

A Fire Management Plan
for
Craters of the Moon National Monument

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Prepared by

Mack Barrington
Stephen Bunting
Gerald Wright

Cooperative Park Studies Unit
and
Range Resources Department
University of Idaho
Moscow, Idaho

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INTRODUCTION

Fire is a natural component of ecosystems. It is also the result of human actions. In either case, it can have devastating or rejuvenative effects on the resources of an area. Thus fire, like other natural processes, needs to be managed. The policy of the National Park Service (NPS) dictates that all units of the NPS system develop a plan to manage fire. In some areas these plans consist of little more than a procedure for the complete suppression of all fires. However, most plans recognize that fire can play an important role in ecosystem dynamics. The particular role that fire can play varies with the management objectives of a given park but generally they are oriented toward 1) producing specific types of vegetation mosaics (Bonnicksen and Stone (1982), 2) reversing or mitigating anthropogenic influences (Leopold et al. 1963) or 3) including fire as a natural process in the environment being managed or protected (Parsons et al. 1986).

At CRMO, it is probable that the effects of Euro-Americans on the vegetation, while substantial, are not beyond the range of changes that could have occurred prior to Euro-American settlement. This is the case for many NPS managed lands Parsons et al. (1986). Therefore, we have assumed that mitigation of anthropogenic influences and restoration of vegetation mosaics is not necessary and thus the primary objective of developing this fire management plan is to provide for the inclusion of fire as a natural process within the monument.

The fire management plan for Craters of the Moon National Monument (CRMO), Idaho is designed to provide the information necessary to determine if, how, and when a natural fire should be suppressed, and the probable outcome of allowing a naturally ignited fire to burn.

The specific objectives of this plan are to:

1. Describe the role and effect of natural fire in the various vegetation types on the monument;
2. describe the administrative structure of a fire management program; and to
3. outline the procedures for the development of a prescribed fire program.

BACKGROUND

Craters of the Moon National Monument is located on the northern edge of the Snake River Plain in south-central Idaho. The 21,650 ha (53,500 ac) monument was established in 1924 to protect a unique series of volcanic cones, craters, lava flows, and caves located along the Great Rift. The monument's north end includes the foothills of the Pioneer Mountains. Elevations range from 1625 m (4880 ft) to 2355 m (7730 ft.). Soils are derived from basaltic magma resulting from several volcanic eruptions which have occurred at least every 2500 years, with the most recent being about 2200 years ago (Kuntz et al. 1983).

Over half the monument consists of relatively barren lava flows. The vegetated areas are dominated by sagebrush communities intermixed in many areas with limber pine. Douglas-fir occurs on the north-facing slopes of older cinder cones and in the Pioneer foothills. Many of the vegetated areas are separated from surrounding areas on the Snake River Plain by barren lava flows up to five km wide. These flows make travel difficult and have led to little use by domestic livestock prior to the monument's establishment. Relatively little free water over most of the monument has also prevented significant use by domestic livestock and limits mule deer use of the southern two-thirds of the monument during late summer (Griffith 1983). These factors, combined with the management protection afforded by the area's wilderness status has resulted in little non-natural disturbance to the plant communities and many areas appear to be in pristine condition.

Overview of the effects of fire on the major vegetation types

Fire has long been an important influence shaping the plant communities of the Snake River Plain. The frequency with which a given area burned was dependent on the frequency of ignition, the plant community types, topography and regional climate. Fire may have several ecological functions in an area. These include:

1. maintenance of plant vigor and productivity (Loope and Gruell 1973, Harniss and Murray 1973, Bunting et al. 1985);
2. reduction of woody fuel accumulations (Cooper 1961, Habeck 1974, Martin et al. 1979);
3. maintenance of early successional stages (Burkhardt and Tisdale 1976, Bunting et al. 1985, Gruell et al. 1985);
4. an increase in plant community diversity (Lyon et al. 1978, Romme 1982); and
5. an increase in forage availability and nutritional quality (Cook 1959, Spencer and Hakala 1964, Lyon 1971, Hobbs and Spowart 1984).

The native plant species have adapted many different strategies to survive fire in this ecosystem. Some, such as the rabbitbrushes, resprout profusely after fire while others such as big sagebrush temporarily disappear from the site and reestablish from seed later. Rhizomatous grasses such as western wheatgrass and shrubs which are capable of resprouting from the lateral roots may increase in dominance in communities following fire. Other species are adapted to taking advantage of the reduced post-fire competition in the community. Their seeds may be stored in the soil for long periods and germinate following fire or their seeds may be readily transported to the site by wind or animals after the fire occurs. Many exotic weeds rely upon efficient seed dispersal to arrive on disturbed sites. Since fire usually sets back succession and creates openings in the plant community, burned sites have a high potential for weed invasion if a seed source is readily available.

The post-fire successional sequence is dependent upon 4 primary factors including:

1. prefire community plant composition;
2. the effects of fire on the existing community;
3. the post-fire environmental conditions including climatic, herbivory and disease; and
4. the availability of seeds, rhizomes and other propagules to revegetate disturbed sites.

The first 2 factors can be measured or predicted prior to fire occurrence. The final 2 factors occur more or less at random through time. As a consequence, succession may follow several differing pathways after fire. The sequence can be predicted but variation will occur as a result of the random processes.

Fire History At CRMO

The fire season at CRMO extends from mid-June through mid-September. Research indicates that vegetation similar to that on the monument has burned about every 25 to 75 years during pristine conditions (Houston 1973, Wright and Bailey 1982). With the exception of areas in the northern portion of the monument, the vegetation is isolated into pockets by lava flows and cinder gardens. Fires burning in many of these small patches of vegetation would have little chance of spreading. The discontinuous fuels and low fuel loadings on the monument have probably resulted in fire-free-intervals greater than those previously reported for similar vegetation types.

There are some relatively large areas of contiguous vegetation. One of these is the Little Prairie area located in the southeast corner of the monument. There is ample evidence that the Little Prairie area has burned occasionally in the past, however, no fires have occurred since the monument was established.

There is clear evidence of recent fires in the Split Butte area. Many charred limber pine boles can be observed in vegetation now dominated by sagebrush or grass vegetation. These burns appear to be somewhat older than those in Little Prairie. In the immediate area of Split Butte there is heavy grass cover, mainly bluebunch wheatgrass and arrowleaf balsamroot. Species which are good indicators of past fire occurrence.

Small areas around Two Point Butte and Fissure Butte also show a history of recent fire. These burns, however, were much more localized due to surrounding younger lava flows and cinder. Farther north around Crescent Butte, the evidence of fire is also common and there are numerous charred boles of limber pine. There is evidence of low intensity fires in this area as reflected in surviving fire-scarred plants.

The Big Cinder Butte area has also burned, within the last 100 years. Most of the recent fire evidence on Big Cinder Butte is confined to the southwest slopes. The area west of the Tree Molds parking area has also burned in the same time interval. Vegetation has been set back by fire and a community dominated by rubber rabbitbrush has replaced the big sagebrush vegetation. Some charred limber pine boles and sagebrush stems are present here. A fire boundary can be observed on the hillside southwest of the trailhead.

There is less evidence of fire between Big Cinder Butte and Park headquarters than in any other area on the monument. This is probably due to the small amount of vegetated area which is separated by recent lava flows and cinder gardens. If ignitions occurred, the area burned would have been small.

The plant communities north of the highway seem to be more influenced by fire than those to the south. All vegetation types in this area show evidence of burning, with the exception of the dwarf sagebrush types along ridgetops which apparently seldom burn (Gipe 1976, Bunting et al. 1987). In most locations, these types offer excellent fuel breaks, not only because of reduced fuel, but also due to their location. In most cases, fires initiated on lower slopes would not burn through these areas. In most years, herbaceous production will be too low to allow the fire to spread across the ridgetop to the slope on the other side and back into a community with higher fuel loadings. The remaining vegetation types in the northern portion, such as Great Basin wildrye, aspen, Douglas-fir, and other sagebrush types, show evidence of past fire occurrence. In many locations, charred sagebrush stumps are still rooted in the soil. On some of the older burns in the southern parts of the monument, sagebrush stumps have been dislodged and are disintegrating, indicating older burns.

Most aspen types in the north end show evidence of past fire occurrence. This is indicated by even-aged stands (all trees seem to be the same size and age), charcoal remnants in understory, reduced down woody fuels, and in some areas an

increase in snowbrush. Increment cores of aspen and cross sections of sagebrush were collected in the vicinity of the CRMO Research camp. These data indicate that most of the woody plants have become established in the last 25 to 30 years. Records do not indicate any fires occurring in the northern portion of the monument since it was created in 1924. The increase of aspen on the perimeter of the individual clones in this portion may be a cumulative result of the absence fire and not the result of plants resprouting following the last fire.

Fire scars were dated on several fire-scarred Douglas-firs in Little Cottonwood Canyon using the increment core technique (Barrett and Arno 1988). We concluded that fire has occurred every 30 to 35 years prior to Euro-American influence. Fire reedgrass, a species enhanced by fire, is common as an understory species in the aspen and Douglas-fir types. There is little recent fire evidence in this area. Fire may have been actively controlled by man during the period between Euro-American settlement and monument creation. Fires were more probably reduced inadvertently, however, by reduction of fine fuel loading by grazing livestock. The east facing slopes of Little Cottonwood Creek show much evidence of fire, indicating that the road and Little Cottonwood Creek might have served as fuel breaks.

In general, the influence of fire at CRMO is consistent with other areas of the Snake River Plain. The effect of fire can be observed in almost all vegetation types.

Major plant communities and their response to fire

The plant communities of CRMO are highly diverse and range from those on recent lava and cinder material to well-developed Douglas-fir and sagebrush communities. The majority of vegetation of CRMO is not included in recently developed habitat types for southern Idaho (Steele et al. 1981, Hironaka et al. 1983). Neither of these works included sagebrush-grass or limber pine vegetation on recent volcanic material. The vegetation on the well-developed soils of the Pioneer Mountain foothills and in the Carey Kipuka are included in one of these habitat type classifications. Day and Wright (1985) described 26 distinct vegetation community types within the monument. This study uses the same types. It was determined that 20 of these community types had potential to sustain fire and these were combined into the nine broad vegetation groups discussed below. The correspondence of these groups with the types described by Day and Wright (1985) and the area of each is described in Table 1.

The following section provides a general description of the anticipated impact of fire is given for each of the vegetation groups. The ecological consequences of the lack of fire is also included. A brief description of the fire response of the major species not discussed in the text is included in Table 2. Further information can be found in Harniss et al. (1981),

Table 1. Areas occupied by each of the major plant communities, and their correspondence with areas mapped by Day and Wright (1985).

Vegetation type	Area occupied (ha)	Percent of vegetated area	Community types (Day & Wright 1985)
Mountain big sagebrush	4069	63	4, 5, 6, 7, 8, 10
Low sagebrush	167	3	12, 13, 14, 15
Three-tipped sagebrush	41	<1	11
Antelope bitterbrush	562	9	16, 17
Limber pine	1525	24	21, 22, 23
Great Basin wildrye	9	<1	20
Douglas-fir	29	<1	24
Upland quaking aspen	15	<1	25
Riparian zone	30	<1	26
Total	6447	100	

Table 2. Effects of fire on understory species common to vegetation types of Craters of the Moon National Monument. More information on fire response of each species can be found in Harniss et al. (1981), Tisdale and Hironaka (1981), Wright and Bailey (1982), Blaisdell et al. (1982), and Bunting et al. (1987).

Species	Short- (1-5 year) and long-term (5-25 year) effects of fire
<u>Grasses</u>	
Bluebunch wheatgrass	Resistant to fires during most seasons of the year but may be damaged if grazed too severely the first spring following the burn. Productivity may decline the first season following the fire but recovers by the third year. In many instances, productivity is enhanced the first season.
Needle-and-thread	One of the most fire-sensitive species of this region. However, regeneration potential is high and species recovers within 10 to 15 years.
Western needlegrass	Species is moderately sensitive to fire but recovers quickly due to high regeneration potential. Early successional species on many sites and rapidly occupies area opened by fire.
Idaho fescue	Initial mortality of this species may be high as a result of the fire. Mortality may exceed 75% on severe burns but normally varies from 20-50%. It may require more than 25 years to recover if density is severely reduced.
<u>Forbs</u>	
Arrowleaf balsamroot	Very fire resistant but reproduction is infrequent following fire. Biomass production is enhanced by fire and will remain high until grasses or shrubs dominate the site.
Lupine	Very fire resistant. Populations may be enhanced through both seedling establishment and stimulation of sprouting from rhizomes. Will remain a community dominant until grasses or shrubs are abundant.

Tisdale and Hironaka (1981), Wright and Bailey (1982), Blaisdell et al. (1982) and Bunting et al. (1987). The USDA Forest Service Intermountain Fire Sciences Lab, in Missoula, Montana is currently preparing a Fire Effects Information System which gives fire effects on many more species in greater detail. Information concerning this information system can be obtained by contacting William C. Fischer at the Fire Sciences Lab, US Forest Service, Missoula, Montana.

Mountain Big Sagebrush

Mountain big sagebrush, in combination with several species of grasses which dominate the understory, is the most widespread of all vegetation types found on the monument, comprising 63% of the vegetated area. North of the highway, it occurs with bluebunch wheatgrass, Sandberg bluegrass, downy brome, bottlebrush squirreltail, and antelope bitterbrush. There, its occurrence is highly variable with respect to slope, aspect, and elevation. Idaho fescue is found on loess soils but does not occupy sites developed from recent cinder material.

Mountain big sagebrush intermixed with rubber rabbitbrush and green rabbitbrush with an understory of Sandberg bluegrass and the needlegrasses are prevalent in the southern portions of the monument, particularly in the Little Prairie area, around Echo Crater, and on Carey Kipuka. In the latter area it is often mixed with Idaho fescue and junegrass. In many areas in the southern portion of the monument, the mountain big sagebrush is a common associate in limber pine communities.

Of the sagebrush species, mountain big sagebrush is one of the best adapted to fire. It establishes readily following fire. Its seeds germinate more readily following a heat treatment than if untreated (Chaplin and Winward 1982). The plants grow rapidly and reach reproductive maturity within 3 to 5 years. Sagebrush may return to preburn levels within 15 to 20 years if sagebrush seedlings successfully establish the first year. If not, it may require 30 to 50 years for sagebrush to fully occupy the site (Blaisdell et al. 1982, Bunting et al. 1987). Observation of past burned sites on the monument indicate that sagebrush probably takes longer to return to preburn levels on the young cinder soils. There, we estimate that more than 75 years are required for the sagebrush to reoccupy the site.

Herbaceous productivity normally increases following fire in mountain big sagebrush vegetation (Harniss and Murray 1978, Uresk et al. 1980, Tisdale and Hironaka 1981, Johnson and Strang 1983, Blaisdell et al. 1984). Most perennial grass species such as bluebunch wheatgrass, bottlebrush squirreltail, Indian ricegrass, Great Basin wildrye and western needlegrass are well adapted to withstand fire. Productivity may be reduced the first year following fire if the fire was severe. Herbaceous productivity will remain at higher levels until the shrubs re-establish on the site. Initially forbs will dominate the site following fire

(Kuntz 1982). Perennial grasses will gradually increase and dominate. If substantial perennial grass exists on the site at the time of the fire, forbs may dominate for only 1 or 2 years. At lower elevations and on more xeric sites, annual grasses such as cheatgrass may initially dominate if post-burn coverage of perennials is low. This could occur in sagebrush communities on cinder derived soils because these soils are more xeric than most typical soils of this vegetation zone. There are few native annual grasses common to this zone, however, annual forbs such as blue-eyed Mary, slenderleaf collomia, cryptantha, mentzelia and monkey flower may also increase greatly during this period until perennials dominate the burned site. Annuals may dominate the site for 5 to 10 years following the fire.

If these communities are not burned periodically, sagebrush cover will continue to increase. Potential cover of mountain big sagebrush may exceed 40%, which is greater than most other sagebrushes of the Artemisia zone (Bunting et al. 1987). Increasing sagebrush cover will suppress the herbaceous productivity in the understory. In particular, many of the forbs will be diminished and may disappear from the site. Some of these species may remain on the site through seeds stored in the soil seedbank. Severity of fires in dense old sagebrush is greater than those in stands of low sagebrush cover. This increases the direct impact of the fire on the herbaceous species and reduces the number of viable seeds stored in the soil.

Diversity of the community is probably greatest within a few years post-burn and gradually declines as the sagebrush stand develops. The increase in diversity is caused by the temporary increase in forbs within the community. Some grasses such as western needlegrass may also increase rapidly during the initial years after the fire.

Antelope bitterbrush is common within this vegetation type and may be greatly reduced in density by the fire. Bitterbrush density is reduced 50% on the average but variation between stands is high (Bunting et al. 1985). Murray (1983) found that in eastern Idaho, bitterbrush would remain below preburn levels for over 30 years. It appears from observations of old burns on the monument that bitterbrush may recover more rapidly than sagebrush on the cinder soils. An area near Coyote Butte was burned by a wildfire in the 1940s. Bitterbrush has repopulated the site but mountain big sagebrush is still absent. It is likely that bitterbrush can tolerate these infertile harsh sites better than sagebrush. Bitterbrush is often observed as one of the pioneer plants that invade onto new road cuts and other severely disturbed sites.

Three-tip Sagebrush

Three-tip sagebrush vegetation types occur primarily on the Carey Kipuka and on areas north of the highway. In the north it is found on northeast slopes of Little Cottonwood Canyon. Idaho

fescue is a co-dominant in this type. Bluebunch wheatgrass and Hoods phlox occur less frequently in this type.

Three-tip sagebrush has been reported to sprout following fire (Pechanec et al. 1965, Morris et al. 1976). The ability to resprout varies, however, which indicates that several ecotypes exist (Hironaka et al. 1983). Our experience with the populations of three-tip sagebrush in the CRMO region has shown that it has only moderate resprouting potential and that reduction in abundance of the species usually occurs following fire. The herbaceous plants such as bluebunch wheatgrass, western needlegrass and Idaho fescue will gradually increase in density when the canopy of the sagebrush is opened. Recovery of the sagebrush stand will probably take 25-40 years to reach preburn levels. If few perennial grasses are present prior to the fire, cheatgrass may invade the site following disturbance (Hironaka et al. 1983).

Without periodic fire, three-tip sagebrush will gradually increase in density and cover. It appears that maximum coverage for the species is approximately 25 to 30% (Daubenmire 1970, Bunting et al. 1987). Productivity of the herbaceous component will be suppressed by the relatively high coverage of the sagebrush.

Low Sagebrush Communities

Low sagebrush occurs exclusively north of the highway. It is typically found on bare ridgetops on either side of Little Cottonwood Canyon. The herbaceous component is usually diverse but sparse. Due to low productivity, these sites are difficult to burn and may sometimes be used as firebreaks. Care must be taken in years with greater than average production when these communities may be capable of carrying a fire (Bunting et al. 1987).

Sandberg bluegrass is usually abundant with stonecrop and Hoods phlox in lesser quantities. A small amount of low sagebrush with an understory of Idaho fescue, Hoods phlox and bluebunch wheatgrass is found in the extreme northwest corner of the monument on northwest facing slopes.

Low sagebrush does not resprout and is easily killed by fire. Sagebrush cover does not tend to increase greatly in the absence of fire and is normally less than 13% at CRMO. Recovery of low sagebrush following fire is slow and may require 25-50 years to reach preburn levels.

Antelope Bitterbrush

Plant communities dominated by antelope bitterbrush are well distributed throughout the central portions of the monument. Major occurrences of this type can be found in the vicinity of

Big Cinder Butte. In most locations it is associated with young cinder substrates and is one of the initial species to occupy this material. Generally the dominant, antelope bitterbrush is associated with considerable amounts of rubber rabbitbrush. In areas where succession is more advanced, mountain big sagebrush and wax current are important associates. Bluebunch wheatgrass, downy brome, Indian ricegrass and several forbs make up the understory. In some distinct but widely scattered areas, Great Basin wildrye and bluebunch wheatgrass share dominance in the understory.

Bitterbrush rapidly occupies sites following a disturbance. This ability to tolerate bare sites is one of the factors allowing it to be a pioneer species on the cinder substrates. Bitterbrush has re-established more rapidly than sagebrush following the fire that occurred in the 1940's on Coyote Butte. On heavier soils, mountain big sagebrush would probably re-establish with bitterbrush.

Bitterbrush is not shade tolerant and will often decline in a stand as the canopy of trees develops. This may be a factor for long-term bitterbrush productivity on sites where Douglas-fir or limber pine stands are developing. The stands of decadent bitterbrush on Grassy and Big Cinder Buttes are probably declining as a result of conifer overstory closure.

Bitterbrush is a relatively short-lived plant. McConnell and Smith (1977) found that biomass productivity declined in Oregon high desert populations after approximately 70 years. We have noted similar declines in populations on the southern Boise National Forest. This indicates that conditions for adequate seedling establishment must be frequently met to maintain vigorous populations. Without periodic disturbance, we predict that bitterbrush not associated with limber pine would decline in seed and biomass production but would remain in the community. Those bitterbrush stands associated with limber pine would be affected by the degree of tree canopy closure. Probably only those in the high density limber pine stands would be reduced.

Populations of bitterbrush associated with mountain big sagebrush are reasonably well adapted to periodic fire (Bunting et al. 1985). They are normally of the decumbent growth form which resprouts well. Resprouting of bitterbrush averaged 45% in nonforested communities where mountain big sagebrush was present. Moderate seedling establishment occurs on these sites and it is expected that bitterbrush populations would recover within 10 to 20 years following fire.

Great Basin Wildrye

This community is restricted to two areas north of the highway, one at the mouth of Little Cottonwood Canyon and a second just north of the group campground. Great Basin wildrye is the dominant plant species in both areas. Mountain big

sagebrush and rubber rabbitbrush are found in limited quantities along the margins of this community but do not occupy the community. The shrubs are probably restricted by the high water content of the soil during the spring period. Stickseed, tumble mustard, and field pennycress are found on disturbed areas within this type. Small amounts of Canada thistle are found adjacent to Little Cottonwood Creek. These forb species tend to behave as weeds (tumble mustard, field pennycress and Canada thistle are also exotics) and would increase temporarily following fire.

The wildrye community is productive and appears to be maintaining itself. The major environmental factor determining its development as a community is the periodic moisture saturated soil. Wildrye is well adapted to fire and annual biomass production would probably increase following a fire for several years. There is no evidence, however, that the current community is dependent upon fire for maintenance. Fire would control the big sagebrush at the community boundary but sagebrush encroachment is limited by the saturated soil.

Canada thistle would increase in the community following fire. Its rhizomatous rootsystem and aggressive seedlings would make it possible for this species to rapidly occupy the plant interspaces created by the fire. Once established the thistle would likely remain in the newly occupied area. Therefore, fire would only serve to spread thistle.

Limber Pine-Bitterbrush

Day and Wright (1985) defined three separate limber pine/antelope bitterbrush communities based on the density and cover of the limber pine. In each type, limber pine dominates the landscape. The distribution of limber pine is probably heavily influenced by seed caching activity of Clark's nutcracker. Reproduction of whitebark pine is nearly completely dependent upon Clark's nutcracker (Lanner 1980). The reproduction of limber pine has a similar dependence on the birds.

Low cover limber pine/antelope bitterbrush stands are found on the older block lava flows. These are typical in the Devil's Orchard area and in the vicinity of the Sentinel. The understory is variable but is primarily composed of rubber rabbitbrush, antelope bitterbrush and lava phlox.

High cover limber pine/bitterbrush stands tend to occur in association with cinder and older pahoehoe lava flows on many areas of the monument south of the highway. Antelope bitterbrush and mountain big sagebrush are co-dominant shrubs in these stands, with rubber rabbitbrush a frequent associate. All 3 of these shrub species are shade intolerant but can persist in the stand at the densities which limber pine achieves. At high tree density such as on the north slope of Grassy Cone, these shrubs will begin to decline on the site. Grasses include Sandberg bluegrass, bottlebrush squirreltail and occasionally Indian

ricegrass. These grass species are also shade intolerant and will decline under conditions of high tree density. Limber pine is also shade intolerant but densities which interfere with reproduction are seldom achieved on CRMO.

Selected locations in the central and southern portions of the monument support very high densities of limber pine (up to 456 trees/ha). Usually these sites are on the northeast slopes of older cinder cones. The shrub component is similar to the other limber pine types, but herbaceous production and cover are lower.

Substantial numbers of mature limber pine on the monument were removed or poisoned in the mid-1960s in order to "control" a dwarf mistletoe outbreak. Despite this loss, the number of limber pine trees appears to be increasing on many sites throughout the monument (Table 3). The increase appears to have been most rapid during recent years as the mean annual density change has been 3.8% since 1961. This increase has resulted in spite of over 6000 trees being killed during the dwarf mistletoe control program.

The increase in limber pine is consistent with observed changes in the distribution of other conifers throughout the region (Franklin et al. 1971, Koterba and Habeck 1971, Vale 1981, Arno and Gruell 1983, Butler 1986). This has been attributed to an number of factors including fire suppression, grazing by domestic livestock and climatic variation. At CRMO the influence of the former 2 factors has been minimal, suggesting that climatic variation is the predominant factor involved. This is confounded by the primary succession occurring on the monument. Successional changes may be occurring more rapidly than formerly expected. The cause of the increase is probably "natural" and not human induced, and therefore, no management action is required to rectify the situation.

The occurrence of fire would set succession back and reduce the abundance of both limber pine, sagebrush and bitterbrush. If rubber rabbitbrush was abundant at the time of the fire, it would probably then dominate the site. If rabbitbrush were not present, then grasses would probably dominate until the shrubs and limber pine became re-established. It would probably require 50-100 years for the shrubs to dominate and over 100 years for the limber pine to re-establish on the site. The establishment rate for limber pine is not well documented, however. Data indicate that it requires over 50 years for whitebark pine to become re-established following fire and then up to 100 additional years for the individual to reach maturity (Morgan and Bunting Unpublished data). Whitebark pine has many similar site requirements to limber pine and is also dependent upon the Clark's nutcracker for reproduction (Lanner 1980).

Table 3. Change in limber pine density at Craters of the Moon National Monument from 1922 to 1986 based on paired photographs (Wright and Bunting Unpublished data).

Years	Interval length (yr)	Percent change (Range)	Annual change (Range)	Mean annual change (%)
1961-1986	25	21 - 244	0.84 - 11.64	3.8
1955-1986	31	-10 - 85	-0.34 - 2.94	1.1
1922-1986	64	-8 - 160	-0.13 - 3.08	1.3

Douglas-fir

This type is found in three discrete areas, Grassy Cone, Sunset Cone, and in the upper portions of Little Cottonwood Canyon. The stand on Grassy Cone is on a more xeric site with cinder substrate. Mountain snowberry is the dominant understory shrub and antelope bitterbrush and rubber rabbitbrush are common in certain locations. Chokecherry is frequent in restricted areas. The herbaceous understory is sparse and includes arrowleaf balsamroot, bluebunch wheatgrass, Sandberg bluegrass, and desert parsley. The Sunset Cone stand is also a xeric site. The substrate is also cinder, but mixed with a more coarse aggregate. The shrub and understory components are sparse in this stand as well. Sandberg bluegrass, antelope bitterbrush and cinquefoil occur infrequently. Scattered aspen are also present.

A Douglas-fir stand, more typical of those found in central Idaho, is located in upper Little Cottonwood Canyon. This stand appears to be quite viable with numerous young trees. The understory dominant, mountain snowberry, is much more prevalent than in the preceeding stands. Other understory species such as nettleleaf, slender wheatgrass, and starry solomonplume indicate a more moist environment. In all of the Douglas-fir stands, understory cover is reduced due to wildlife use. These stands are a favored mule deer foraging and resting area, particularly in late summer and early fall.

Based on photographic evidence, the Douglas-fir stands have increased both in density and in area by spreading into adjacent sagebrush grasslands over the past 50 to 75 years. The increase in Douglas-fir is consistent with the results found by other researchers in the region (Patton 1969, Sindelar 1971, Arno and Gruell 1982, Gruell et al. 1986). The stand in Little Cottonwood Canyon has invaded into adjacent sagebrush-grass and aspen vegetation types. The development of a coniferous overstory alters the understory significantly as shade-tolerant species become more abundant. Eventually most species found in the sagebrush-grass and the aspen stands will be lost from the

community. The effects of conversion to Douglas-fir have been described by Gruell et al. (1986).

The primary cause of the regional increase in Douglas-fir is thought to be fire suppression which allows the young seedlings to become established in the adjacent communities (Houston 1973, Arno 1980). This is also probably the case for Little Cottonwood Canyon and Grassy Cone. Fire scars can be found on the older Douglas-fir trees in Little Cottonwood Canyon. It appears from dates on these trees that the last major fire in this drainage occurred over 100 years ago. Lavas and cinders from recent volcanic activity at the mouth of the canyon would have prevented fires from sweeping out of the valleys and up the canyon. Thus, fire was probably not as prevalent here as in many similar canyons out of the monument and they would tend to be less extensive with local ignitions.

Fire within this type would reduce the abundance of Douglas-fir and increase the abundance of shade intolerant shrub species such as sagebrush and bitterbrush. Low intensity fires would primarily effect the young trees and saplings leaving the mature trees as a seed source for regeneration. High intensity fires could potentially kill most Douglas fir within the stand. The recovery period would then be substantially longer and it may require several hundred years for the site to recover to the preburn conditions.

Upland Quaking Aspen

The majority of the aspen on the monument is located north of the highway. However, scattered stands occur in the central and southern portions of the monument on Big Cinder Butte, Fissure Butte, and small areas within the Silent Cone flow. In each, quaking aspen is the dominant species. Woods rose, chokecherry, antelope bitterbrush and mountain big sagebrush are common associates. Fireweed grass, bluebunch wheatgrass, slender wheatgrass and mountain brome grass are the most abundant grass species in this type.

Like the limber pine and Douglas-fir, the aspen stands on the northern portion of the monument have increased in area substantially in the past 50 years (Wright and Bunting, unpublished data). In many areas the understory cover has been heavily depleted by mule deer which use the stands for shade and resting cover in summer and early fall.

In the absence of fire, aspen will tend to invade into adjacent sagebrush grassland vegetation (Loope and Gruell 1973). Older stands on northern aspects will be invaded themselves by Douglas-fir if a seed source is available. Fire in aspen stands will invigorate the stand by inducing resprouting and controlling competing vegetation. Non-resprouting species such as conifers will be temporarily removed from the stand. Lack of fire in the stands invaded by Douglas-fir will result in a conversion of this

type to a Douglas-fir forest and eventual loss of the aspen. In stands which are not invaded by conifers, the situation is less clear. Some researchers consider the aspen to be climax on these sites (Langenheim 1962, Reed 1971). Many aspen stands will deteriorate in time if not invigorated by fire and will revert back to grassland or sagebrush grassland (Krebill 1972, Schier 1975, DeByle 1976, DeByle and Winokur 1985). It is not clear which will happen at CRMO but there is no evidence at this time of aspen stand deterioration.

Riparian Zone

Two small zones of riparian vegetation are found in the northern portions of the monument along the drainages of Little Cottonwood Creek and Leach Creek. Both areas are comprised of dense woody vegetation and an understory of dense tall forbs. The dominant tree species include quaking aspen, cottonwood, chokecherry, alder, and willow. The forb layer is comprised primarily of cow parsnip, big-sting nettle (both exotics), and small-leaf angelica.

Little information is available on the effects of fire or lack of fire on riparian systems. Most of the overstory shrub species resprout vigorously following fire and most understory species can probably survive infrequent fires of low intensity. Fire would tend to remove Douglas-fir from riparian zones but Douglas-fir probably would not become a dominant in any case because it is best adapted to upland, well drained sites. Riparian sites can accumulate substantial amounts of dead wood in the shrub canopies and on the soil surface. This is particularly true for those dominated by willows. Periodic fire probably would maintain the shrubs in a more healthy and productive condition if fires did not occur too frequently. There is no evidence to indicate that fire is necessary to maintain the vegetation type in this area.

If fires occurred too frequently in riparian systems, the stream course would begin to straighten and water flow would accelerate. Debris dams and overhanging banks would be reduced. Water quality would probably decline due to increased sediment loads. Riparian zones are disproportionately important to wildlife species as compared to the area of upland vegetation (Ames 1977, Thomas 1979, Wright and Hoffman Unpublished data from CRMO). Frequent fires within these types would greatly change the structure of the plant community, reducing the tree and shrub component and thereby reduce the habitat value for wildlife.

SAMPLING METHODS USED IN DATA COLLECTION

Data which served to characterize the plant communities at CRMO and which provide input into the fire behavior models were collected during the summer of 1987 and 1988. The vegetation map developed by Day and Wright (1985) was used to stratify vegetation sampling by plant community extent and spatial distribution within the monument. Only those communities which were thought to be capable of sustaining a fire were sampled.

A series of four 10 m transects were established at each sample point or macroplot (Fig. 1). The 4 transects originated from a common center and were oriented to the 4 cardinal directions. Five microplots (50x50cm) were located along each transect at 2, 4, 6, 8 and 10 m from the center. The following data were recorded for each microplot:

- 1) Total percent cover of annual forbs, perennial forbs, annual grasses, and perennial grasses
- 2) Estimated weight of standing herbaceous material
- 3) Actual field weight of herbaceous material
- 4) Actual air dry weight of herbaceous material
- 5) Estimated dry weight of litter

Down woody fuels were inventoried using the methods of Brown (1974) and Brown et al. (1982). In this method each transect can be visualized as a vertical plane from ground level to 2 m in height (Fig. 2). Along this plane the total number of intersections by diameter class (<0.65 cm, 0.65-2.5 cm, 2.5-7.5 cm, and >7.5 cm) of down, dead woody material were recorded. Total shrub canopy coverage for each species and non-fuel interspaces were recorded along each transect using the line transect method (Canfield 1941) (Fig. 3). In order to characterize fuel discontinuity, all areas not covered by aerial portions of plants or litter were classified as fuel interspaces.

Shrub height data are used in fuel load calculations. Shrub heights were measured at 3.3 m intervals along the transect. Height of the closest shrub was measured. Shrub heights were then averaged by species for each macroplot.

Shrub density was determined with four 2 m radius plots in each macroplot (Fig. 1). One was located at the outside end of each 10 m transect. Tree density was determined through the use of a 10 m radius plot using the 10 m transect as a basis for location. All densities were transformed to number of individuals per ha.

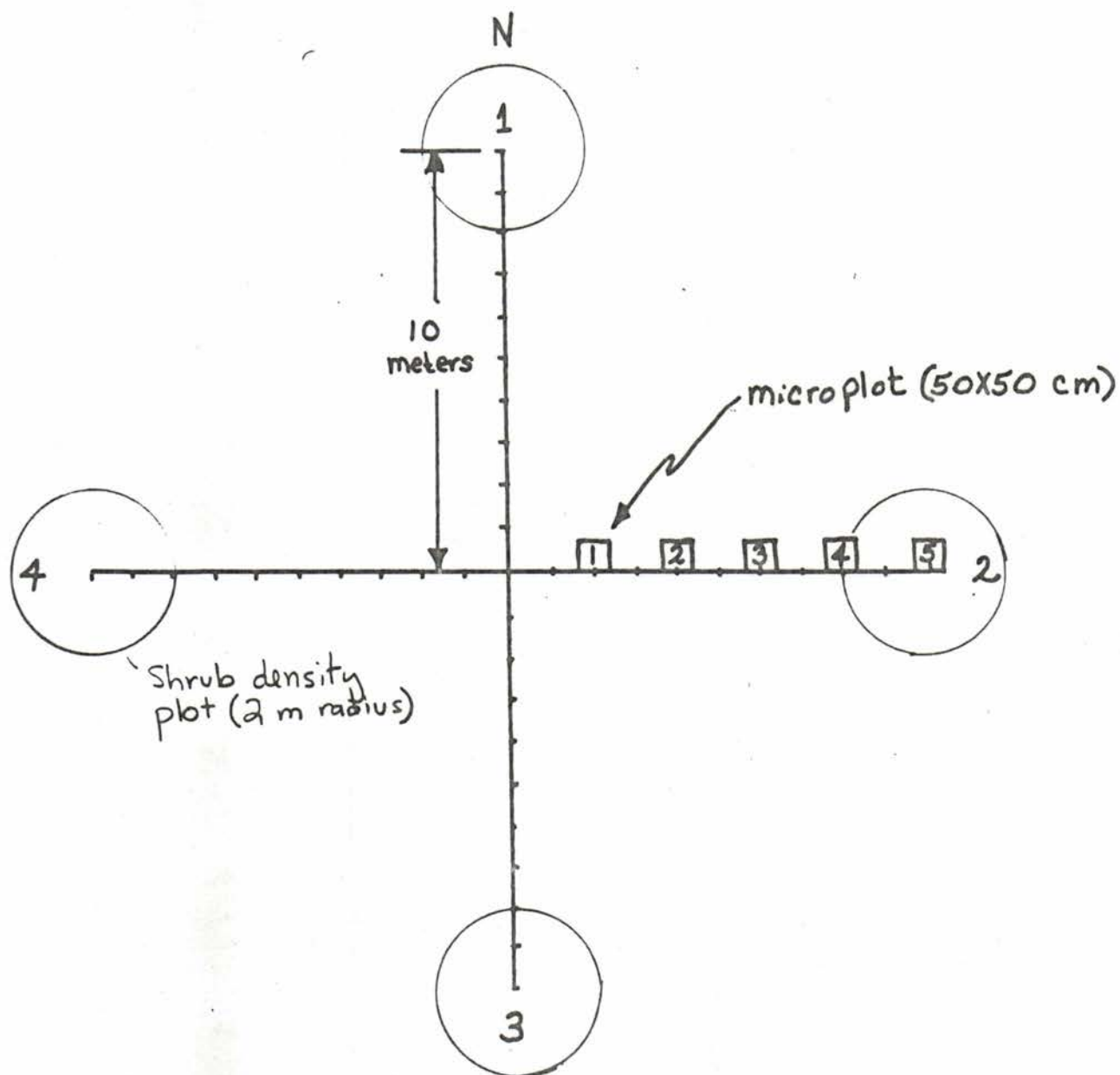


Figure 1. General layout of the four transects at each macroplot including the associated microplots.

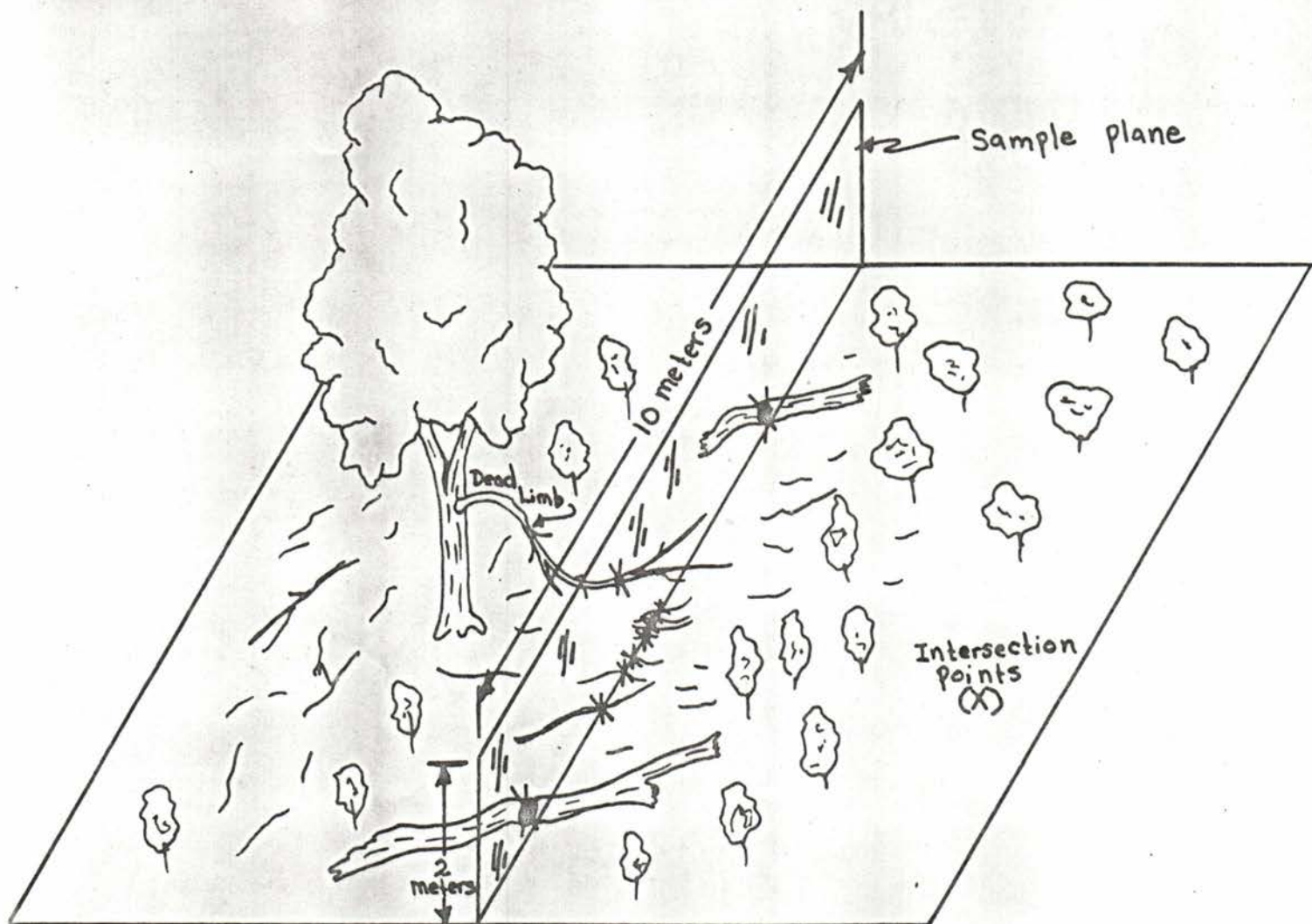


Figure 2. Procedure used to determine amount of down woody fuels present by size classes ($< \frac{1}{4}$ ", $\frac{1}{4}$ "-1", 1"-3", > 3 ") (after Brown, 1974).

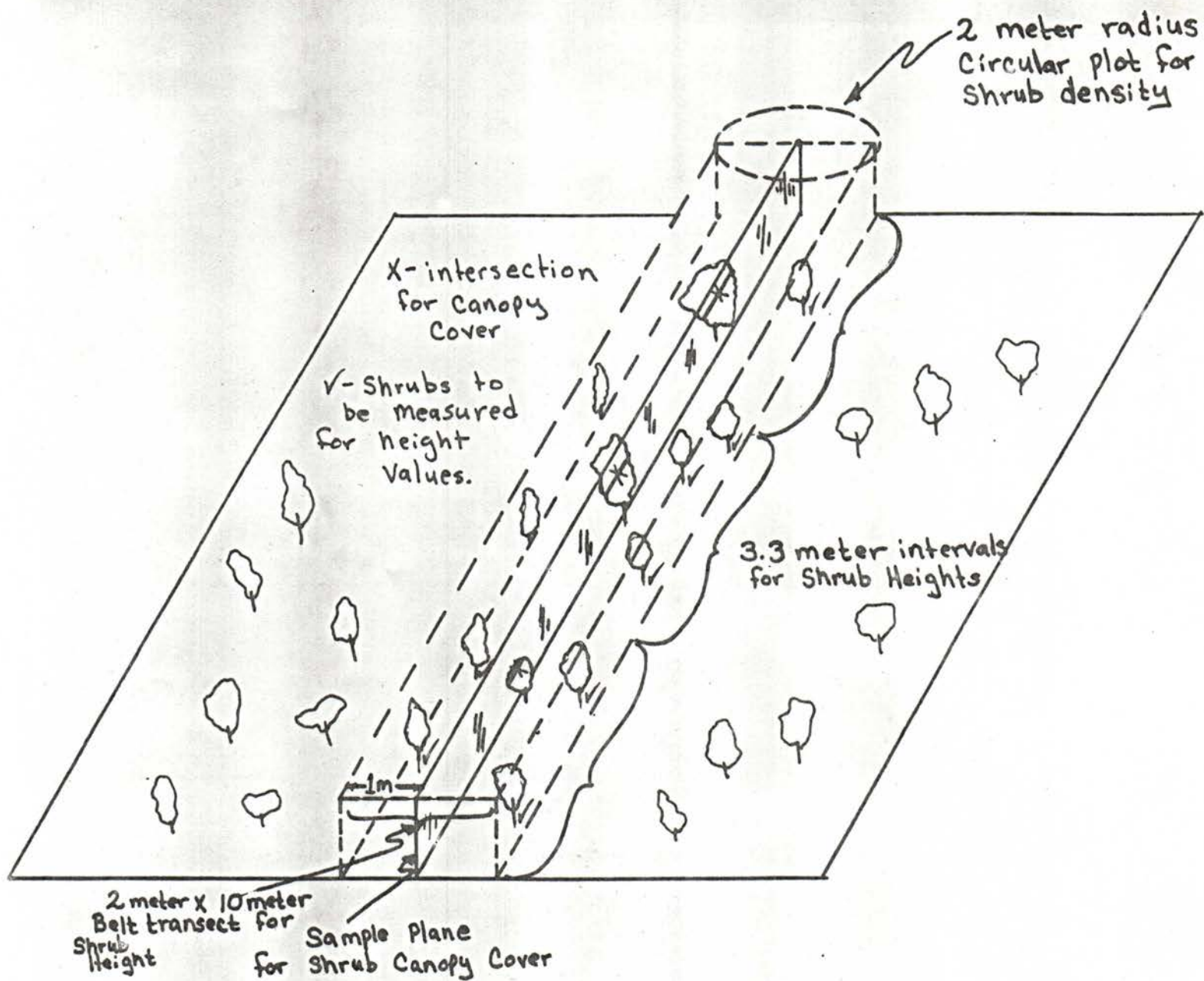


Figure 3. Procedure for determining shrub canopy cover, shrub height, and shrub density at each macroplot.

A species list was prepared for each macroplot. Species were recorded by their relative abundance. The following scale was used:

- | | |
|---------------|--|
| 1) Abundant | Major component of plant community based on either high coverage or density |
| 2) Frequent | Subdominant plant in the community based on coverage or density |
| 3) Common | Plant evenly distributed throughout macroplot but of minor importance in community |
| 4) Occasional | Only a few individuals on the site, but plants are evenly distributed throughout the macroplot |
| 5) Rare | Only a few individuals on the site with patchy, uneven distribution pattern |

Cross-sections and increment cores were taken from aspen, limber pine and Douglas-fir in order to age some individuals in selected stands. The increment core method (Barrett and Arno 1988) was used to date past fires in Little Cottonwood Canyon.

Fire weather data were obtained from the Fire Management Office, Bureau of Land Management, Idaho Falls, Idaho. Weather data collected at CRMO were also summarized.

CRATERS OF THE MOON FIRE MANAGEMENT PLAN

Designation of Fire Management Units

The CRMO Fire Management Plan classifies the monument into 11 Fire Management Units (FMU) each of which have similar in vegetation, suppression, and visitor use characteristics. The FMUs are in turn grouped into the four existing CRMO Land Classification Zones (Fig. 4). All FMUs are developed so to be a subdivision of a single Land Classification Zone.

I. Natural Environment Zone

This zone includes all portions of CRMO north of US Highway 20. The Land Classification Zones include a 65 m Buffer Zone around the perimeter of the Natural Environment Zone. For simplicity, these 2 zones have been combined in this plan and will be referred to as the Natural Environment Zone. This zone is subdivided into 4 FMU's. These include:

FMU 1. Includes areas in Little Cottonwood, Quickshot and Leech Creek drainages. Most areas in this zone have slopes in excess of 20%. The vegetation is comprised of primarily sagebrush-

grass, upland aspen, Douglas-fir, and riparian communities. Access is moderate to poor and limited to the lower portions of the valleys. Fires in this FMU will tend to spread upslope and out of NPS managed lands. The ridge above Little Cottonwood is dominated by low sagebrush and Sandberg bluegrass vegetation which will help contain the fires in that portion. All fires will be suppressed in FMU 1 unless agreements can be developed with the adjacent landowners and agencies.

FMU 2. Includes the Great Basin wildrye community at the base of Little Cottonwood Creek and is composed of that single vegetation type. The topographic position make a natural ignition unlikely. However, the abundant fine fuels (>15,000 kg/ha) make fire likely if an ignition occurs. Vehicle access is good. All fires in FMU 2 will be suppressed because 1) the community appears to be maintaining itself in the absence of fire, 2) fire will likely aid the spread of the exotic noxious weed, Canada thistle, and 3) there is a high likelihood of spread into FMU 1 and then out of CRMO. If fire were determined to be important in the management of this vegetation type, prescribed fire (planned ignition) should be considered as the best alternative to accomplish this management objective.

FMU 3. All areas dominated by sagebrush-grass vegetation with slopes less than 20%. Vehicle access is moderate. Lava and cinder outcrops and other fuelbreaks are common. All fires will be suppressed due to the high probability of fires crossing the boundaries of CRMO onto adjacent lands.

FMU 4. Areas of Sunset and Grassy Cones with slopes greater than 20% are included in this FMU. The lower slopes of FMU 4 are dominated by a variety of perennial grasses intermixed with mountain big sagebrush vegetation types. The upper slopes are dominated by stands of Douglas-fir. There is vehicle access to the bottom of both cones. The possibility of natural ignition from lightning is high. The possibility of human caused ignitions are probably greatest in this FMU of all in CRMO due to the slope, high fine fuel loadings, and the proximity of the highway and the group campground. All fires will be suppressed in FMU 4 due to the high probability of fires burning onto adjacent lands beyond the CRMO boundary.

II. Development Zone

This zone includes that portion of CRMO near the Visitor Center, campground and south of US Highway 20 for 2 km toward Arco. The entire zone is included within FMU 5.

FMU 5. This fire management unit is composed primarily of relatively new lavas. A small area of sagebrush grassland occurs northeast of the visitor center. This is the only portion that has a high fire potential. All fires will be suppressed in this FMU due to the proximity of structures and high visitor use areas.

III. Outstanding Natural Feature Zone

This zone includes the area adjacent to the CRMO loop road and contains the volcanic features of most interest to the monument visitor. The area is of the most recent volcanic origin and consequently is highly dissected by lava flows and cinder gradens and is incapable of sustaining a large fire. The entire zone has been designated as FMU 6.

FMU 6. This unit does have a number of plant communities which though small in size do produce adequate fuels to sustain fires. These are predominantly limber pine and bitterbrush vegetation types. Charcoal evidence indicates that many of these communities have burned in the past. However, the fires were small due to the numerous fuel breaks. The presence of cinder cones and limber pine make natural ignition from lightning the most likely source of fire ignition. The region adjacent to the Tree Molds parking lot has the greatest likelihood of human-caused ignition. The fuels are dense and continuous. This area has burned in the recent past. Areas near the Tree Molds parking lot and the on south side of Silent Cone present the only possibility of a fire burning out of the zone.

Due to the small area a given fire is likely to cover and the possible damage caused by suppression, only high intensity fires with predicted flame lengths greater than 2.5 m (8.2 ft) and fireline intensities greater than 400 Kcal/m/s (500 Btu/ft/s) will be suppressed. Fires more intense than this are likely to present serious control problems related to spot fires and crowning (Rothermel 1983). Fires that occur adjacent to the Tree Molds parking area and south of Silent Cone may possibly spread out of FMU 6 if ignited under severe burning conditions and a northerly or northeasterly wind. The fires would burn into a less restrictive fire management unit (FMU 7) and therefore, do not require suppression unless flame lengths and fireline intensities exceed those specified above. All fires will be suppressed in the limber pine stands on the east side of Inferno Cone because this area is of major importance as a deer fawning area and alternate use areas are not readily available. All fires which are not suppressed will be periodically monitored with respect to weather, fire behavior and area burned. Fire weather forecasts will be acquired through the National Weather Service to predict future fire behavior.

IV. Wilderness Zone

The remainder and largest portion of the monument is included within this zone which has the legal classification of "wilderness". As a result of the wilderness classification, certain types of suppression techniques may not be permitted. It contains a wide variety of vegetation types including: mountain big sagebrush, antelope bitterbrush and limber pine. The major vegetated portions are near the center of CRMO and are surrounded

by recent lava and cinder gardens that are incapable of supporting a fire. This will result in containment of any future fires in this zone of the monument except those cases indicated in FMU 7. There is no possibility for fires ignited in the Wilderness Zone to spread outside of CRMO. The Wilderness Zone is subdivided into 5 FMU's (Fig. 4).

FMU 7. This unit is located in the vicinity of Big Cinder and Half Cone Buttes and is dominated by limber pine vegetation types with dense bitterbrush understory and bitterbrush vegetation types. While many communities contain relatively high fuel loads, the continuity is low due to recent lava flows and cinder gardens. The possible extent of a fire is therefore limited. Fires will not burn into the Outstanding Natural Feature Zone with the exception of 2 locations: 1) southwest of Silent Cone and 2) north of Big Cinder Butte. Fires in these locations will be monitored. If predicted fire behavior exceeds conditions of 1) flame lengths greater than 2.5 m (8.2 ft), 2) fireline intensities greater than 400 Kcal/m/s (500 Btu/ft/s), and 3) southerly wind directions; the fires will then be suppressed.

FMU 8. Limber pine communities which have developed on lava dominate this unit. The amount of fuels is very low in this FMU and they are likely to burn only under extreme weather conditions. It is subdivided into three discrete sections located near Echo Crater, Sheep Trail Butte, and west of Coyote Butte (Fig. 4).

FMU 9. This unit is located in the sagebrush-dominated communities between Coyote Butte and Little Prairie. Fuel loads are relatively high in some locations and past fires have been of moderate size (50-100 ha). Fires ignited in this FMU could readily burn into FMU 7 and 8.

FMU 10. FMU 10 is composed of small isolated tracts of vegetation in southern portions of the monument between Fissure and Two Point Buttes. Since the areas are small, ignitions in these areas will be rare and the fires small when they do occur. Vegetation is composed primarily of limber pine communities.

FMU 11. Carey Kipuka, Round Knoll and other small kipukas on the monument comprise this FMU. The vegetation is primarily a mixture of sagebrush communities. If ignited it is likely that the entire kipuka would burn due to the high fine fuel loads and limited access. The fires, however, would not be able to spread to another FMU or off the monument.

Table 4. Area and major vegetation types of the Fire Management Units (FMU's) of Craters of the Moon National Monument.

FMU	Area (ha(ac))	Major vegetation groups
1	897 (2216)	Mountain big sagebrush, low sagebrush, Douglas-fir, upland quacking aspen riparian zone
2	32 (79)	Great Basin wildrye
3	560 (1384)	Mountain big sagebrush
4	440 (1087)	Mountain big sagebrush, Douglas-fir, limber pine
5	42 (104)	Limber pine-bitterbrush, antelope bitterbrush, mountain big sagebrush
6	1760 (4349)	Limber pine-bitterbrush, antelope bitterbrush
7	750 (1853)	Limber pine-bitterbrush, upland quaking aspen, antelope bitterbrush
8	1840 (4547)	Limber pine-bitterbrush, upland quaking aspen, antelope bitterbrush, mountain big sagebrush
9	2270 (5609)	Mountain big sagebrush, antelope bitterbrush
10	640 (1581)	Limber pine-bitterbrush, antelope bitterbrush
11	160 (395)	Mountain big sagebrush, three-tip sagebrush

Fire behavior estimation

Considerable research has taken place in recent years to develop computer models of fire behavior. These models permit estimation of fire characteristics and are useful in developing suppression tactics. Rate-of-spread, rate of growth, fire intensity, and flame length are among the characteristics that can be estimated through the use of Rothermel's fire behavior model (1972) and Albini's nomograms (1976). Rothermel's models have recently been adapted for use on personal microcomputers (PC/BEHAVE) (Cooney 1986).

The models do possess a number of limitations. The model is primarily intended to describe a flame front advancing through surface fuels within 6 m and contiguous to the ground. They are best adapted to free running head-fires spread in the direction of the wind and are not constrained by fuel breaks or affected by other fires. However, severe, erratic fire behavior such as fire whirls (cyclonic wind behavior which may form near fires under similar conditions to either dust devils or tornados (Davis 1959)), spot-fire ignition and crown fires (those which burn through the canopies of trees) are not predicted by the model (Rothermel 1983). Van Wagner (1977) does discuss the conditions for the spread of crown fires.

The fire behavior models do not necessarily predict behavior of planned-ignition prescribed fires. The models assume a free running head-fire and this situation is usually modified by the ignition pattern on prescribed fires. Frequently patterns such as strip head-fires, back-fires, and flank-fires are employed to reduce fire intensity and to maintain control of the fire. In spite of these limitations, the prediction models are useful when planning prescribed fires in order to assess the hazard of fire escape and resistance to control. The use of these models is described fully in Rothermel (1983). Additional models have been developed to predict crown scorch (Van Wagner 1973) and spotting distance (Albini 1979). Brown's (1982) predictions are also useful in predicting fire behavior in big sagebrush communities.

Previous computer versions of the fire behavior models contained only the pre-set standard Northern Forest Fire Laboratory (NFFL) fuel models. PC/BEHAVE allows the use of the standard NFFL fuel models but also allows the user to develop custom fuel models that reflect existing vegetation and fuels. The result is better prediction of fire behavior for the site. Custom fuel models were developed to represent the conditions present in CRMO vegetation (Table 5 and 6). These are intended as initial fuel models to be modified further as the personnel of CRMO become more experienced with fire behavior.

The fixed inputs in the custom fuel models were extracted from information collected in the field at CRMO. Dead, live woody and herbaceous fuel loading information are summarized for the vegetation groups in Tables 7 and 8. Fuel depth data were extracted from Table 9 by vegetation group. This information is

also available in the appendix for each of the 20 community types described by Day and Wright (1985) that were sampled. Other values shown in Table 5 and 6 were determined through the experience of the authors and with the assistance of the PC/BEHAVE documentation. Fuel moisture of extinction is the fine fuel moisture at which the fire can no longer sustain itself. It is a sensitive variable in light fuels such as are present at CRMO. This variable requires further adjusting to the conditions present at CRMO as these data become available.

Table 5. Parameters for the custom fuel models to be used in PC/BEHAVE for predicting fire behavior in non-forested vegetation types in Craters of the Moon National Monument (Data collected on site by the authors).

Fuel characteristic ¹	<u>Vegetation type</u>			
	Great Basin wildrye	Antelope bitterbrush	Mountain big sagebrush	Low sagebrush
1-hr fuel load (T/ac)	3.01	0.75	0.68	0.20
10-hr fuel load (T/ac)	0.00	0.60	0.45	0.20
100-hr fuel load (T/ac)	0.00	0.35	0.75	0.00
Herbaceous load (T/ac)	1.80	0.12	0.18	0.00
Live woody load (T/ac)	0.00	1.50	3.00	1.00
1-hr S-V ratio (1/ft)	1500.00	1500.00	1500.00	1500.00
Herbaceous S-V ratio (1/ft)	1500.00	1500.00	1500.00	1500.00
Live woody S-V ratio (1/ft)	1500.00	1500.00	1500.00	1500.00
Fuel depth (ft)	2.50	2.00	1.85	0.40
Fuel heat content (BTU/lb)	8000.00	7000.00	8000.00	8000.00
Fuel moisture of extinction (0.01%)	0.25	0.25	0.25	0.25
Wind reduction factor (0.01%)	0.40	0.40	0.40	0.40
Model type (static/dynamic)	Dynamic	Dynamic	Dynamic	Dynamic

1) Imperial units of measure are used by PC/BEHAVE program as inputs and outputs.

Table 6. Parameters for the custom fuel models to be used in PC/BEHAVE for predicting fire behavior in forested vegetation types in Craters of the Moon National Monument (Data collected on site by the authors).

Fuel characteristic ¹	Vegetation type		
	Aspen woodland	Limber pine	Douglas-fir
1-hr fuel load (T/ac)	2.50	1.16	2.50
10-hr fuel load (T/ac)	0.83	0.61	0.50
100-hr fuel load (T/ac)	2.20	0.82	0.90
Herbaceous load (T/ac)	0.16	0.05	0.18
Live woody load (T/ac)	0.50	2.00	1.50
1-hr S-V ratio (1/ft)	3000.00	2000.00	2000.00
Herbaceous S-V ratio (1/ft)	1500.00	1500.00	1500.00
Live woody S-V ratio (1/ft)	1500.00	1500.00	1500.00
Fuel depth (ft)	0.50	2.00	0.25
Fuel heat content (BTU/lb)	8000.00	8000.00	8000.00
Fuel moisture of extinction (0.01%)	0.18	0.18	0.25
Wind reduction factor (0.01%)	0.40	0.40	0.40
Model type (static/dynamic)	Dynamic	Dynamic	Dynamic

1) Imperial units of measure are used by PC/BEHAVE program as inputs and outputs.

Table 7. Down woody and duff fuel loadings for major vegetation type in Craters of the Moon National Monument (Data collected on site by the authors).

Vegetation type	<u>Fuel loading (kg/ha)</u>				Total fuel loading	Duff dept (cm)
	Class 1 (<0.62cm)	Class 2 (0.62-2.5cm)	Class 3 (2.5-7.5cm)	Class 4 (>7.5cm)		
MBS	384	1008	1690	1619	4,701	-
TTS	90	63	-	-	153	-
LS	121	436	-	-	557	-
AB	658	1370	826	1265	4,119	-
GBW	-	-	495	1150	1,645	-
LP	429	1361	1831	2194	5,815	1.0
DF	377	1120	1981	2531	6,009	5.3
UQA	407	1868	4954	2531	9,760	3.5
RZ	480	1750	5200	2700	10,130	4.2

MBS=Mountain big sagebrush, TTS=Three-tip sagebrush, LS=Low sagebrush, AB=Antelope bitterbrush, GBW=Great Basin wildrye, LP=Limber pine/bitterbrush, DF=Douglas-fir, UQA=Upland quaking aspen, RZ=Riparian zone

Table 8. Percent cover by herbaceous plant growth form, herbaceous production, plant litter and plant interspace in major plant communities in Craters of the Moon National Monument (Data collected on site by the authors).

Vegetation type	<u>Plant coverage (%)</u>				<u>Production</u>		<u>Interspace</u>	
	Annual forb	Peren. forb	Annual grass	Peren. grass	Total cover	(kg/ha) Herb. Litter	(%)	
MB	1	5	1	8	15	410 1136	16	
TT	-	23	-	37	60	1040 800	6	
LS	1	19	-	11	30	480 360	28	
AB	1	3	1	9	14	280 1626	13	
GBW	2	1	-	72	75	4040 11160	1	
LP	1	2	1	4	8	115 2226	21	
DF	-	3	-	18	21	160 5600	6	
UQA	1	6	-	19	26	360 5680	4	
RZ	4	20	5	5	30	850 7200	2	

MBS=Mountain big sagebrush, TTS=Three-tip sagebrush, LS=Low sagebrush, AB=Antelope bitterbrush, GBW=Great Basin wildrye, LP=Limber pine/bitterbrush, DF=Douglas-fir, UQA=Upland quaking aspen, RZ=Riparian zone

Table 9. Mean shrub canopy coverage (cc, %) and height (ht, cm) from sample plots on Craters of the Moon National Monument (Data collected on site by the authors).

Species	Vegetation Type						DF	UQA	RZ
	MBS	TTS	LS	AB	GBW	LP			
AMUT cc	-	-	-	-	-	-	3	1	1
ht	-	-	-	-	-	-	90	65	70
ARAR cc	0.3	2.5	20	-	-	-	-	-	-
ht	30	10	12	-	-	-	-	-	-
ARTRV cc	17	5	-	5	-	11	-	4	1
ht	56	-	-	52	-	61	-	40	45
ARTRI cc	-	13	-	-	-	-	-	-	-
ht	-	30	-	-	-	-	-	-	-
CHNA cc	6	-	-	14	-	6	-	2	1
ht	60	-	-	58	-	51	-	-	60
CHVI cc	5	-	3	-	-	-	-	2	-
ht	30	-	21	-	-	-	-	-	-
LEPU cc	3	-	-	-	-	2	-	-	-
ht	20	-	-	-	-	14	-	-	-
PRVI cc	0.3	-	-	-	-	0.3	4	-	8
ht	20	-	-	-	-	15	62	-	95
PUTR cc	11	-	-	37	-	24	-	5	1
ht	51	-	-	50	-	41	-	30	40
RIAU cc	0.5	-	-	-	-	-	-	-	2
ht	30	-	-	-	-	-	-	-	35
RICE cc	1.3	-	-	9	-	8	-	5	-
ht	60	-	-	56	-	48	-	-	-
SYOR cc	7.2	-	-	-	-	2	13	9	2
ht	37	-	-	-	-	49	57	27	52
TECA cc	1.8	-	-	-	-	-	-	-	-
ht	30	-	-	-	-	-	-	-	-
TOTAL cc	53.7	20.9	22.5	64.7	-	53.3	20.7	27.3	16.0
AVG. ht	39	20	17	54	-	40	70	41	57

MBS=Mountain big sagebrush, TTS=Three-tip sagebrush, LS=Low sagebrush, AB=Antelope bitterbrush, GBW=Great Basin wildrye, LP=Limber pine/bitterbrush, DF=Douglas-fir, UQA=Upland quaking aspen, RZ=Riparian zone

AMUT-serviceberry, ARAR-low sagebrush, ARTRV-mountain big sagebrush, ARTRI-three-tip sagebrush, CHNA-rubber rabbitbrush, CHVI-low rabbitbrush, LEPU-prickly phlox, PRVI-chokecherry, PUTR-bitterbrush, RIAU-golden currant, RICE-squaw currant, SYOR-snowberry, TECA-gray horsebrush.

As an example of the use of this information, fire behavior was predicted for a mixture of mountain big sagebrush (85%) and low sagebrush (15%) vegetation. Inputs are shown in Table 10 and outputs in Table 11. The model can estimate fire behavior for a single vegetation type or it can utilize 2 vegetation types and calculate weighted values. For this example, it will provide fire behavior for both vegetation types and calculate a weighted rate-of-spread through a combination of the 2 vegetation types.

Inputs include the moistures at the time of the fire of the 1-, 10-, and 100-hr fuels, i.e. those down fuels in diameter classes: 1 (<0.62 cm), 2 (0.62-2.5 cm) and 3 (2.5-7.5 cm) diameter fuels (Table 7). The fuel moistures can be estimated based on: 1) the National Fire Danger Rating System (NFDRS) (Deeming et al 1972), 2) fuel moisture sticks, 3) or they can be estimated through procedures outlined in Rothermel (1983). For example, we chose herbaceous moisture of 150% indicating that the moisture content of the current year's biomass was moderately high but that the vegetation was beginning to cure. The midflame windspeed varied with the height of the flame. In this example with flame lengths of 33.5 cm, the midflame windspeed would be measured at 17 cm. This windspeed measurement is different from normal meteorological windspeed measurements which are collected at 3 to 4 m above the height of vegetation. Consequently, the windspeed value may vary considerably from midflame windspeed. The average slope of the site was 25%. Steeper slopes result in faster moving fires given that all other factors remain constant. The model is capable of predicting maximum rate of spread or rates lateral to the maximum. These are options to be selected by the user.

The predicted fire behavior for this example is included in Table 11. The rate-of-spread for the big sagebrush type is 80 m/hr (4 chain/hr) (1 chain = 66 ft). The rate-of-spread declines to 4 m/hr (13 ft/hr) when the fire burns into the low sagebrush vegetation type which indicates that the fire probably cannot sustain itself in this vegetation under these conditions and will go out. This is a realistic prediction as the fuels in low sagebrush are usually inadequate to carry low intensity fires. Flame length and fireline intensity relate directly to the difficulty of fire control. When these values exceed 1.2 m (4 ft) and 80 Kcal/m/s (100 Btu/ft/m), respectively, the fire is normally too intense to be controlled directly by hand crews at the head of the fire. If flame length and fireline intensity exceed 3 m (10 ft) and 400 Kcal/m/s (500 Btu/ft/m), respectively, direct attack with machines is not advised. The fire in this example could be readily controlled with suppression crews. Areas dominated by low sagebrush vegetation could be used as fire control points.

Table 10. Example of fuel and weather input for utilizing PC/BEHAVE fire behavior program. (Information collected from field measurements at time of fire).

Dominant fuel type	SAGEBRUSH-BIG
Cover of dominant fuel type	85%
Secondary fuel type	SAGEBRUSH-LOW
1-Hr fuel moisture	8%
10-Hr fuel moisture	7%
100-Hr fuel moisture	8%
Herbaceous moisture	100%
Live woody moisture	150%
Midflame windspeed	8 mi/hr
Terrain slope	25.0%
Wind direction	0 degrees
Spread in maximum direction?	Yes

Table 11. Predicted fire behavior in mountain big sagebrush (85%) and low sagebrush vegetation when burning under the conditions specified in Table 10 when using PC/BEHAVE.

Fuel model:	SAGEBRUSH-BIG	(85%)
Rate-of-spread	4.0	chain/hr
Heat per unit area	206.5	Btu/sqft
Fireline intensity	15.0	Btu/ft/sec
Flame length	1.6	ft
Reaction intensity	797.6	Btu/sqft/m
Effective windspeed	8.2	mi/hr
Fuel model:	SAGEBRUSH-LOW	(15%)
Rate-of-spread	0.2	chain/hr
Heat per unit area	60.9	Btu/sqft
Fireline intensity	0.2	Btu/ft/sec
Flame length	0.2	ft
Reaction intensity	235.4	Btu/sqft/m
Effective windspeed	2.4	mi/hr
Weighted rate of spread between:		
Fuel model:	SAGEBRUSH-BIG	(85%)
Fuel model:	SAGEBRUSH-LOW	(15%)
Rate-of-spread	1.8	ch/hr

ADMINISTRATION OF FIRE MANAGEMENT PLAN

All operational and administrative matters relating to fire management are under the direct jurisdiction of the Park Superintendent or his/her designate. This organization follows closely that of NPS-18.

Positions involved in this process include the Superintendent, the Fire Management Committee, the Fire Management Officer, Chief Park Ranger, Fire Bosses 1 and 2, Fire Teams 1 and 2, and the Chief Park Interpreter. The fire management responsibilities of these positions are as follows.

SUPERINTENDENT- As the authority on all fire management at CRMO, the Superintendent serves as chairman of the Fire Management Committee, and has general oversight of the planning, budget and administration of all fire management issues at CRMO.

FIRE MANAGEMENT COMMITTEE- This committee, composed of three members, Superintendent (chairman), Chief Park Ranger, and the Natural Resource Specialist (Fire Management Officer), can convene with as few as 2 members present in the event of reduction of personnel or absence of a committee member from CRMO. The committee is charged with detailed and overall fire management, annual reviews of the Fire Management Plan and revisions of it needed, approval of all prescribed fire plans, development and implementation of all pre-attack, step-up and initial attack plans, and evaluation of the conformance of prescribed fire to the Resource Management Plan.

FIRE MANAGEMENT OFFICER- (Natural Resource Specialist) serves as member of the Fire Management Committee and has the following responsibilities, which can be delegated. Works with interagency agreements and cooperation, monitors fuel loadings in all areas of the park, particularly in full suppression areas, formulates and writes plans and carries out all prescribed burns, develops fire research recommendations and solicits research proposals through the Fire Management Committee, monitors contract work done in relation to fire management, assesses need for and recommends burn rehabilitation to the Fire Management Committee, maintains all fire history records, coordinates equipment and its maintenance, keeps current on recent advances in fire management and ecology, manages yearly fire exercises, coordinates fire fighting personnel including training and physical fitness and coordinates fire dispatch with other agencies.

CHIEF PARK RANGER- As a member of the Fire Management Committee the Chief Park Ranger is in charge of collecting and storing environmental data and fire weather data for use in AFFIRMS, remote fire weather data collection and instrumentation, and air quality information.

FIRE BOSS 1- Fire Boss 1 is the on site authority for all prescribed burns and wildfires and manages initial attack in

suppression and conditional zones, conducts fire monitoring and prepares reports, supervises the 5-person fire team, and is responsible for equipment coordination on all fires.

FIRE BOSS 2- Fire Boss 2 is one of two on site authorities for wildfire suppression but this position is activated only in absence of Fire Boss 1 during suppression situations. At this time Fire Boss 2 assumes all of the above responsibilities.

FIRE TEAM- The Fire Team is composed of 5 people selected by the Fire Management Officer. This team conducts initial attack team on all full suppression fires, and participates in fire monitoring. Due to limitations in the number of NPS staff available, additional personnel for prescribed burning or wildfire suppression will be acquired from other agencies through cooperative agreements.

CHIEF PARK INTERPRETER- The Chief Park Interpreter is responsible for fire information and public relations, develops literature and talks relating to fire management and ecology, works with the Fire Management Officer in developing fire prevention methods.

Training of personnel will be required to maintain crews qualified for fire suppression and prescribed burning. Fire team members will need training in fire control and first aid procedures. This training may be presented by permanent personnel at CRMO or scheduled in conjunction with Bureau of Land Management or US Forest Service training. Personnel designated to act as fire bosses will need additional training. This will include additional coursework and experience in fire suppression and fire behavior. This training can be acquired at Boise Interagency Fire Center (BIFC), Boise, Idaho or at the National Advanced Resource Training Center (NARTC), Marana, Arizona. Prescribed burning requires different skills and experience than fire suppression, particularly of the Fire Boss. Some of these needs may be able to be met with cooperative agreements with the Bureau of Land Management and the US Forest Service. It will be the responsibility of the Fire Management Officer at CRMO to determine what training is required and schedule the needed training.

DECISION PROCESS AND SUPPRESSION STRATEGY

In the event of a fire, the following strategy will be utilized. The cause of the fire will be determined if possible. If the fire is determined to be man-caused, personnel will be dispatched to suppress the fire. The BLM, USFS and other cooperating fire suppression organizations will be contacted. If the fire is determined to be caused from natural (non-human) factors the procedure outlined in Table 14 will be followed. If the cause of the fire cannot be easily or quickly determined, the fire will be assumed to be a natural ignition and Table 14 will be followed.

Fire suppression within CRMO will adopt a strategy that will minimize the suppression impact on the landscape. Motorized heavy equipment may be utilized in fireline construction only in FMU 1, 2, 3, and 4. It is to be used in these FMU's only when hand crews are unable to contain the fire within the boundary of CRMO. All firelines, both hand and heavy equipment, will be located as to take advantage of natural fuel breaks and to minimize erosion potential and other adverse environmental impacts. Aircraft delivered fire retardants may be used within any FMU.

All fires not suppressed will be monitored until the fire has been out for 24 hours. Fire monitoring will consist of the following activities: 1) The collection of fire behavior and weather data at 4 regular periods (0600, 1000, 1400 and 1800 hours). 2) Spot fire-weather forecasts will be attained from the National Weather Service following each data collection period. 3) Estimates of future fire behavior and fire size will be developed through the use of PC/BEHAVE predictive models. 4) Activity will be coordinated daily with BLM and USFS in the event that additional fire suppression crews are required. After the fire is declared extinguished, a report will be prepared by the Fire Management Officer which accurately maps extent of fire, summarizes weather and fire behavior and described anticipated effects of fire.

Table 12. Fire management responsibilities at Craters of the Moon National Monument.

Responsibility	Person responsibility
Prevention and Public Relations	Fire Management Officer and Chief Park Interpreter
Detection	All park employees coordinated coordinated through the Fire Management Officer
Dispatch	Fire Management Officer
Pre-attack Planning	Fire Management Committee
Step-up Planning	Fire Management Committee and Fire Management Officer
Initial Attack	Fire Management Committee, Fire Management Officer and Fire Boss 1 (Fire Boss 2 if 1 absent)
Escaped Fire Analysis	Fire Management Committee
Extended Attack	Fire Management Officer, Fire Boss 1 and Fire Boss 2
Rehabilitation	Fire Management Officer and Fire Management Committee

Table 13. Important contacts relating to fire management at CRMO.¹

Person/Facility	Agency	Phone Number
_____, FMO	BLM - Idaho Falls District	_____
_____	BIFC (Boise)	_____
_____, FMO	BLM - Shoshone District	_____
_____, FMO	USFS - Sawtooth Nat'l For	_____
_____	Private Land Owner	_____
_____	Private Land Owner	_____
_____	Sun Valley Hospital	_____
_____	Arco Fire Department	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

¹ This table needs to be completed by CRMO personnel and updated annually prior to the beginning of the fire season (May 1).

Table 14. Procedure for decision analysis for natural fire occurrence at Craters of the Moon National Monument.

Initial actions in the event of any fire:

4. Fire is located in NATURAL ENVIRONMENT or
DEVELOPMENT ZONE Yes > C4a
No > C5
- a. Suppress fire as quickly as possible > E
5. Fire is located in OUTSTANDING NATURAL FEATURE or
WILDERNESS ZONE Yes > C5a
- a. Suppress fire with minimum site disturbance and
environmental damage. > E
- D - Monitor fire behavior > D1
1. Predicted fire behavior exceeds acceptable limits
(Flame length is greater than 2.5 m (8.2 ft) or
fireline intensity is greater than 400 Kcal/m/s
(500 Btu/ft/s).) Yes >
No > D2
2. Fire continues to burn through next monitoring
period (4 hrs). Yes > D2a
No > E
- a. Request spot fire weather forecast for next
monitoring period. > D
- E - Fire is declared out. Prepare post-burn report.

PROCESS OF DEVELOPING PRESCRIBED FIRE PROGRAMS

Information in this section conforms to NPS-13 guidelines chapter 18. More in depth information on prescribed fire and associated policies can be found in that publication.

Fires can be of 2 types, wildfire and prescribed fire. All fires caused by human factors are considered to be wildfires and will be suppressed. Prescribed fires may be one of two types, natural ignition and planned ignition. Natural ignition prescribed fires primarily include those caused by lightning. These fires will be not suppressed if they occur Wilderness Zone except in those conditions specified (Fig. 1). Natural ignitions within the Outstanding Natural Environment Zone (Fig. 1) will not be suppressed if they occur within specified fire behavior conditions. There exist sufficient fuel breaks within these zones to limit the size of burns and prevent the spread to adjacent fire management zones or off CRMO onto adjacent lands. All fires that exceed the specified conditions are classified as wildfires and will be suppressed.

Planned ignition prescribed fires are intentionally ignited in specified areas under specified conditions. Each fire must have identified objectives. However, the objectives of prescribed burn will vary depending on location at CRMO. One or more of the overall objectives listed in NPS-18 will apply. These objectives include the following:

- Restoration or perpetuation of a historic scene or setting
- Re-establishing natural processes related to or dependent upon fire
- Reduction of hazard fuels
- Re-establishing wildland fuel loadings to natural levels
- Open field maintenance
- Control of exotic plant species

Actual objectives for a burn must be more specific than these, however.

Prescribed Burning (Planned ignitions)

An orderly planning process must take place so that the above objectives can be achieved. This planning process will be initiated by the Natural Resource Specialist through the Fire Management Committee. In most cases the planning process should be started at least one year in advance of ignition date and follow the recommended timetable (Table 15) (Bunting et al. 1987). Each activity should be assigned to specific individuals to ensure that each is accomplished in a timely manner. More complete information on planning prescribed burns relative to specific objectives can be found in Fischer (1978), Martin and Dell (1978), Gruell et al. (1986) and Bunting et al. (1987).

Table 15. Suggested timetable and checklist for planning prescribed burning.

Activity	Date to be completed
Develop burn plan including specific quantifiable objectives	One year prior to burn
Sample monitoring plots	Growing season prior to fire
Install RAWS unit in field	
Reserve fire equipment, firing and holding crews	
Secure burning permit	Ten days prior to burn
Weather and fuel moisture monitoring	Regularly, beginning 10 days prior to fire or as conditions require
Prepare firelines	End of growing season prior to fire or immediately before fire
Inspect fire lines	Post fireline preparation
Inspect fire equipment and water sources to be used in fire	Ten days prior to burn
Determine firing and holding burn pattern	Day prior to burn
Review burn plan with all personnel	Day of burn
Notify local fire departments	Day of burn
Monitor weather	Hourly on day of burn
Sample vegetation and other monitoring plots	Yearly as required
Evaluate burn relative to fire behavior	Immediately following fire
Evaluate burn relative to achievement of specific objectives	Periodically post-burn as necessary

(Adapted from Bunting et al. 1987)

The actual prescribed burn plan is composed of four major components (NPS-18). First, specific objectives are identified, then the fire prescription and burning plan are designed to safely accomplish desired effects. Required documentation and monitoring plans are also included.

Objectives and Treatment Area

A short general discussion of the specific objectives of the fire. This discussion would be headed by a general objective such as to conduct a burn in the vicinity of the Group Campground in order to reduce hazardous fuel loads. More specific objectives should also be listed. Also included are data on size of burn needed, location, elevation, landforms, soil types (if known), vegetation community types, fuel types and loadings, expected weather status, threatened species (unlikely at CRMO), cultural features (minimal at CRMO), and any critical sites. General land management objectives should also be noted for the site. One objective for the Group Campground area might be to enhance deer forage values and at the same time increasing visitor satisfaction through wildlife observation. Any constraints of the use of fire, such as environmental, economic, operational, administrative or legal, must be identified.

The more specific objectives of the burn should also be listed. For example, 10 and 100 hour-time-lag fuel loads near the Group Campground area must be reduced by 75% in order to reduce hazardous fuel loads and reduce fuels to within expected natural amounts. Another specific objective might be to increase the cover of bluebunch wheatgrass by 10%. Bunting et al. (1987) and Gruell et al. (1986) have discussed development of prescribed burning objectives in order to allow successful evaluation and monitoring.

Fire Prescription

Using the above objective of reducing fuel loads, a more detailed framework is developed. Fire behavior and the environmental factors associated with it will dictate what changes will take place in the community. So, in order to achieve an objective such as reducing fuel loads by 75% and enhancing deer habitat, fire behavior must be predicted as close as possible. In order to make this prediction several environmental factors must be quantified. Components of this prediction include the following:

- fuel moisture content
- wind speed and direction
- temperature
- soil moisture
- relative humidity
- season of the year
- plant moisture content
- topography (slope and aspect)

Changes in one factor may be compensated by changes in another so more than one combination may result in the same predicted fire behavior.

Fire behavior is contingent on the interaction of these components and their fluctuation during the burning interval. Rate-of-spread, fire intensity, and flame length will determine, to a large extent, the effects of the burn on the plant community. For example, a hot, slow-moving fire in late spring will have a much different effect than a fast-moving fire in mid spring. Fire behavior can be predicted through the use of existing models (Albini 1976, Brown 1982, Rothermel 1983). While these models were specifically designed to predict the behavior of wildfires, they can also be useful in developing burning prescriptions. The outputs may have to be adjusted to successfully predict prescribed fire behavior.

A detailed preburn plan must also be a part of the prescription. Preburn activities such as fireline construction, ignition techniques, ignition pattern must be outlined and approved before ignition.

Direct monitoring of the fire behavior yields some predictive capability on how the plant community will respond. Portable weather kits including 10-HTL fuel sticks and scale are needed to document on site environmental fluctuations. These data are important in adjusting fire behavior models to more accurately predict behavior in the future. The US Weather Bureau Fire Weather Forecasting Center in Boise, Idaho is the primary source of information on weather fronts or other environmental changes. Spot weather forecasts should be received prior to ignition on all prescribed fires.

The Burning Plan

In order for the burn to progress smoothly, a plan of exactly how the burn will take place is important. Each task must be outlined along with who will do it, when it will be done, where it will be done and what equipment will be needed to accomplish each task. These tasks include preburn tasks, ignition, monitoring and holding actions, and evaluation of the burn.

Documentation and Reporting

Adequate monitoring must also be a component of the plan. A standard procedure to evaluate prescribed burns is outlined in Fischer (1978). Attributes of the community should be sampled prior to ignition to allow monitoring of objectives. Plant community measurements such as shrub cover, herbaceous production and down woody material are often included. Generally only those components which are related to evaluation of the burn should be sampled. These same components should be quantified post-burn. A discussion of monitoring methodology can be found in Bunting et al. (1987). These procedures are critical to understanding

whether the objectives for the burn were realized.

Simply, this section deals with determining if the burn meets its original objectives. Both long- and short-term methods can be used to evaluate success or failure. The effected plant communities should be monitored for several years.

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Appendix 1. List of species (scientific and common names)
used in the text.

Scientific Name	Common name
<u>Agastache urticifolia</u>	Nettle-leaf horsemint
<u>Agropyron spicatum</u>	bluebunch wheatgrass
<u>Agropyron trachycaulum</u>	slender wheatgrass
<u>Allium simillimum</u>	dwarf onion
<u>Alnus incana</u>	mountain alder
<u>Amelanchier alnifolia</u>	Saskatoon serviceberry
<u>Angelica pinnata</u>	small-leaf angelica
<u>Antennaria stenophyllus</u>	narrow-leaf pussy-toes
<u>Aquilegia formosa</u>	Sitka columbine
<u>Arabis holboellii</u>	Holboell rockcress
<u>Artemisia arbuscula</u>	low sagebrush
<u>A. longiloba</u>	early low sagebrush
<u>A. tridentata</u>	
ssp. <u>tridentata</u>	big sagebrush
<u>A. tridentata</u>	
ssp. <u>vaseyana</u>	mountain big sagebrush
<u>A. tripartita</u>	three-tip sagebrush
<u>A. tripartita</u>	
var. <u>rupicola</u>	
<u>Aster canescens</u>	hoary aster
<u>Balsamorhiza sagittata</u>	arrowleaf balsamroot
<u>Betula glandulosa</u>	bog birch
<u>Bromus tectorum</u>	cheatgrass
<u>Calamagrotis koeleriodes</u>	fire reedgrass
<u>Calyptidium roseum</u>	rosy calyptidium
<u>Capsella bursa-pastoris</u>	shepherd's purse
<u>Castilleja miniata</u>	scarlet painted-cup
<u>Ceanothus velutinus</u>	sticky laurel
<u>Chaenactis douglasii</u>	Douglas chaenactis
<u>Chamaebatiaria millefolium</u>	tansybush
<u>Chrysothamnus nauseosus</u>	rubber rabbitbrush
<u>C. viscidiflorus</u>	green rabbitbrush
<u>Cirsium</u> spp.	thistle
<u>Crepis acuminata</u>	taper-tip hawksbeard
<u>Cryptantha interrupta</u>	bristly cryptantha
<u>Cymopterus terebinthinus</u>	desert parsley
<u>Ceanothus velutinus</u>	snowbrush
<u>Delphinium andersonii</u>	Anderson larkspur
<u>Elymus cinereus</u>	great basin wildrye
<u>Erigeron compositus</u>	fernleaf fleabane
<u>Eriogonum caespitosum</u> mat	erogonum
<u>E. heracleoides</u>	Wyeth eriogonum
<u>E. microthecum</u>	slenderbrush eriogonum
<u>E. ovalifolium</u>	
var. <u>depressum</u>	dwarf buckwheat
<u>E. umbellatum</u>	sulfur buckwheat
<u>Festuca idahoensis</u>	Idaho fescue
<u>Gayophytum decipiens</u>	deceptive groundsmoke
<u>Geranium viscosissimum</u>	sticky purple geranium

<u>Haplopappus nanus</u>	dwarf goldenweed
<u>H. acaulis</u>	stemless goldenweed
<u>Helianthella uniflora</u>	oneflower helianthella
<u>Heracleum lanatum</u>	cow parsnip
<u>Holodiscus spp.</u>	ocean spray
<u>Koeleria nitida</u>	prairie junegrass
<u>Lappula redowskii</u>	western stickseed
<u>Leptodactylon pungens</u>	lava phlox
<u>Leucopoa kingii</u>	spikegrass
<u>Lewisia rediviva</u>	bitterroot <i>Lewisia</i>
<u>Lithospermum ruderale</u>	stoneseed
<u>Lupinus argenteus</u>	silvery lupine
<u>Lygodesmia spinosa</u>	thorn skeleton plant
<u>Melica bulbosa</u>	onion grass
<u>Mentzelia albicaulis</u>	whitestem mentzelia
<u>Mertensia ciliata</u>	broadleaf bluebell
<u>Mimulus nanus</u>	dwarf monkeyflower
<u>M. suksdorfii</u>	Suksdorf's mimulus
<u>Oryzopsis hymenoides</u>	Indian ricegrass
<u>Oxytropis lagopus</u>	rabbit-food crazyweed
<u>Penstemon deustus</u>	scabland penstemon
<u>Phacelia hastata</u>	silverleaf phacelia
<u>Philadelphus lewisii</u>	mockorange
<u>Phlox hoodii</u>	Hood's phlox
<u>Pinus flexilis</u>	limber pine
<u>Poa pratensis</u>	Kentucky bluegrass
<u>P. sandbergii</u>	Sandberg bluegrass
<u>Populus tremuloides</u>	quaking aspen
<u>P. trichocarpa</u>	black cottonwood
<u>Potentilla glandulosa</u>	sticky cinquefoil
<u>Prunus virginiana</u>	common chokecherry
<u>Pseudotsuga menziesii</u>	Douglas-fir
<u>Purshia tridentata</u>	antelope bitterbrush
<u>Ribes cereum</u>	wax current
<u>Rudbeckia occidentalis</u>	blackhead coneflower
<u>Salix spp.</u>	willow
<u>Sedum stenopetalum</u>	stonecrop
<u>Sitanion hystrix</u>	squirrel tail
<u>Stephanomeria tenuifolia</u>	narrowlved. skeletonweed
<u>Stipa occidentalis</u>	
var. <u>nelsonii</u>	Nelson's needlegrass
<u>S. comata</u>	needle-and-thread
<u>S. thurberiana</u>	Thurber needlegrass
<u>X Stiporyzopsis bloomeri</u>	
<u>Symphoricarpos oreophilus</u>	mountain snowberry
<u>Tetradymia canescens</u>	gray horsebrush
<u>Urtica dioica</u>	bigsting nettle
<u>Valeriana acutiloba</u>	sharpleaf valerian
