 157, 156, 122, 247, and 15.
RANDOM NUMBER TABLE
43420
75384
84635
35577
67327
63978
19004
90681
70397
10727
85149
76280
14497
13825
76967
66349
63054
60529
64917
98923
31059
77156
46020
26104
35063
79087
93861
64053
43183
20766
08585
42994
25096
45698
66903
57215
02042
36452
72084
15066
96824
64659
03964
88959
83807
41011
68939
65367

17861
23716
97805
33639
06835
14332
31174
94254
47379
07043
33276
14948
03898
57269
72422
23796
36107
53243
87234
56687
49038
66008
36649
07323
43030
99424
49914
77217
63739
40159
76590
25695
52132
07696
36550
19897
94487
04331
69980
84772
72397
65169
87377
53085
12766
08132
19553
15412

27541
92241
51941
65961
28539
01203
92411
56333
07639
74192
34494
11781
21628
94949
23259
98079
41357
48777
92835
57559
01736
72540
16417
59118
51741
04666
56260
48215
04408
35146
13683
96872
86838
55532
79066
53673
90192
08940
81853
93764
19695
40047
40550
68853
44634
45094
12725
57214

93247
89857
02346
33222
36493
70540
09206
95457
46995
48202
87791
26523
04392
21625
52894
79106
46135
84898
52124
76203
17488
77427
15900
61125
21526
33929
07455
47495
69139
34433
72833
69248
29028
54280
90892
30634
77706
14125
23302
56211
49500
29934
64545
40854
86548
62988
91917
99747

30645
56180
31448
07508
12186
41428
76051
70753
87271
68548
75795
35319
66984
91201
36296
93148
88972
77113
64729
25245
67443
58070
19837
51681
43169
79923
61921
81584
33484
52582
02847
63149
82285
00023
56043
33632
10029
10283
86499
69351
63740
85462
60767
35686
67001
91721
96963
37082

Appendix B: Random Number Generators

58654
73441
46943
50196
30192
85812
67576
60606
35161
74131
11849
43618
90309
27411
12917
73404
32696
92479
99247
56945
69694
23973
44617
84035
28991
34344
18120
77284
08583
43855
34160
42109
26781
30584
02454
16745
72209
80419
78031
22236
53801
37061
11232
12438
50807
52023
97713
24023

22765
91722
60803
44245
09663
00262
85574
62576
54082
76272
72237
33411
55778
02711
71327
84240
53570
89100
47446
44116
75337
21523
29255
93654
88024
12627
59478
15032
47637
51621
44903
41990
49243
54275
06379
09832
76974
12925
28819
05421
54022
46467
11196
17186
92645
50359
16549
85117

79767
70441
31937
39508
64532
57857
47613
85834
03295
56927
79179
63710
46791
68774
25022
40666
28563
14831
41344
79544
14969
86849
92158
88498
55180
96887
99291
70994
31176
27318
92382
75813
07754
80829
58880
47046
82521
30416
94052
74096
35897
69390
50971
41682
81114
61376
90527
79832

79506
02346
99144
90236
38836
50984
32144
97304
56480
22476
12789
42533
30241
63451
95914
73334
09485
59604
62916
51183
45140
85689
71752
01617
39694
55527
06944
64234
97202
71996
29577
42698
73278
77042
27298
54733
25101
01669
64314
82126
61410
15946
31397
20726
92507
79004
95882
30446

11802
96199
99445
22251
42944
67619
10358
12912
38204
97041
92396
90653
54176
94574
31058
63239
92762
53137
32154
96245
51180
98464
71808
63060
71960
39098
46454
94885
92942
16398
22842
30733
97282
54533
88032
67432
63445
10486
99395
09619
15212
24052
34620
19746
71674
67837
41702
68076

89126
64682
61523
92363
18308
48422
49050
34783
37946
78466
81012
11275
28265
74490
50915
48548
33551
07735
91327
99872
12153
51003
23880
95082
86485
28660
09266
90574
93021
66634
97241
19308
32297
42414
76624
40804
18913
35054
25296
91147
31533
75168
60200
32984
62879
94935
87342
05522

28268
52857
80094
27309
22898
57640
06722
06834
97723
62578
26608
98207
62071
58637
09233
71302
33079
82096
06893
16304
85698
64546
04694
93711
02693
82894
70558
84334
24639
09354
05215
39295
99926
61456
92212
30031
34753
52043
47905
98289
43136
39268
71465
06129
96900
76599
94874
85926

B. 3


USING THE HP-71B HANDHELD COMPUTER

Two ways to generate random numbers using the HP-71B are described below. Both methods require starting out with a RANDOMIZE command:

Type RANDOMIZE, which causes the HP-71B to generate an initial number, based on the current HP-71B clock reading. Then press RND every time a new random number is desired.

Generate a 12-Figure String of Numbers

The fastest method to locate many numbers is to generate a string of 12 figures using the RANDOMIZE and RND commands and then divide the 12-figure string into equal sets of 2, 3, 4, or more numbers depending on the intended purpose. Use the following commands:

```
RANDOMIZE (ENDLINE key)
RND (ENDLINE key)...repeat until enough numbers are generated.
```

Periodically the number generated is an exponent with 2 or 3 more characters. If the number is an exponent, use the following procedure:

- E-2--move the decimal point 2 places to the left and begin the first 3-digit number with one zero. Reject numbers less than 3-digits long at the end of the string.
- E-3--move the decimal point 3 places to the left and begin the first 3-digit number with two zeros. Reject numbers less than 3-digits long at the end of the string.

Generate a 3-figure Random Number

To directly generate a 3-figure random number follow the procedure outlined below.

```
RANDOMIZE (ENDLINE key)...to randomize the starting number
IP(999×RND+1) (ENDLINE key)
```

The same sequence must be repeated to generate the next 3-digit number.
Appendix C; Data and Label Coding Guidelines

GENERAL CODING RULES

♦ Always use and regularly update form FMH-6 to record species codes used
♦ Always use capital letters when using alpha characters
♦ Never use hyphens (-), slashes (/ or \), asterisks (*), or any other non-alphanumeric character

INDEX PLOT IDENTIFICATION CODE

Every index plot must be identified by the following code to facilitate computerization and comparative analyses within and between NPS units:

Assign unique 9-character code as described here:

- Plot Type: F=forest, B=brush, G=grass
- Dominant Species Code (see below)
- Burn Period Phenology (phenological stage of key plants affected by or carrying the fire during a burn (a burn prescription element)):
  G = green-up (period of active plant growth)
  T = transition (plants setting and dispersing seed)
  D = dormant (plants cured, dormant; deciduous trees lost leaves)
- Fuel Model (#01-13 or custom model)

examples: FSEGI1T08 (forest, giant sequoia (*Sequoia giganteum*), transition, model 8)
BARTR1D05 (brush, sagebrush (*Artemisia tridentata*), dormant, model 5)
Assign Plot Number

Start at 01 and number index plots consecutively within each monitoring type, ex.: FSEGI1T0801, FSEGI1T0802, BARTR1D0501, BARTR1D0502.

SPECIES CODES

Use 4-character alpha code composed, if possible, of the first 2 letters of the genus name, the first 2 letters of the species name and the number "1", if there are no duplications and if no subspecies or varieties are named.

Examples
ABCO1 Abies concolor
PIPO1 Pinus ponderosa
GITR1 Gilia tricolor

If there is both a species and one or more subspecies or varieties, or if the species code is identical for two different species, use a 1 for the first species, subspecies, or variety (a blank or zero (0) in the fifth position is unacceptable), a 2 for the second, etc. Note on the data sheet which species, subspecies, or variety is represented by each numeric addition. (Keep track of all assigned species codes on form FMH-6 to avoid duplicate codes.)

Examples
OEH01 Oenothera hookeri ssp. angustifolia
Oeh02 O. hookeri ssp. grisea
EPAN1 Epilobium angustifolium
EPAN2 Epilobium anagallidifolium

If the plant cannot be identified to genus because the field technician lacks plant identification skills or identifying parts are lacking, collect, label, and preserve the plant material. Use an identification guide, however, to make every attempt to determine genus.

Some difficult identifications, such as the bryophytes, fungi, and algae, can be grossly distinguished and coded:

MOSS1 (moss species unknown, but different from MOSS2)
MOSS2 (moss species unknown, but different from MOSS1)
LICH1 (lichen species unknown, but different from LICH2)
LICH2 (lichen species unknown, but different from LICH1)
MUSH1 (mushroom, etc.)
ALGA1 (algae, etc.)

Appendix C: Data and Label Coding Guidelines
Unknowns in the field should be collected or drawn, and described so that future field technicians will record the same unknown with the same code. Unknowns are coded to allow for up to 99 entries:

UNK21 for unknown number 21, etc.
GRA01 for unknown grass number 1, etc.

If the unknown is identified at a later date, the code (ex.: UNK21, etc.) must be globally corrected in the database.

**CODES FOR DEAD AND INORGANIC MATERIALS**

<table>
<thead>
<tr>
<th>Material</th>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>rock</td>
<td>ROCK</td>
<td>mineral particles ≥ 1 inch diam.</td>
</tr>
<tr>
<td>bare ground/gravel/soil/ash</td>
<td>BARE</td>
<td>soil particles &lt; 1 inch diam.</td>
</tr>
<tr>
<td>dead and detached wood</td>
<td>WOOD</td>
<td>(1)</td>
</tr>
<tr>
<td>vegetation litter</td>
<td>LITT</td>
<td>(2)</td>
</tr>
<tr>
<td>forest duff</td>
<td>DUFF</td>
<td>(3)</td>
</tr>
<tr>
<td>standing dead tree</td>
<td>SDED</td>
<td>self explanatory</td>
</tr>
<tr>
<td>water</td>
<td>WATR</td>
<td>permanent body of water or running water present 6 months/year or more</td>
</tr>
<tr>
<td>scat or dung</td>
<td>SCAT</td>
<td>native, exotic, and feral animal scat</td>
</tr>
</tbody>
</table>

(1) Dead and downed twigs, branches, and tree stumps in and above the litter.
(2) Forest litter includes freshly fallen dead plant parts other than wood such as cones, bracts, seeds, bark, needles, and detached leaves that are less than 50% buried in the duff layer.
(3) Duff is the fermentation and humus layer. It lies below the litter and above mineral soil.
LABELING INDEX PLOT STAKES

Install permanent plot identification tags on each stake described below.

- Use rectangular or oblong brass tags (Appendix E).
- The recommended format includes the index stake location code, plot purpose, plot identification code, and date on the tag. An abbreviated format may be used to reduce the amount of minting. It includes the vegetation code from the plot identification code, plot number, index stake location code, plot purpose, and date. The two formats are displayed below:

Recommended Stake Label

- stake location code*
- indicates plot purpose
- plot identification code
- date; month, day, year

Abbreviated Stake Label

- stake location code*
- indicates plot purpose
- dominant species code & plot number**
- date; month, day, year

* The stake location codes are identified in Figure 15 (forest plots) and Figure 16 (brush or grassland plots) below.

** The dominant species code is from the index plot identification code.
Figure 15. Stake location codes for forest plots.

Figure 16. Stake location codes for brush or grass index plots.

LABELING SLIDES

Slides should be labeled as soon as they are developed. The Photographic Record Sheet (Form FMH-26) should greatly facilitate the labeling of slides. Slides should be labeled as follows (format is on the left, example on the right):

<table>
<thead>
<tr>
<th>Plot ID Code</th>
<th>FSEGI1T0803</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn Status</td>
<td>8/23/89</td>
</tr>
<tr>
<td>Date</td>
<td>yr1 postburn</td>
</tr>
<tr>
<td>Time</td>
<td>Q2-Q3</td>
</tr>
<tr>
<td>Subject</td>
<td>1215</td>
</tr>
</tbody>
</table>
Appendix C: Data and Label Coding Guidelines
STANDARD PROCEDURES

A camera with a 35 mm lens is preferred for the photodocumentation required by this Handbook. A databack (date and time is printed on the film) camera is useful for ensuring that each photograph can be identified after development. At a minimum, a coded photograph identification "card" should be prepared and made visible in every photograph. Follow these guidelines for establishing photopoints; they may also be used to photograph index plots.

- Mark the photo point so that it can be found again. Use a permanent stake that won't deteriorate or be easily dislodged. Describe reference features to facilitate plot relocation. Record the plot location on an aerial photo, if possible.

- Write the plot identification code and stake code in large black letters on white paper. Place this paper within the field of view such that it is readable, but does not block important plot features.

- Use the same kind of camera, lens and film each time you rephotograph. Try to retake the photo at the same time of year and day, or at about the same phenological stage of the brush and herbaceous species. To avoid shadows, it is best to take photographs when the sun is directly overhead.

- Always try to include the stake (photo point) you are shooting from and the stake you are shooting towards in the field of view.

- Note the compass azimuth in the direction of the photo.

If possible, bring a reference photo along to facilitate duplication of earlier shots.

OPTIONAL STEREO PHOTOGRAPHY PROCEDURES

Always use fast film to maximize the depth-of-field (100-400 ASA Ektachrome). Select the subject, then set the exposure as follows:
Try to obtain f/16 and still have a shutter speed of 1/60 second or faster. If not, then back off to f/12 or f/8 (try to get the smallest aperture possible).

Set the depth of field to just include the farthest object visible in the shot (usually infinity).

Note the nearest distance that will be in focus (shown on the depth-of-field indicator).

Be sure that the light meter reading has not included any sky.

You are now ready to take the shot:

Don't change the lens setting or focus, even if the view seems out of focus; it will give an excellent, clear shot with the entire field of view in focus if used as set from the above instructions.

Look through the view finder and place the bottom of the view at the nearest distance that will be in focus.

Select an object in the center of the view that is easy to find and center the shot on it, using the "crosshairs" as a reference.

Be sure that the camera is level and shoot the first shot.

While still looking through the view finder at the center point, advance the film, shift 3 to 4 inches to the RIGHT, recenter and level the view, and shoot the second shot.

That's all there is to it. The lower-numbered shot of the pair will be on the left.

REFERENCES


LOCATING, MARKING, AND INSTALLING AN INDEX PLOT

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>topographic maps for locating random points</td>
<td>variable</td>
</tr>
<tr>
<td>orthophoto quads or aerial photos for locating random points</td>
<td>variable</td>
</tr>
<tr>
<td>databack camera with 35 mm lens</td>
<td>1</td>
</tr>
<tr>
<td>high ASA film (64-400) (± 20 exposures per plot)</td>
<td>1 roll + spare</td>
</tr>
<tr>
<td>Photo Record Sheet (form FMH-26)</td>
<td>1 per roll</td>
</tr>
<tr>
<td>compass (declination preset)</td>
<td>1</td>
</tr>
<tr>
<td>clinometer</td>
<td>1</td>
</tr>
<tr>
<td>flagging</td>
<td>1 roll</td>
</tr>
<tr>
<td>rebar stakes*</td>
<td>2 / 7 (grass/brush)</td>
</tr>
<tr>
<td>rolled steel stakes</td>
<td>4 to 13 (forest)</td>
</tr>
<tr>
<td>plot identification tags</td>
<td>4 (forest)</td>
</tr>
<tr>
<td>wire for attaching tags to stakes</td>
<td>2 / 7 (grass/brush)</td>
</tr>
<tr>
<td>hand stamp steel dies to mint plot ID tags</td>
<td>17 (forest)</td>
</tr>
<tr>
<td>hammer</td>
<td>variable</td>
</tr>
<tr>
<td>clipboard and pencils</td>
<td>2</td>
</tr>
<tr>
<td>small plant press with blotter paper</td>
<td>2 + (1 per monitor)</td>
</tr>
<tr>
<td>plant identification guides</td>
<td>1</td>
</tr>
<tr>
<td>WR Fire Monitoring Handbook</td>
<td>1</td>
</tr>
<tr>
<td>FMH-4 Monitoring Type Description Sheet</td>
<td>1 per monitoring type</td>
</tr>
<tr>
<td>FMH-5 Index Plot Location Data Sheet</td>
<td>1 per plot</td>
</tr>
<tr>
<td>FMH-6 Species Code List</td>
<td>1 per park</td>
</tr>
</tbody>
</table>

* Three stakes should be painted blue and three should be painted orange with heat-resistant paints for forest plots. One stake should be painted blue and one orange for grass/brush plots.
## MONITORING FOREST PLOTS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-m tape</td>
<td>3 / 4 (or 2 25-m and 2 50-m tapes)</td>
</tr>
<tr>
<td>20-m or 30-m tape</td>
<td>3</td>
</tr>
<tr>
<td>10-m diameter tape</td>
<td>1-2</td>
</tr>
<tr>
<td>1+ or 2-m rangepole, ¼-inch in diameter; marked in decimeters</td>
<td>1</td>
</tr>
<tr>
<td>sequentially numbered brass tree tags</td>
<td>150+ per plot</td>
</tr>
<tr>
<td>aluminum nails, 2 7/8-inch length</td>
<td>150+ per plot</td>
</tr>
<tr>
<td>hammer</td>
<td>1</td>
</tr>
<tr>
<td>go-no-go gauge</td>
<td>2</td>
</tr>
<tr>
<td>50-ft tape (for Downed Fuel Inventories)</td>
<td>1</td>
</tr>
<tr>
<td>12-inch metal ruler graduated in tenths of inches</td>
<td>1</td>
</tr>
<tr>
<td>1-yard (1-m) metal rule to estimate log diameters</td>
<td>1</td>
</tr>
<tr>
<td>calipers or 24-inch ruler for log diameters</td>
<td>variable</td>
</tr>
<tr>
<td>small gardening trowel for digging duff holes</td>
<td>1</td>
</tr>
</tbody>
</table>

required single forms:

- FMH-7 Forest Plot Data Sheet: 1 per plot
- FMH-9 Full Plot (1000m²) Tree Map: 1 per plot
- FMH-12 Quarter 1 Pole-sized Tree Map: 1 per plot
- FMH-13 Alternate Pole-sized Tree Map: 1 per plot
- FMH-15 50m² Seedling Tree Map: 1 per plot
- FMH-16 Quarter 1 (250m²) Seedling Tree Map: 1 per plot
- FMH-18 Belt Transect Data Sheet: 1 per plot
- FMH-20 Forest Index Plot Fuels Inventory Data Sheet: 1 per plot
- FMH-22 Forest Plot Burn Severity Data Sheet: 1 per plot

required multiple forms:

- FMH-8 Overstory Tagged Tree Data Sheet: 5+ per plot
- FMH-10 Quarter Overstory Tree Map: 4+ per plot
- FMH-11 Pole-sized Tree Data Sheet: 5+ per plot
- FMH-14 Seedling Tree Data Sheet: 5+ per plot
- FMH-17 50 Meter Transect Data Sheet: 2 per plot
- FMH-21 Overstory Tree Postfire Assessment Data Sheet: 5+ per plot

optional form:

- FMH-19 Herbaceous Density Data Sheet: 5+ per plot
**MONITORING BRUSH AND GRASS**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-m tall, ¼-inch wide rangepole</td>
<td>1</td>
</tr>
<tr>
<td>30-m (100-ft) tape</td>
<td>2</td>
</tr>
<tr>
<td>required forms:</td>
<td></td>
</tr>
<tr>
<td>FMH-18 Belt Transect Data Sheet for Brush Density</td>
<td>5+ per plot</td>
</tr>
<tr>
<td>FMH-23 30 Meter Transect Data Sheet</td>
<td>1 per plot</td>
</tr>
<tr>
<td>FMH-24 Brush and Grassland Plot Burn Severity</td>
<td>1 per plot</td>
</tr>
<tr>
<td>Data Sheet</td>
<td></td>
</tr>
<tr>
<td>optional form:</td>
<td></td>
</tr>
<tr>
<td>FMH-19 Herbaceous Density Data Sheet</td>
<td>5+ per plot</td>
</tr>
</tbody>
</table>

**DETERMINING BRUSH BIOMASS**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>go-no-go gauge</td>
<td>2</td>
</tr>
<tr>
<td>airtight containers</td>
<td>25+</td>
</tr>
<tr>
<td>pruners for brush</td>
<td>1</td>
</tr>
<tr>
<td>calipers</td>
<td>1</td>
</tr>
<tr>
<td>drying oven and scale</td>
<td>1</td>
</tr>
<tr>
<td>FMH-25 Brush Stem and Biomass Data Sheet</td>
<td>variable</td>
</tr>
</tbody>
</table>

**DETERMINING GRASS BIOMASS**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-pint airtight containers</td>
<td>10</td>
</tr>
<tr>
<td>clippers for grass</td>
<td>1</td>
</tr>
<tr>
<td>13.3-inch hoop for grass</td>
<td>1</td>
</tr>
<tr>
<td>drying oven and scale</td>
<td>1</td>
</tr>
</tbody>
</table>

*Appendix E: Equipment Checklist for Index Plots*
**DURING A PRESCRIBED BURN**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-ft pieces of wire or short metal stakes</td>
<td>32</td>
</tr>
<tr>
<td>belt weather kit</td>
<td>1</td>
</tr>
<tr>
<td>10-m or 20-m tape</td>
<td>1</td>
</tr>
<tr>
<td>10-hr fuel sticks*</td>
<td>1</td>
</tr>
<tr>
<td>fuel stick scale</td>
<td>1</td>
</tr>
<tr>
<td>airtight containers for collecting fuels (fuel moisture)</td>
<td>10</td>
</tr>
<tr>
<td>24-inch ruler</td>
<td>2</td>
</tr>
<tr>
<td>chronograph watch with sweep second hand</td>
<td>2</td>
</tr>
<tr>
<td>FMH-1 Onsite Weather Data Sheet</td>
<td>variable</td>
</tr>
<tr>
<td>FMH-2 Fire Behavior/Weather Data Sheet</td>
<td>variable</td>
</tr>
<tr>
<td>FMH-3 Smoke Monitoring Data Sheet</td>
<td>variable</td>
</tr>
</tbody>
</table>

*Set out at least three days prior to planned burning.*
### DURING A PRESCRIBED NATURAL FIRE

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>park briefing package (including maps of fire area, fire</td>
<td>1</td>
</tr>
<tr>
<td>management zone, important telephone numbers, radio</td>
<td></td>
</tr>
<tr>
<td>call numbers, significant portions of fire management</td>
<td></td>
</tr>
<tr>
<td>plan, portable radio and extra batteries and a completed FSA Part II)</td>
<td></td>
</tr>
<tr>
<td>fire behavior field reference book</td>
<td>1</td>
</tr>
<tr>
<td>clipboard</td>
<td>1</td>
</tr>
<tr>
<td>NWCG fireline notebook</td>
<td>1</td>
</tr>
<tr>
<td>belt weather kit</td>
<td></td>
</tr>
<tr>
<td>sling psychrometer (w/extra wick)</td>
<td>2</td>
</tr>
<tr>
<td>water bottle (filled with distilled water)</td>
<td>1</td>
</tr>
<tr>
<td>anemometer</td>
<td>1</td>
</tr>
<tr>
<td>compass, with adjustable declination</td>
<td>1</td>
</tr>
<tr>
<td>notebook</td>
<td>1</td>
</tr>
<tr>
<td>RH tables</td>
<td>variable</td>
</tr>
<tr>
<td>pencils, mechanical</td>
<td>variable</td>
</tr>
<tr>
<td>first aid kit</td>
<td>1</td>
</tr>
<tr>
<td>HP-71B calculator and worksheets</td>
<td>1</td>
</tr>
<tr>
<td>ruler (graduated in tenths)</td>
<td>2</td>
</tr>
<tr>
<td>file folders</td>
<td>variable</td>
</tr>
<tr>
<td>long envelopes</td>
<td>variable</td>
</tr>
<tr>
<td>protractor</td>
<td>variable</td>
</tr>
<tr>
<td>chronograph watch with sweep second hand or digital timer</td>
<td>1</td>
</tr>
<tr>
<td>portable radio with extra batteries</td>
<td>1</td>
</tr>
<tr>
<td>personal protective equipment</td>
<td>variable</td>
</tr>
<tr>
<td>hand tool</td>
<td>1</td>
</tr>
<tr>
<td>food and water for 24 hours</td>
<td>variable</td>
</tr>
<tr>
<td>Fire Situation Analysis (Part I)</td>
<td>variable</td>
</tr>
<tr>
<td>FMH-1 Onsite Weather Data Sheet</td>
<td>variable</td>
</tr>
<tr>
<td>FMH-2 Fire Behavior/Weather Data Sheet</td>
<td>variable</td>
</tr>
<tr>
<td>FMH-3 Smoke Monitoring Data Sheet</td>
<td>variable</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>OPTIONAL ITEMS</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>batteries (AA)</td>
<td></td>
</tr>
<tr>
<td>dot grids for acreage</td>
<td>variable</td>
</tr>
<tr>
<td>mini binoculars</td>
<td>1</td>
</tr>
</tbody>
</table>

*Appendix E: Equipment Checklist for Index Plots*
<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>altimeter</td>
<td>1</td>
</tr>
<tr>
<td>clinometer</td>
<td>1</td>
</tr>
<tr>
<td>pocket stereoscope</td>
<td>1</td>
</tr>
<tr>
<td>camcorder</td>
<td>1</td>
</tr>
<tr>
<td>camera (35 mm w/yellow filter for smoke)</td>
<td>1</td>
</tr>
<tr>
<td>extra film</td>
<td>variable</td>
</tr>
<tr>
<td>flagging</td>
<td>variable</td>
</tr>
<tr>
<td>AM/PW portable radio with weather band (190-400 KC)</td>
<td>1</td>
</tr>
<tr>
<td>alarm clock</td>
<td>1</td>
</tr>
<tr>
<td>printer for HP-71B and paper</td>
<td>1</td>
</tr>
<tr>
<td>tape recorder</td>
<td>1</td>
</tr>
<tr>
<td>fuel type guides (photoseries if available)</td>
<td>variable</td>
</tr>
<tr>
<td>other maps</td>
<td></td>
</tr>
<tr>
<td>state/county</td>
<td>variable</td>
</tr>
<tr>
<td>park districts</td>
<td>variable</td>
</tr>
<tr>
<td>topographic</td>
<td>variable</td>
</tr>
<tr>
<td>weather zone</td>
<td>variable</td>
</tr>
<tr>
<td>recently prepared FSA's (for same area or ecotype)</td>
<td>variable</td>
</tr>
<tr>
<td>conversion charts</td>
<td>variable</td>
</tr>
<tr>
<td>2-ft pieces of wire or short metal stakes</td>
<td>variable</td>
</tr>
<tr>
<td>10-m or 20-m tape</td>
<td>1</td>
</tr>
<tr>
<td>10-hr fuel sticks*</td>
<td>1</td>
</tr>
<tr>
<td>fuel stick scale</td>
<td>1</td>
</tr>
<tr>
<td>airtight containers for collecting fuels (fuel moisture)</td>
<td>10</td>
</tr>
<tr>
<td>FMH-20 Forest Index Plot Fuels Inventory Data Sheet</td>
<td>1 per plot</td>
</tr>
<tr>
<td>WR Fire Monitoring Handbook</td>
<td>1</td>
</tr>
<tr>
<td>flares</td>
<td>variable</td>
</tr>
<tr>
<td>range finder</td>
<td>1</td>
</tr>
<tr>
<td>FBWS (RX Fire) job task book</td>
<td>1</td>
</tr>
</tbody>
</table>

*Set out at least three days prior to assessment.

Appendix E: Equipment Checklist for Index Plots
SUGGESTED EQUIPMENT SUPPLIERS:

FORESTRY SUPPLIERS, INC.
205 West Rankin Street
P.O. Box 8397
Jackson, MS 39204-0397
1-800-647-5368

BEN MEADOWS Company
2601-B West Fifth Ave
P.O. Box 2781
Eugene, OR 97402
1-800-241-6401

Recommended equipment specifications:

**Stake Tags**

brass racetrack tags (special order)
standard size: 1-inch x 2 3/4-inch
standard hole size: 3/16-inch
unnumbered

**Tree Tags**

brass round tags (special order)
standard size: 1 ¼-inch
hole size: 3/16-inch (not standard)
numbered sequentially

**Hand Stamp Steel Dies**

¼-inch combination letter and figure set
Appendix F: Individual Fire Report (DI-1202)

General instructions for completing the Individual Fire Report and a copy of the DI-1202 form are included here. For complete instructions, contact the National Park Service, Branch of Fire Management, Boise Interagency Fire Center, Boise, Idaho.
INDIVIDUAL FIRE REPORTS

The Fire Information Retrieval and Storage System (FIRESTOR) is an upgrade of the current DOI Wildland Fire Reporting System sponsored by NPS, BLM, BIA, and FWS. This upgrade provides for improved accuracy and control of DOI Wildland Fire reporting and analysis procedures.

The revised individual fire report, the Test Form 1202, is the key to this new system. The interagency use of the form required common terminology. Read the instructions carefully in order to properly report all of our wildland fires.

The data on this report will be entered by field areas into the National Park Service’s Fire Management computer system. Refer to the NPS Fire Management Computer System User Guide for instructions on entering reports on the computer.

Field areas with computer terminals that cannot emulate the Digital Equipment Corp. VT-100 terminal will send their TF-1202’s to the regional office for processing.

Fire reporting on the TF-1202 is required to assure accurate recording of all wildland fires, and responses, including fires for research, support to other agencies, wildfires, and prescribed fires.

GENERAL INSTRUCTIONS, TF-1202

1. Type or print plainly with a ball point pen.

2. Report and record each individual fire response on a separate form.

3. Make entries for all mandatory items designated for completion as indicated by the Type 1 through Type 5 instructions.

4. Do not enter zeros (0) to the left of significant numbers except where indicated as part of the code entry. Most entries are "right justified" and zeros on left are not necessary to hold spaces.

5. Do not enter more digits than are indicated by the number of spaces provided for each item. Do not add commas in items 8d or 10a, b, c, or 13e.

6. Enter only code numbers except where other information is required in the Specific Instructions (e.g., Fire name in Item 9.a.)

7. A narrative for each fire will be included in the "Remarks" section. Other items that require clarification are also
reported in this section, identified by item number (e.g., Items, Specific cause)

8. For each fire type, certain items are required and others optional. Refer to Table 1 for required and optional items by fire type.

9. Reports are to be submitted to the Regional Director within ten (10) days after the fire is declared out.

10. Fire reports must be approved and signed by the Superintendent or the designated person before distribution to Regional Director.

11. As a Departmental form, items are included on the TF-1202 that may not be applicable to every agency. NPS does not use the following items at this time. Do not make an entry in these spaces.

| Item | Net Resource Value Change (BIA use) |

12. The Superintendent shall send a clearly marked machine copy of the approved report to the appropriate office of each cooperating agency having a legitimate interest in the fire.

13. The Superintendent will submit one (1) concise machine copy of the approved report to the Regional Director. The original will be maintained with the fire data in the park.

14. One copy will be maintained in the Regional Office.
## UNITED STATES DEPARTMENT OF THE INTERIOR

### INDIVIDUAL FIRE REPORT

<table>
<thead>
<tr>
<th>1. STATUS CODE</th>
<th>2. REPORTING AGENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>3. a. UNIT</th>
<th>b. SUB-UNIT</th>
<th>c. YEAR</th>
<th>d. FIRE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. TYPE</th>
<th>5. CAUSE</th>
<th>6. PEOPLE</th>
<th>7. NET RESOURCE VALUE CHANGE</th>
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</thead>
<tbody>
<tr>
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<td></td>
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</tr>
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### 8. STATISTICAL DATA

<table>
<thead>
<tr>
<th>a. STATE</th>
<th>b. OWNER</th>
<th>c. VEGETATION</th>
<th>d. ACRES BURNED</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 9. AGENCY DATA

<table>
<thead>
<tr>
<th>a. FIRE NAME</th>
<th>b. AREA NAME</th>
<th>c. LATITUDE</th>
<th>d. LONGITUDE</th>
<th>e. TWNSHP</th>
<th>f. RANGE</th>
<th>g. SECTION</th>
<th>h. MERIDIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>i. UTM</th>
<th>j. PROB. CL.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

### 10. SUPPRESSION DATA

<table>
<thead>
<tr>
<th>a. DISCOVERY</th>
<th>b. INITIAL ATTACK</th>
<th>c. CONTROLLED</th>
<th>d. DECLARED OUT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME</th>
<th>TYPE</th>
<th>AMT</th>
<th>ACRES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3</td>
<td>1 2 3</td>
<td></td>
</tr>
</tbody>
</table>

### 11. SITE DATA

<table>
<thead>
<tr>
<th>a. TOPOGRAPHY</th>
<th>b. ASPECT</th>
<th>c. SLOPE</th>
<th>d. ELEVATION</th>
<th>e. STATION</th>
<th>f. MSGC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>g. BEHAVIOR</th>
<th>h. BURNING INDEX</th>
<th>i. ADJ CLASS</th>
<th>j. RVC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

### 12. PREVENTION DATA

<table>
<thead>
<tr>
<th>a. FORM OF HEAT</th>
<th>b. CERTAINTY</th>
<th>c. EQUIP</th>
<th>d. MATERIAL</th>
<th>e. FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>f. CLASS PEOPLE</th>
<th>g. AGE</th>
<th>h. SEX</th>
<th>i. ACTIVITY</th>
<th>j. ESTIMATED DAMAGE TO IMPROVEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 13. PRESCRIBED FIRE DATA

<table>
<thead>
<tr>
<th>a. UNIT NO</th>
<th>b. PLOT NO</th>
<th>c. PLOT OBJECTIVE</th>
<th>d. FIRING TYPE</th>
<th>e. COST/ACCRE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>f. FUEL MODEL</th>
<th>g. TEMPERATURE</th>
<th>h. RELATIVE HUMIDITY</th>
<th>i. MID-FLAME WIND</th>
<th>j. FLAME LENGTH</th>
<th>k. ROS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAX</td>
<td>MIN</td>
<td>MAX</td>
<td>MIN</td>
<td>MAX</td>
</tr>
<tr>
<td></td>
<td>MIN</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Test Form 1202 (March 1985)
Appendix G;
Fire Situation Analysis

Part I. Current Fire Situation ............................................. G.3
Part II. Holding/Suppression Considerations ...................... G.7
1. FIRE # & NAME_________________________ NPS UNIT_________CAUSE_____________

1a) DATE: ____/____/____

1b) MONITORED air, lookout, at scene? (circle one)

2. FBWS:______________________________________________________________

FBWS: ______________

Lead

Trainee

3. 3a) FIRE SIZE ________; 3b) DATE ____ TIME ____;

3c) ELEVATIONAL RANGE __________; 3d) T ____; R ____; Section(s)____.

4. VEGETATION TYPE____ __ __ __% 4a) FUEL MODEL ______ __ __%

(of area burned)

(________ __ __%)

_____ __ __% 

_____ __ __%

5. MAP--ATTACH!!! (Indicate fire perimeter and fuel models in the area; also indicate points where weather/fire behavior readings were taken and use a large arrow to indicate where the daily fastest rate of spread (recorded in 6c--below) was observed).

6. FIRE ACTIVITY

6a) Relative Intensity: ____________________________________________________

________________________________________________________

6b) Daily Rate of Fire Growth: _______ acres/day

6c) Daily Fastest ROS: _______ Direction--H, B, or F (circle one)

Fuel Model____ Compass direction_______

7. PROJECTED FIRE ACTIVITY

7a) NFFL Fuel Model(s) in Direction of Spread: ______________________________

________________________________________________________

________________________________________________________

________________________________________________________

Revised 12/89
7b) Factors that Affect Fire Spread: 

7c) Forecasted Weather (1-5 days, specify number of days): attach forecast forms.

7d) Predicted Fire Behavior (specify number of days):

8. THREATS/CONSTRAINTS

8a) Life or Property:

8b) Natural Resources:

8c) Cultural Resources:

8d) Management Boundaries:

8e) Threats to Exceed Prescription:

9. Smoke Movement:
10. FIRE MONITORS' (FIRE BEHAVIOR/WEATHER SPECIALIST) RECOMMENDATIONS

10a) Closures/Evacuations: ________________________________________________________

_____________________________________________________________________________

10b) Holding Actions: _____________________________________________________________

_____________________________________________________________________________

10c) Monitoring Frequency: _________________________________________________________

_____________________________________________________________________________

11. SPECIAL CONCERNS OR COMMENTS: _____________________________________________

_____________________________________________________________________________

12. NARRATIVE (OPTIONAL) Use back of page

Attach prescribed natural fire data sheet (page 4), photographic log, and weather forecast.

13. PREPARED BY:________________________ Date: _______ Time: _______

   Lead FBWS

   _______________ Date: _______ Time: _______

   Trainee FBWS

   NO CHANGE:________________________ Date: _______ Time: _______

   Lead FBWS

14. MANAGEMENT ACTIONS: (if applicable) __________________________________________

_____________________________________________________________________________

REVIEWED BY:________________________ Date: _______ Time: _______

   PFM/PBB/FMO

SUPPRESSION RESOURCES ASSESSMENT______________________________________________

_____________________________________________________________________________

15. Nearest Available ICSR/ICMR: Name_____________________________________________

   Home Phone_______ Work Phone_______ On Paid Standby? Yes/No (circle)
**16. PRESCRIBED NATURAL FIRE DATA SHEET**

<table>
<thead>
<tr>
<th>FIRE # &amp; NAME</th>
<th>PARK PNF Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Aspect</th>
<th>Slope</th>
<th>WEATHER</th>
<th>Temp.</th>
<th>R.H.</th>
<th>Mid W.S.</th>
<th>Wind Dir.</th>
<th>Shading</th>
<th>FUEL MOISTURE</th>
<th>1 hr.</th>
<th>10 hr.</th>
<th>100 hr.</th>
<th>Live</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>FIRE BEHAVIOR</th>
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</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Drought Indicies (BI, ERC, KBDI, 1000 hr, etc.)

---

By FUEL MODEL

FM | FM | FM
PART II

Park __________________ Fire #/Name __________________________ Date __________

17. Fire Situation (including multiple fire problems): __________________________

__________________________________________________________

__________________________________________________________

__________________________________________________________

18. ALTERNATIVE ACTIONS:

HOLDING ACTIONS
A. (No Action) ____________________________________________

__________________________________________________________

__________________________________________________________

B. ________________________________________________________

__________________________________________________________

__________________________________________________________

C. ________________________________________________________

__________________________________________________________

__________________________________________________________

FURTHER ALTERNATIVES MAY BE ADDED, if necessary: __________________________
SUPPRESSION ALTERNATIVE ACTIONS:

Alternative ___.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Alternative ___.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Alternative ___.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Alternative ___.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

FURTHER ALTERNATIVES MAY BE ADDED, if necessary: __________________________

__________________________________________________________________________
## DECISION MATRIX

<table>
<thead>
<tr>
<th>Impacts On:</th>
<th>Alternative (No Action)</th>
<th>Alternative</th>
<th>Alternative</th>
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<tbody>
<tr>
<td>Soil</td>
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<td></td>
</tr>
<tr>
<td>Air</td>
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</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T &amp; E Species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developments</td>
<td></td>
<td></td>
<td></td>
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20. Management Constraints From Fire Management Plan:

21. Projected Containment/Suppression Needs/Costs:

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TOTAL COST | | | |

Alternative: | | | |

Est. Completion Time (days) | | | |

Est. Fire Size at Project Completion (acres) | | | |

Remaining Uncontained Perimeter (%) | | | |

22. Preferred Alternative and Rationale: 

---

Attach map of fire for each alternative.
23. Prepared by: ______________________  Date: ____________
    Signature: ______________________  Date: ____________
    Title: ____________________________

Reviewed by: ______________________  Date: ____________
    Title: ____________________________

Reviewed by: ______________________  Date: ____________
    Title: ____________________________

Approved by: ______________________  Date: ____________
    Superintendent
The fire situation analysis (FSA) is standardized for National Park Service use and has been broken into Parts I and II. Part I, which is prepared by a FBWS I/II, is designed for use in routine monitoring of prescribed natural fires. It documents the daily fire situation, makes forecasts for upcoming fire activity, and documents that the daily fire situation does not exceed that which has been specifically approved by the Superintendent in the fire management plan. Part II, which will be prepared jointly by the FBWS and/or the PFM/PBB/FMO and other tactical experts as needed, will be prepared along with Part I at the beginning of a PNF and thereafter when a new threat or constraint, referenced in 8a-8e Part I is identified, or when increased holding actions in 10b are indicated; or when the fire management plan and progress of the fire or other situations develop which indicate that a different management strategy is appropriate.

Parts I and II are initially approved by the Superintendent in order to declare that a new fire is to be managed as a PNF. Thereafter, Part I is prepared by an experienced PFM/PBB or FMO specified by NPS policy. This individual then completes and signs block 14 of the FSA, Part I, specifying all management actions taken during the last burning period and actions to be taken during the next burning period in order to comply with the park's fire management plan. The recommendation of whether or not to carry the PNF into the next burning period as a PNF or to activate Part II of the FSA is documented and approved on the NPS-PNF Daily Decision Record. This record remains on the Superintendent's desk throughout the PNF season and is updated daily by the FMO. Part II is always approved by the Superintendent on the document itself, since Part II legally documents a change in management strategy.

Should additional space be required for any FSA inputs, the back side of each page should be used for continuation.

INSTRUCTIONS FOR PART I (CURRENT FIRE SITUATION)

Part I is a very important management tool. Its usefulness depends on the quality of work by the fire monitor (fire behavior/weather specialist). The information collected and compiled provides the key link between the fire and management actions. It is easy to misinterpret the intent of a simple category title; take the time to read these instructions carefully so that management (at all levels) will receive the complete picture. Turn the page over and write on the back if the space provided for any particular element is inadequate. Do not lump two or three days of information onto one form. If any entry on this FSA does not apply to the fire being analyzed, place an NA in the appropriate blank space; this will ensure that all elements of this document are considered.

1. FIRE # & NAME, NPS Unit, and monitoring method are self-explanatory. Fill in the date of the reconnaissance/report. Cause of ignition: lightning, natural, unknown, human.

2. Write in the name of the Fire Behavior Weather Specialist (FBWS) and the assigned trainee. The lead monitor must be at least a fully qualified FBWS II. The trainee monitor must have successfully completed the training course prerequisites and may use this assignment to fulfill the job experience prerequisites.
3. **FIRE SIZE** - Calculate in acres using a dot grid, perimeter tables, etc.
   3b--Enter the date and time when the fire size was determined.
   3c--Enter the highest and lowest elevations at which the fire has burned.
   3d--Give legals: T (township); R (range); and Sections.

4. **VEGETATION/FUEL TYPES** - Identify for area burned. Use a conventional identification system (i.e., NFFL or NFDRS, etc.).

5. **MAP** - A map must be included with every submission of the FSA. Outline vegetation or fuel model areas both within and around the burn. Completely label and date every map. Use a large arrow to indicate where the fastest rate of spread was observed. Label location of fire weather/behavior data readings that are recorded on the Fire Data Sheet (page 3) with labels A, B, C, D, etc, on both the map and the data sheet.

6. **FIRE ACTIVITY** - The intent of this section is to summarize today's "observed" fire activity.

   6a--Relative Intensity - Use an adjective rating system; i.e., smoldering, creeping, running, torching, crowning, spotting. Describe for all fuel models present.

   6b--Daily Fire Growth - Calculate from fire position/time maps and/or by fire behavior system analysis, using observed weather data. This rate of growth should be expressed as acres/day.

   6c--Daily Fastest R.O.S. - Record the fastest rate of spread (linear) observed during the entire day's fire activity (chains/hour). Circle the direction of the fire spread (heading, backing, flanking). Also list the compass direction of spread; i.e., NS, S, NNE. Indicate the fuel model through which the fastest R.O.S. was observed.

7. **PROJECTED FIRE ACTIVITY** - The intent of this section is to have the fire monitor(s) observe and employ the key variables that influence fire behavior and to predict fire activity.

   7a--Fire Behavior System (NFFL) Fuel Models in Direction of Spread - Discuss the predicted fire activity in the various fuel models that are going to be involved as the fire spreads; this will require mapped locations of the fuel models present in all directions of fire spread.

   7b--Factors that Affect Fire Spread - Describe barriers and deterrents to fire spread, as well as factors that are likely to increase the spread; i.e., barren sites, fuel changes, local weather patterns, etc.

   7c--Forecasted Weather - Obtain long range (1-5 day) forecast, if possible. Specify the type of forecast received. Request spot weather forecasts for time periods of known or expected significant fire danger and for times of any locally observed changes in winds, etc. at the fire site which could increase fire activity. Attach the weather forecast form if received.

   7d--Predicted Fire Behavior - Predict fire activity for the next 1 to 5 days (specify the number of days), given current fire position and forecasted weather. Predict the acreage growth expected in the next 24 hours and display the expected growth and fire shape on the map.
8. THREATS/CONSTRAINTS - Address threats and constraints identified in the park's Fire Management Plan. Specify both potential and actual threats.

8a--Life or Property - Briefly describe threats to visitors as well as to fire monitors, firefighters, etc. Threats to consider are reduced visibility, location of roads, trails, ranger station buildings, local land ownership other than NPS, etc.

8b--Natural Resources - Briefly summarize threats to rare, threatened, or endangered species, scenic vistas, water quality, etc.

8c--Cultural Resources - Identify threats to cultural and/or archaeological resources. Indicate whether the persons responsible for protection/management have been notified.

8d--Management Boundaries - Describe the proximity of the fire to any management boundaries. Do not simply state that there is a boundary and then describe it; indicate how far the fire is from the boundary(ies) and anticipated arrival time, if any.

8e--Threats to Exceed Prescription - Parks must have specific prescriptions for prescribed natural fires. These are specified in the FMP and must contain fire condition indicies, and fire behavior parameters (ie; FL, ROS). Indicate if these are likely to be exceeded.

9. SMOKE MOVEMENT - Describe altitudes containing smoke, direction of smoke movement, relative density, color, presence of inversion and time of lifting (if it occurs). If a highly scenic or popular recreational area is being impacted, describe the time and extent of visibility reduction. Also estimate the smoke concentration and probable impacts on nearby towns, cities, or other important targets that are likely to be or are being affected by smoke.

10. FIRE MONITORS' (FIRE BEHAVIOR/WEATHER SPECIALIST) RECOMMENDATIONS

10a--Closures/Evacuations - Advise on closures and/or evacuations; include trails, buildings, roads, recreation or wilderness areas, etc. Also recommend the need for safety signs.

10b--Holding Actions - If fire warrants a holding action to maintain the prescription, provide the justification based on the current situation and predicted fire behavior. Indicate the extent of the proposed action, i.e., natural barriers to be used, length of line to be cut, etc.

10c--Monitoring Frequency - Indicate how often the fire should be monitored on site, given the current and projected conditions. Distinguish between air and ground reconnaissance frequency.

11. SPECIAL CONCERNS OR COMMENTS - Stress the points of concern in the Fire Situation Analysis that only ground monitoring can provide (ie; length of active fire perimeter, number of acres burned, erratic fire behavior, threats to safety, reduced visibility, future monitoring requirements, etc.). Suggested points to address are threats to safety, reduced visibility, future monitoring requirements, or specific local concerns such as land status, etc.

12. NARRATIVE (OPTIONAL) - Use the back of the page or attach notes to the FSA to record information that may be of interest and for which space has not been provided.
13. SIGNATURES - Both fire monitors (lead/trainee) contributing to the Part I analysis should sign, date, and time the submission. Refer to the NPS Prescribed Fire Qualifications System Flow Chart and job complexity analysis for appropriate staffing levels. A "no change" signature is optional and can be entered by the lead monitor when and if there are no significant changes in items 6-11 of Part I from the previous day's activities; the use of this signature block eliminates the need for duplication associated with the completion of this document.

14. The PFM/PBB/FMO has the responsibility for ensuring that the FSA is properly completed each day and must sign that it has been reviewed and is recommended for approval. The line officer is the Superintendent who has the ultimate responsibility for authorizing the appropriate action(s) based upon Part I submissions, including a daily assessment of available suppression resources. The Superintendent signifies acceptance and approval by signing the Daily Decision Record (NPS Form #).

15. The FMO is responsible for designating a ICSR or ICMR, whichever is most appropriate, to each PNF for contingency actions. A copy of the FSA Part I (and Part II if changed) should be sent to the incident commander (IC) designate daily and, if necessary, this individual can be placed on paid standby. Ideally the designate IC can and should be the PFM OR PBB if s/he is qualified for the IC job function.

16. A Prescribed Natural Fire Data Sheet (page 4) should be included with all "at scene" reconnaissance reports. The hours listed across the top of the form are only suggested data collection times. The actual frequency is dependent upon the fire and information requirements of the NPS unit. Actual monitoring time for each data collection point is recorded after the date. The * at 1400 hours indicates the recommended time (depending on a unit's time zone and specific needs) at which FSA data should be called into Fire Dispatch or to the park "Fire Contact". It is a critical fire data collection time.

Location identifiers (use letters to identify points) on the data sheet; make sure these data labels correspond with points identified on the map.

The data sheet has space for listing prescription elements. Include park-specific PNF prescription(s) for as many fuel models as applicable; three prescriptions can be listed in the space provided below the fuel model numbers (Fire Behavior System-NFFL).

A photographic log may be required in some situations.

INSTRUCTIONS FOR PART II (HOLDING/SUPPRESSION CONSIDERATIONS)

17. FIRE SITUATION - Briefly describe the single or multiple fire problems, smoke problems, fire load or other situations. Discuss the availability of suppression forces, if they are indicated as needed, and their location is known.

18. ALTERNATIVE ACTIONS - Describe the holding and/or fire suppression alternatives which may be used to manage the fire situation. This discussion can include no actions needed, specified holding actions, or a combination of control, confine, contain strategies if suppression is called for. Any of these may involve only a portion of the fire perimeter.
19. DECISION MATRIX - A narrative analysis of the effects of each alternative management action on park values. In essence, you are analyzing the effect of the action and not the effect of the fire. Address only those values which are critical to the selection of a desired alternative. Be brief and to the point!

20. MANAGEMENT CONSTRAINTS - Refer to the park Fire Management Plan for the general management constraints (e.g., public safety protection of features and resources, restoration of natural processes, etc.). These may be listed on a separate sheet or simply referenced to the park Fire Management Plan.

21. PROJECTED HOLDING/SUPPRESSION NEEDS/COSTS - Estimate needs and costs of the holding or suppression action (e.g., contain, confine, control) for each alternative. List by broad category, general considerations such as aircraft costs, personal services, major equipment acquisition, etc.

22. PREFERRED ALTERNATIVE AND RATIONALE - The selection of the preferred alternative will be based upon a relative weighting of management constraints from the fire plan and the impacts of the various alternatives. The objective of this process is to manage the fire problem with the least impact on park natural and cultural resources. This determination requires those responsible for making such decisions to undertake and document a project review similar to that required under NEPA.

23. Signature(s) - of PFM or PBB and others who prepared the FSA.

Reviewed - signature of any designate discussed in fire management plan.

Approvals - the Superintendent must sign the FSA Part II each time it is changed to reflect new management strategy.
Appendix H; Methods for Nonstandard Variables

References have been developed to assist you in formation of techniques for monitoring parameters which are not required on a regular basis. Included are bibliographies dealing with soil erosion, forest "pests", reptiles, birds, and mammals. Other nonstandard variables may be considered Minimum Acceptable Standard for a park depending on its fire management program. Always seek the assistance of subject matter experts for monitoring methods for nonstandard variables. The techniques used to monitor these nonstandard variables must be accurate, defensible, and statistically significant.

Suggested informational sources are Cooperative Parks Study Units, USFS Research Stations, USFS Pest Management Offices, and local universities. Many universities can conduct computerized literature searches quite rapidly at low cost. Literature computer searches can be conducted through the Department of Interior by writing Department of Interior, Computerized Literature Search, Natural Resources Library, 18th & C Streets, N.W., Washington, D.C. 20240.

SOIL AND WATER


Describes a range of field techniques for assessing rates of erosion by various processes. Emphasizes methods that are relatively low in cost.


A textbook giving general information on measuring soil erosion, river processes, sediment production and water quality.

Appendix H: Methods for Nonstandard Variables
MISTLETOE, FUNGI, AND INSECTS

While most commercial foresters consider native mistletoe and many native fungi and insects as "forest pests", the National Park Service recognizes that the occurrence, even in large numbers, of these organisms is a part of a "natural process". Non-native forest pests, however, may be removed or increased by management fires; if this is a concern the park manager should develop and implement a "pest" monitoring program. Suggested "pest" identification sources and monitoring method references are listed below.


General reference which helps identify conifer diseases, and provides basic biological information and treatments for numerous types of rots, blights, mistletoe, rusts, etc.


Chapter 5 contains information on survey and sampling methods. Chapter 6 contains information on rating stand hazard to western spruce budworm. Chapters 7 and 8 discuss management schemes.


Appendix H: Methods for Nonstandard Variables


General reference which helps identify forest pests and provides life history information, symptoms, importance, and control strategies for forest pests.


Survey methods are listed in booklet 1.


Various. Various Dates. FIELD Forest Insect and Disease Leaflet. USDA.

A series of leaflets each of which deals with a specific insect or disease. More than 164 leaflets are available. Obtain a copy through your local USDA Forest Service Office or government publications center.

REPTILES

Census Techniques


Davis, D. E., (ed.). 1982. CRC Handbook of Census Methods for Terrestrial Vertebrates. Includes the following:

- Major, P. D. Snapping Turtles, p 20-22.
- Parker, W. S. Whipsnakes, p 18-19.
- Philibosian, R. Anolis acutus, p 17.


Appendix H: Methods for Nonstandard Variables


Fire Effects


BIRDS

Generally three census methods have been used in assessing the effect of fire on bird populations. They are the Spot Mapping, Plot, and Transect techniques. These will be briefly explained below. Other methods have been successfully used to estimate bird numbers, but were not found in the literature that relates to fire. These are the Variable Circular-plot, Variable Distance Transect, and Mark-Recapture methods, which are described and evaluated in Ralph, 1981.

In all methods, individuals flying over head, such as raptors, were not counted; censuses were made in the early morning; and censuses were not conducted in bad weather.
Potential pitfalls common to all techniques:

- Observer may lack experience
- Observation conditions related to weather, time of day, etc. may be poor
- Habitat has a screening effect
- Birds are not equally conspicuous (relative to noise, movement behavior patterns, size, and color)

The choice of research method depends upon availability of money and observers. The spot mapping technique is best for assessing density, but "floaters" are lost using this technique, and it is the most labor-intensive technique. No method is really good for monitoring density; consider measuring for density only if lots of money is available. The variable-circular-plot method is currently gaining in popularity. Spending a specified time at one spot seems more controlled than walking a transect, because different observers walk at different rates and therefore will record differing results. The variable-strip is actually the same method as the variable-circular plot; both show promise.

Census Techniques


Spot Mapping


The spot mapping technique calls for determining the distribution of number of birds on a grid. The census technique requires slow walking along grid
lines, and recording bird positions and movements on mimeographed maps of the grids.


Ruzicka's Index (RI) was used to compute the similarity of birds between plots and among years (Pielou 1984:44):

\[ RI = \sum \left( \frac{\min(i,j)}{\max(i,j)} \right) \]

where i and j were the numbers of territories of each species for any pair of plots or years, and s was the total number of species in the two plots.

The long-term nature of this study permits discussion of overall predictability of bird population changes in response to habitat change in the study area.

**Plot**


Using dittoed maps, workers recorded bird observations on a route including a series of U-turns that ran back and forth between a burned and unburned plot. The route passes within 30.5 m of every point in each plot. All bird activities were noted; however, considerable effort was taken to record simultaneously singing males. At least 10 census trips were made each year between April and July. Concentrated groups indicated an activity area. The basic results of feeding height and species were used as an index to food intake and converted to consuming biomass (Salt, 1957).


Breeding bird population data consisted of recording activity of the resident bird species on 20-acre burned and unburned plots of chaparral and grassland. The route included two U-turns so that each point in the area came within 32 m of the view or hearing of the observer. All activities of each bird species were recorded on a separate map. Censusing occurred for 7:30-11:00 am and from late March through June. Each gridded 20-acre plot was traversed five or six times during this period. Where activity records for a given species revealed a pair was repeatedly present they were considered a resident pair.

Transect


Censusing occurred from June to September 1974. On each of the four transects, 12 censuses were conducted, six each in the nesting and post-nesting seasons. A strip-transect method was used (Kendeigh 1944, Salt 1957). Fixed width transects were used in preference to the variable-strip method (Emlen 1971) because it was difficult to estimate accurately the lateral distances to vocalizing birds in these forests. More than 85% of the bird detections were based on vocalizations alone.

All birds noted within a 15-m band on either side of a measured trail were noted. Also noted were the foraging substrate, location and behavior for each bird. Individuals flying overhead, such as raptors, were not noted. Since transects were somewhat different in size, a conversion factor was used to determine relative numbers per hectare.


A transect survey method was used to estimate breeding bird density. One person made all bird counts. Authors recommend transect counts when large areas must be sampled in a short time. A 75-foot-wide belt on each side of a 1000-yard transect was used. Classification of birds into feeding categories according to foraging level and food type follows Salt (1957).

Appendix H: Methods for Nonstandard Variables

A wide geographical area was divided into eight communities according to major vegetation. In each community, plots 671 m long and 63 m wide (4 ha) were established by measurement. Each plot was studied by walking the mid longitudinal line slowly, noting all birds heard or seen within 31 m on each side. Each plot was walked at least twice, usually on consecutive days. Elongated plots were used to fit narrow vegetational zones. The typical census plot entails many days observation for each plot and was unsuitable here.

For each plot, the number of species recorded was the sum of all different species found on the three surveys. The number of individuals was the maximum number recorded for each species on any of the surveys.

Coefficients of similarity based on densities of each species were calculated for each community to compare various bird populations (Beals 1960).

Estimating Bird Numbers


Critically evaluates methods and assumptions used in data gathering and analysis. Suggests ways to increase the sophistication and accuracy of analytical and sampling methods. Diverse points of view are brought together in these proceedings. Topics include:

Estimating relative abundance
Estimating birds per unit area
Comparison of methods
Species variability
Environmental influences
Observer variability
Sampling design
Data analysis

The Mark-Recapture method has rarely been used by ornithologists for estimating population size. There are theoretical and practical problems in this technique.
The Variable-Strip method calls for an observer to traverse a transect of predetermined length and record the lateral distance from the transect of each bird observed. This differs from the fixed-strip method, in which the width is fixed. This method is described in Emlen (1971) cited under transect techniques.

The Variable-Circular-Plot method has been fully described by Reynolds et al. (1980). Basically, stations are established within a habitat at intervals along a transect or are scattered in such a manner as to minimize the probability of encountering the same bird at several stations. Each bird heard or seen during a fixed time period from each station is counted and the horizontal distance to its location estimated. The basal radius for each species is then determined as the distance from the stations where the density of birds first begins to decline. Finally the density of each species is determined from the total number of birds encountered within the circle radius, r, which is determined from the data.


MAMMALS


Reviews papers on monitoring a wide range of animals, including statistical methods for data analysis.


Includes discussion on relative measures (indices), absolute abundance, and dispersal and mark/recapture methods.


A general reference on a wide variety of techniques and analytical methods.


Excellent guide to methods used for density and abundance measures, particularly mark/recapture methods.

Appendix I; Glossary of Terms

**Abundance.** The relative number of individuals of a species in an area under consideration.

**Adult.** See mature.

**AFFIRMS.** Administrative and Forest Fire Information and Management System. It is a user-oriented, interactive computer program that permits entry of fire weather observations and forecasts, and which performs the computation of fire danger indices, both observed and predicted. Additional information and services are available, including data storage.

**Alien species.** See non-native species.

**Anemometer.** An instrument used to measure the velocity of the wind.

**Aspect.** The direction towards which a slope faces.

**Backing fire.** A prescribed fire or wildfire burning into or against the wind or down the slope without the aid of wind.

**Barrier.** Any obstruction to the spread of fire; typically an area or strip devoid of flammable fuel.

**Basal area.** The cross sectional area of the stems of a plant or of all plants in a stand. Herbaceous and small woody plants are measured at or near the ground level; larger woody plants are measured at breast or other designated height. (Synonym **basal cover**).

**BEHAVE.** A refinement of the Fire Behavior Prediction System that allows development of customized fuel models that can access the Rothermel fire spread equation (Burgan and Rothermel 1984).

**Biomass.** Total dry weight.

**Canopy.** Stratum containing the crowns of the tallest vegetation (living or dead); usually above 20 feet.

**Char height.** The height of the maximum point of charred bark for each overstory tree.

**Co-dominant.** Refers to trees with crowns forming the general level of crown cover, and receiving full light from above but comparatively little from the sides.

**Complex fire management program.** A program involving either prescribed burning or prescribed natural fire, or
Confidence interval. A range of variable values derived from a sample, which has a stated probability of containing the actual target population value. Usually used as in a "95% confidence interval".

Confine. To restrict the fire within determined boundaries established either prior to the fire, during the fire, or in an escaped fire situation analysis.

Contain. To surround a fire and any spot fires therefrom, with control lines as needed, which can reasonably be expected to check the fire's spread under prevailing and predicted conditions.

Control. To complete the control line around a fire, any spot fires therefrom, and any interior islands to be saved; burn out any unburned area adjacent to the fire side of the control line; and cool down all hot spots that are immediate threats to the control line, until the line can be reasonably be expected to hold under foreseeable conditions.

Cooperative Park Studies Unit. An NPS field research unit associated with a major academic institution to share knowledge and resources in furthering scientific investigation in national parks.

Cover. The proportion of the ground covered by plant material (including woody stems and foliage), usually expressed as a percent. See relative cover.

CPSU. See Cooperative Park Studies Unit.

Creeping fire. Fire burning with a low flame and spreading slowly.

Crown fire. A fire that runs through the tops of the trees, shrubs or brush, it may accompany, or be separate from, the surface fire.

Crown scorch. Browning of needles or leaves in the crown of a tree caused by heat from a fire.

Diameter breast height (dbh). Diameter of a tree 1.35 m (4.5 ft) up the trunk from the tree's base, when measured at midslope. The dbh of a leaning tree is measured by leaning with the tree.

Density. The number of individuals, usually by species, per unit area.

Dominant. (1) trees with canopy extending above the general level of the crown cover, receiving full light from all sides; (2) the most abundant or numerous species.

Dry Bulb. A name given to an ordinary thermometer used to determine the temperature of the air; to distinguish it from the wet bulb. See wet bulb temperature.

Duff. The layer of the forest floor material lying below the litter and above mineral soil, comprised of partially decomposed organic matter whose origins can still be visually
determined and the fully decomposed humus layer.

**Dummy AFFIRMS Station.** A temporary catalogued AFFIRMS weather station used for short-duration weather monitoring. Not a base fire danger rating station with data archived into the National Fire Weather Library.

**Emissions.** Those elements resulting from burning such as smoke, carbon monoxide, lead, particulate matter, and sulfur oxides.

**Escaped Fire Situation Analysis.** EFSA document that land management agencies use to identify and select the most viable decision alternative in regards to escaped wildfires in consideration of environmental, economic, political, social, and other factors.

**Exotic species.** See non-native species.

**Fine fuels.** Fuels such as grass, leaves draped pine needles, fern, tree moss, and some kinds of slash which, when dry, ignites readily and is consumed rapidly. Also called "flash" or "one-hour fuels".

**Fire behavior.** The response of fire to its environment of fuel, weather, and terrain including its ignition, spread, and development.

**Fire Behavior Prediction System.** A system for predicting flame length, rate of spread, fireline intensity, and other fire behavior values. Developed by Albini (1976) at the USFS Northern Forest Fire Laboratory.

**FBOC.** Fire Behavior Observation Circles; used to define an area in which to monitor fire behavior in forest index plots.

**FBOI.** Fire Behavior Observation Intervals; used to define an area in which to monitor fire behavior in grassland and brush index plots.

**Fire monitoring.** The systematic process of collecting and recording fire-related data, particularly with regards to fuels, topography, weather, fire behavior, fire effects, smoke, and fire location.

**Fire behavior monitoring.** A process by which variables are measured to describe and characterize fire behavior, permit fire behavior prediction, and relate fire effects to burning conditions.

**Fire effects.** Any consequence resulting from fire.

**Fire effects monitoring.** A process that allows managers to evaluate whether environmental goals and objectives are being achieved, and to adjust prescriptions to achieve a desired range of effects on the biotic and physical environment. Fire effects monitoring does not necessarily prove cause-and-effect associations. However, such monitoring will indicate if specific prescribed burn objectives were met.
and help management assess long-term change in these fire managed areas.

Fire regime. The systematic interaction of fire with the biotic and physical environment within a specified land area. It includes the timing, number, spatial distribution, size, duration, behavior, return interval, and effects of natural fires.

Fire season. The period or periods of the year during which wildfires are likely to occur, spread and do sufficient damage to warrant organized fire control; a period of the year with beginning and ending dates established by some agencies.

Fire Situation Analysis (FSA). Document that NPS uses to identify and select the most viable decision alternative in regards to a natural fire in consideration of environmental, economic, political, social, and other factors.

Flame length. The distance measured from the tip of the flame to the middle of the flaming zone at the base of the fire. It is measured on a slant when the flames are tilted due to effects of wind and slope.

Flame zone depth. The average depth of that zone of a moving fire that is primarily flaming; measured on a horizontal axis.

Flanking fire. A fire moving across slope or across the direction of wind.

Frequency. The number of times a species occurs in a given number of sample points, expressed as a percent of the total.

Fuel loading. The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area.

Fuel model. A simulated fuel complex for which all the fuel descriptors required for the solution of the mathematical fires spread model have been satisfied.

Fuel type. An association of fuel elements of distinctive species, form, size, arrangement, or other characteristics that will cause a predictable rate of fire spread under specified weather conditions.

Hazardous fuels. Fuels that, if ignited, could threaten park developments, human life and safety, natural resources, or carry fire across park boundaries.

Head fire. A fire spreading or set to spread with the wind or up slope.

Herbaceous layer. Generally the lowest structural layer in a vegetation complex, and usually composed of non-woody plants. See also vegetation layers.

Hygrothermograph. An instrument that records automatically and continuously both temperature and relative humidity.

Immediate post-. Usually less than one year after an event.
**Index.** A distinctive physical feature or group of features in the natural environment that lead the manager to surmise a particular fact or to draw a particular conclusion.

**Index plot.** A line or an area on which transects and plots are established for monitoring fire behavior and fire effects in a monitoring type. Index plots are to be established in each major fuel/vegetation type for each prescription in which burning is planned. See also representative area (RA).

**Intermediate.** In reference to tree crown position, a tree shorter than the main canopy level of the forest and receiving little direct light from above and none from the sides; usually smaller sublevel trees that are relatively dense.

**Key variable.** A fundamental vegetation or fuel component (frequently vegetation) that identifies a monitoring type.

**Litter.** Top layer of the forest, scrubland, or grassland floor, directly above the duff layer, composed of loose debris of dead sticks, branches, twigs, and recently fallen leaves or needles, little altered in structure by decomposition.

**Live fuel Moisture.** Water content of a living fuel expressed as a percentage of the ovendry weight of the fuel.

**Long-term.** Over one year.

**MAS.** See minimum acceptable standard.

**Mature.** For the purposes of this handbook, a shrub that is able to produce flowers and seeds.

**Minimal acceptable standard (MAS).** The lowest level of fire monitoring permitted in the Western Region. Special circumstances such as serious non-native species problems, undetermined "natural state" or other problems will dictate other research or monitoring at a higher level.

**Monitoring type.** A major fuel/vegetation complex or vegetation association subject to a unique burning prescription. For example: white fir dominated (basal area ≥ 50%) Mixed conifer forest burned in the fall when plants are dormant.

**Monitoring type variable.** An index of change relative to the vegetation present by species in a monitoring type.

**Next burning period.** The anticipated period of greatest fire activity on the next day; NPS-18 defines it as 1000 to 1800 hours.

**Non-native species.** A species that is present where it would not have occurred naturally; includes "naturalized species".
NPS Branch of Fire Management. A branch of the Ranger Activities Division of the WASO directorate of the National Park Service. The Branch is stationed in Boise, Idaho, and functions in close cooperation with the Boise Interagency Fire Center, operated by the Bureau of Land Management.

Objective-dependent variable. An index of change related to a burn objective identified in a park fire management or burn unit plan.

Overstory tree. For this Handbook, a living or dead tree with a diameter of > 15.0 cm at diameter breast height (dbh).

Phenology. Stage of plant development; flowering, fruiting, dormant, etc.

Perimeter. The length of the outer edge of a fire.

Pole-sized tree. For this Handbook, a standing living or dead tree with a diameter of ≥ 2.5 cm and ≤ 15 cm at diameter breast height (dbh).

PM-10. A standard established by the Environmental Protection Agency for measuring suspended atmospheric particulates less than or equal to 10 microns in diameter.

Precision. For this Handbook, the closeness with which a sample-derived variable estimates can be expected to fall near the true population variable value.

Prescribed burn(ing). A fire intentionally set by management to meet management objectives and allowed to burn only under certain conditions.

Prescribed burn boss. The person responsible for all tactics and strategy on a prescribed burn. Primary responsibilities are to organize, implement, communicate, and evaluate.

Prescribed fire. Any fire, natural or human caused, that is allowed to burn only under certain conditions.

Prescribed natural fire. A fire started by a natural source and allowed to burn as long as it meets prescription standards.

Prescription Weather Station. A weather station consisting of weather station shelter, hygrothermograph, fuel moisture sticks, rain gauge, and anemometer.

Primary indicator of long-term change. A key element of an ecosystem, linked to the accomplishment of program goals. It is a variable that is sensitive to fire-induced change.

Rate of Spread. See ROS.

Rejection criteria. Criteria used to establish whether a plot can be included within a particular monitoring type. Index plot characteristics that are not representative of the target monitoring type (as defined by managers). For example: all or a significant portion of a monitoring transect falls within 30 m (100 ft) of a road, trail, stream, meadow, large rock outcrop or barren area, or type boundary. Simplistic example: the presence of trees is a characteristic selected to define a monitoring type, then areas without trees would be rejected as part of the type.

Resource value at risk. A natural, cultural, or developed feature subject to threat by fire or significantly impacted by smoke. Resource values at risk are classified as high or low.

Resprout. A shrub that has resprouted after being top-killed by a fire or other disturbance. Sprouting can be from the stem (epicormic) or the base (basal) of the plant.

Restoration burn. A prescribed burn used to bring fuels and or vegetation more closely into a state similar to that which would be found "naturally" or was a part of a historic scene.

Relative cover. The percent cover contribution of a particular species to the total plant cover. Relative cover will always equal 100%.

Relative humidity. The ratio of the amount of moisture in the air compared to the amount it could hold if saturated.

Remote Automatic Weather Station (RAWS). A solar powered weather station that measures temperature, humidity, wind speed and direction, barometric pressure, fuel moisture, and precipitation. The data can be transmitted via satellite, fire radio or recorded on-site for later collection.

Sample. A portion of a population used to draw inferences about the entire population.

Sample standard deviation. A measure of spread for observations in a sample; described by the formula:

\[ s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \]

where \( s \) is the sample standard deviation, \( n \) is the number of elements in the sample, \( x_i \) represents ith sample
element, and $\bar{x}$ represents the sample mean.

**Scorch height.** The maximum height at which leaf mortality occurs due to radiant or convective heat generated by a fire. Below this height, all needles are brown and dead; above it - live and green.

**Seedling.** For this handbook, a plant without a burl that has emerged since the time of the last disturbance, and is too immature to flower. This definition will vary by shrub, by ecosystem and the time since the last disturbance.

**Seedling tree.** For this Handbook, a living or dead tree with a diameter of < 2.5 cm at diameter breast height (dbh).

**Simulated natural fire.** A prescribed burn that (1) is set in an area where fuels and vegetation are within the range of natural variability; and (2) closely simulates the timing, behavior, and burning pattern of a lost prescribed natural fire.

**Sling psychrometer.** A portable instrument for obtaining wet and dry-bulb thermometer readings in order to determine relative humidity.

**Slope.** The natural incline of the ground, measured in percent of rise (vertical rise divided by horizontal distance).

**Smoldering.** Behavior of a fire burning without a flame and barely spreading.

**Snag.** A standing dead tree or part of a dead tree from which at least the leaves and smaller branches have fallen.

**Species composition.** The relative numbers of different species.

**Species diversity.** The number of different species occurring in an area.

**Spotting.** Behavior of a fire, producing sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire.

**Standard error.** A measure of error for a sample mean; related to the standard deviation by the equation:

$$\text{std error} = \frac{s}{\sqrt{n}}$$

where n is the number of elements in the sample, and s is the sample standard deviation.

**Statistically valid sample.** A sample chosen to meet the statistical criteria selected by the user. That is, sampling satisfies the requirements of the tests that will be applied (unbiased and independent), and the standard error of the mean is small enough to meet the levels of uncertainty chosen.

**Statistical variable.** A variable having discrete values that differ through random causes, and when arranged in order form a statistical distribution or array.
**Stratified random sampling.** A means of reducing uncertainty (variance) in sampling by dividing the area under study into blocks with common features. For example, combining forest and brushlands into a common sampling area produces more variance than stratifying them into vegetation types first, then sampling within each. Stratification is a fine tool if you understand what role the variable used to stratify—such as vegetation type—plays in the elements you are measuring (such as growth, or density).

**Subcanopy.** In reference to tree crown position, a tree much below the main canopy level of the forest, and receiving no direct light.

**Suppression.** All actions intended to extinguish or limit the growth of fires, regardless of the strategies and tactics chosen.

**Surface winds.** The wind measured 20 feet above the average top of the vegetation. Often a combination of local and general winds.

**Timelag.** An indication of the rate dead fuel gains or loses moisture due to changes in its environment. The time necessary, under specified conditions, for a fuel particle to gain or lose approximately 63% of the difference between its initial moisture content and its equilibrium moisture content. Providing conditions remain unchanged, a fuel will reach 95% of its equilibrium moisture content after 4 timelag periods. Fuels are grouped in to 1 hour, 10 hour, 100 hour, and 1,000 hour timelag categories.

**Torching.** Ignition and subsequent flare-up, usually from bottom to top, of a tree or small group of trees.

**Variable.** An index that is subject to variation.

**Vegetative association.** For this Handbook, an aggregate association of similar vegetation such as lower mixed conifer forest.

**Vegetative layer.** A structural position within a vegetation complex; generally a forest plot consists of a dead and downed fuel, herbaceous, shrub, understory tree, and overstory tree layer.

**Voucher specimen.** A pressed and dried plant, usually cataloged and stored in an herbarium. Used to confirm the presence of a species at a particular plot.

**Wet-bulb temperature.** The lowest temperature to which air can be cooled by evaporating water into air at a constant pressure when the heat required for evaporation is supplied by the cooling of the air. It is measured by the wet-bulb thermometer, which usually employs a wetted wick on the bulb as a cooling (through evaporation) device.

**Wildfire.** (1) Unplanned fire requiring a type of suppression action, as contrasted with a prescribed fire
burning with prepared lines enclosing a designated area, under prescribed conditions; (2) a free burning fire unaffected by fire suppression measures.
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