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THE ROLE OF FIRE IN LAND-USE MANAGEMENT

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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GLOSSARY

Antinomycetes - filamentous and rod-shaped bacteria of the order

Actinomycetales, which occur as soil-inhabiting saprophytes or disease-producing parasites.

Ambient - surrounding; existing.

Atmospheric stagnation index - an index primarily designed to indentify nights when burning can be conducted safely. It represents a weighted value which considers the mean windspeed, vertical wind velocity, relative humidity, and washout effect of precipitation. The index is on the scale from 0 - 15 (the higher the number, the greater the atmospheric stagnation), with:

0 - 6 nighttime burning permitted

7 - 8 marginal

9 - 15 nighttime burning not permitted.

Broadcast burn - a fire which encompasses a large area; usually an intense burn with a broad advancing front.

Firebrands - smoldering pieces of bark, leaves, branches, etc., which may be carried by heat induced updrafts from burning vegetation to nonburned areas, initiating spot fires.

Mineralization - the conversion of complex compounds into simpler mineral or inorganic form.

Mycorrhiza - a mutual beneficial association in which the mycelium of a fungus invades the root tissue of a seed plant.

Nitrification - the oxidation (addition of oxygen) of ammonium salts (NH4) to nitrites (NO2) and the oxidation of nitrites to nitrates (NO3) by certain bacteria.

Nitrogen fixation - the uptake and assimilation of atmospheric nitrogen by bacteria and algae.

Perennating buds - buds which live over from season to season, persisting for several years giving rise to new herbaceous growth annually; meristems present at all seasons of the year.

Phenology - a branch of science dealing with the relationship between climate and periodic biological phenomena (e.g., flowering in plants).

Photochemical smog - chemical pollutants in the atmosphere resulting from chemical reactions involving hydrocarbons and nitrogen oxides in the presence of sunlight.

Saprophytic - living (feeding) on decaying organic matter.

Shreded line - firebreak cut in vegetation using mowing equipment which chops the vegetation into small pieces.

Sprinkler wetline - firebreak created in vegetation by wetting the vegetation, using a hand operated or vehicular sprinkler system.

Threshold - the maximum level of some input quantity needed for some process to take place.

Vigor - asexual or vegetative plant growth (reproduction).

Vitality - sexual plant reproduction (e.g., flowering).

ABSTRACT

A review of the fire ecology literature is presented, specifically addressing the environmental impacts of fire, and the application of prescribed burning as a land management practice. Guidelines for the application of the prescribed fire to pertinent vegetation and/or fuel types are summarized, including environmental conditions, ignition techniques, and containment precautions. It is concluded that the St. Johns River Water Management District's comprehensive land management program should include provisions for prescribed burning, in order to protect and maintain the properties under its jurisdiction in an environmentally acceptable manner. It is further concluded that District properties should be inventoried to establish land management units and determine the status of existing plant communities. Areas in which fire is to be excluded should be identified and procedures established for their protection.

INTRODUCTION

BACKGROUND

The exclusion of fire from North American ecosystems began during the late 1800's, and the philosophy that fire is harmful persists today (Wright and Bailey, 1982). Leopold, et al. (1963), made the first attempt to inform the public that protecting all plant communities from fire could be detrimental. They recognized fire as a natural force in most plant communities and discouraged total suppression. Since the mid-1960's, biologists and land managers have taken a more constructive view of fire. They have realized that to maintain or where necessary to restore natural ecosystems, the reintroduction of fire must be considered as a viable land management alternative.

Southeastern ecosystems, in particular, owe their existance to periodic fires over eons of time (Komarek, 1974; Wade, et al, 1980). It is evident that fire was a dominant environmental factor, which determined to a large degree, the structure and diversity that provided stability in those early ecosystems (Vogl, 1971). Exactly how much fire was "natural" is not know, but the active exclusion of fire can be detrimental to these ecosystems.

The ultimate decision of whether fire is warranted as a management practice depends on the overall management objectives. The St. Johns River Water Management District, as a trustee of public owned lands, has been charged by the Florida Legislature with the responsible management of all lands under its jurisdiction. Specifically, all District properties are to be managed and maintained in an environmentally acceptable manner, and to the extent practicable, in such a way as to restore and protect their natural state and condition (Sec. 373.59, F.S.). Clearly, the District must begin to consider the alternatives regarding fire as a key, natural, environmental factor.

OBJECTIVES AND SCOPE

The objectives of this study were to review the scientific literature pertaining to controlled burning as a land management practice and (1) outline the effects of fire on ecosystem structure and function; (2) define the advantages and disadvantages of using prescribed burning as a land management practice; and (3) identify guidelines for applying prescription burning to District owned properties.

It is the intent that the summary and recommendations presented here will assist the District's policy makers in an effective and environmentally sound land management program.

PRESCRIPTION BURNING AS A LAND MANAGEMENT TOOL

DEFINITION

Prescribed burning is defined as the skillful application of fire to a predetermined area in a manner which will accomplish certain planned benefits. Weather, fuel moisture, soil moisture, etc., are factors which must be considered to produce the required intensity of heat and rate of spread. Prescribed burning is commonly utilized for silviculture, wildlife habitat management, forage management, fire hazard reduction, etc. (Society of American Foresters, 1958). Prescribed burning is both a science and an art requiring knowledge of weather, fire behavior, fuels and plant ecology, and experience to achieve planned objectives safely and effectively (Wright and Bailey, 1982).

GENERAL CONSIDERATIONS

Prescriptions for burning many vegetation types have been developed and are useful in the planning phase of a burn (Wade, et al., 1980; Wright and Bailey, 1982). However, no guideline is universal, even for the same general vegetation type. It is the responsibility of the fire manager to establish the proper burning technique for the vegetation type, conditions, and objectives at hand.

Safety is the number one concern, and fire managers must evaluate all variables that may influence fire behavior (i.e., wind speed, relative humidity, fuel loading, fuel and soil moisture, and temperature, etc.) before making the decision to burn. In unfamiliar vegetation and/or terrain, the burning of a few test plots to establish fire behavior is warranted. Adequate fire fighting equipment should be on standby in the event that the fire becomes unmanageable.

The secret to successful prescribed burning is to let the weather work for you. When all of the environmental factors are right, the job is handled safely and effectively (Wright and Bailey, 1982).

Weather Requirements

Wind Velocity

Wind speed affects the rate of fuel consumption by influencing the rate of oxygen supply (Davis, 1959) and the rate of fire spread (Countryman, 1976; 1978). A wide range of wind speeds have been applied to burning, and generally some wind is preferred. The threshold value for igniting and burning stands of debris is 13 km/h (8 mph) (Britton and Wright, 1971). The preferred range for burning most volatile fuels is 13 to 24 km/h (8 to 15 mph) (Wright, 1974).

Ambient Temperature

Ambient temperature plays a critical role in fire behavior. Bunting and Wright (1974) found that the distance of spot fires from prescribed fires is a function of air temperature (Figure 1). Danger from firebrands (spotfire ignition) is low at ambient temperatures below 15°C (60°F) but increases exponentially if temperatures are above 15°C (60°F).

Generally, a temperature of 27°C (80°F) is considered the upper limit for safe burning of volatile fuels, unless the relative humidity is greater than 40% and the wind speed is less than 16 km/h (10 mph) (Wright and Bailey, 1982).

Relative Humidity

Britton and Wright (1971) suggest that a relative humidity (RH) of 40% is a threshold level. Between 20 and 40% RH, fires burn easily and with nearly the same intensity. When the RH exceeds 40%, the rate of fire spread is slowed con-

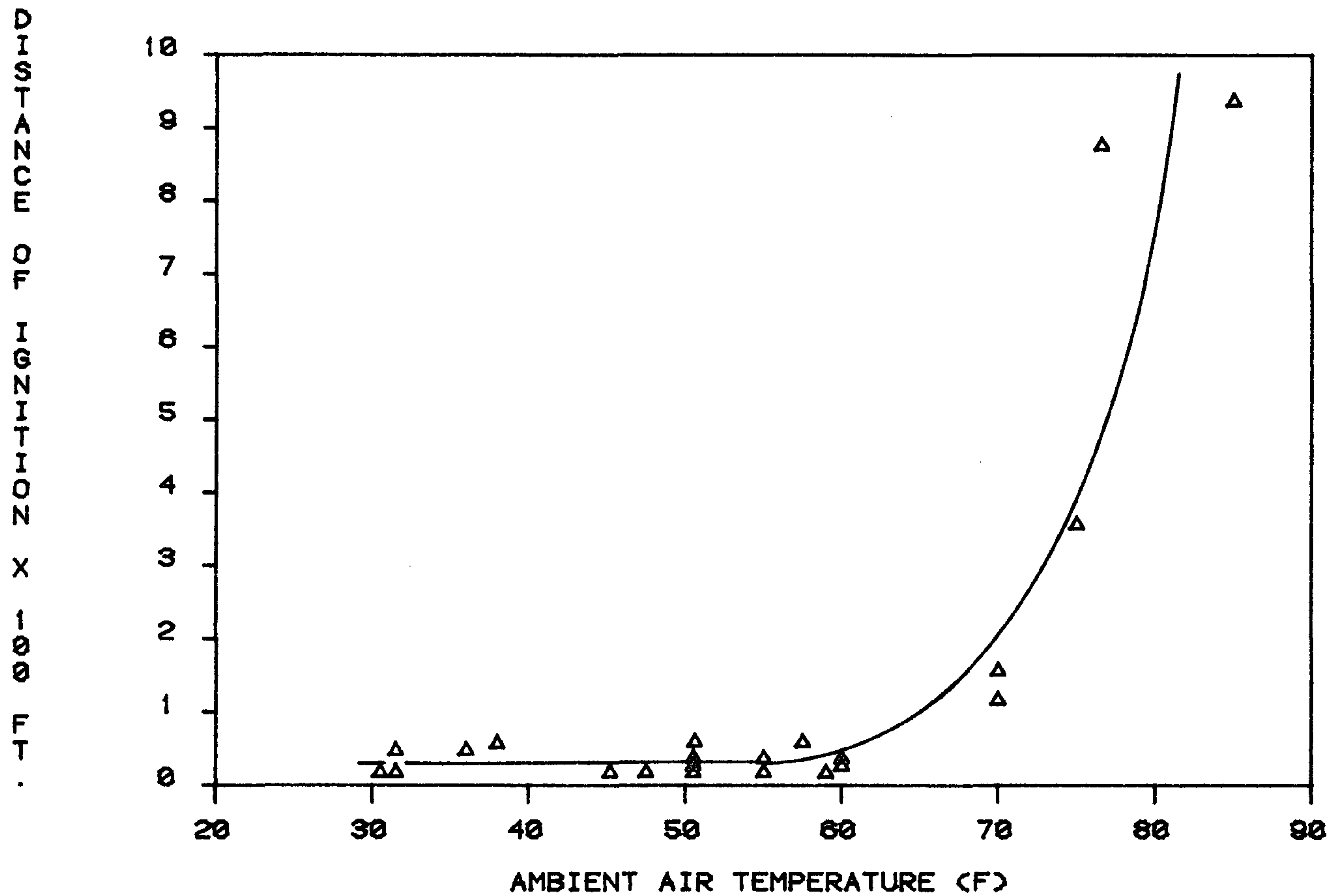


FIGURE 1. The maximum distance of spot fires from prescribed fires in relation to air temperature. Spot fires that started when temperatures were below 16°C (60°F) were caused primarily by flaming firebrands (after Bunting and Wright, 1974).

siderably (Lindenmuth and Davis, 1973), standing woody materials are difficult to ignite (Britton and Wright, 1971), and damage from firebrands is minimum (Green, 1977). If the RH is below 20%, fires are intense and increase the danger of firebrands igniting adjacent or down wind areas. Wright and Bailey (1982) suggest that burning should not be conducted when the RH is below 25%, unless the wind is less than 10 km/h (6 mph) and ambient temperature does not exceed 4°C (40°F). When RH is greater than 60%, fires burn very spottily unless the fuel bed is at least 10 cm (4 in) deep and dry (Wright and Bailey, 1982).

Fuel Volatility and Loading

Vegetation is classified as one of two basic fuel types: low-volatile or high-volatile. Low volatile fuels are grasses and hardwoods that are relatively safe to burn. High-volatile fuels are conifers, wax myrtle, chaparral, and palmettos. These fuels contain extractives such as waxes, oils, terpenes, and fats, which can cause the vegetation to burn explosively.

Fuel loading is quite variable between and among vegetation types, and generalizations describing fuel loads are just that. In low-volatile fuels (grasslands), an accumulation of 670-1120 kg/ha (600 to 1000 lb/acre) of fine fuels is necessary to conduct prescribed burns (Beardall and Sylvester, 1976). Fuel loadings of 15 to 200 metric ton/ha (5.5 to 74 ton/acre) are not uncommon in moderately- to highly- violatile vegetation types (Swanson, 1976; Sackett, 1979).

Adequate prediction of fuel loading and potential burning characteristics are essential for the burn to be conducted safely.

Establishment of Firebreaks

The width of firebreaks and the techniques for establishing them vary depending upon the type of fire and fuels. Firebreak widths of 2 to 6m (5 to 20 ft) are adequate to control fires in southeastern pine communities, slash, and litter in grasslands. However, in moderately- to highly- volatile fuel types (e.g., sagebrush-grass or chaparral communities), 75 to 150 m (250 to 500 ft) firelines are desirable (Wright and Bailey, 1982).

Conventionally, firelines have been dozed, plowed, or disked because these techniques are applicable to various terrains and vegetation patterns. More attention should be given to techniques of fireline preparation that minimize soil disturbance (Wright and Bailey, 1982). Sprinkler wetline systems have been successfully applied in grasslands (Dube, 1977) and broadcast burns in lodgepole pine slash (Quintilio, 1972). Shredded lines have proven useful in tallgrass prairies where vegetation is wet at the time of burning (Wright and Bailey, 1982), and airboat trails have been used to contain fires in wetlands (Wade, et al., 1980).

Smoke Management

Land managers are required by law and policy to limit the emission of air pollutants from prescribed fire and to reduce their impact on society (Appendix A). Managers must be able to predict the volume of smoke produced and where it will travel. Air quality impairment from prescribed burning must be minimized in accordance with the Clean Air Act (PL 88-206) and ambient air quality standards (Appendix B).

In order to minimize the environmental impact of emissions from prescribed burning, it is suggested that fire managers adhere to the following guidelines (Southern Forest Fire Laboratory Staff, 1976; Wright and Bailey, 1982):

a. Comply with all local and national pollution control guidelines.

b. Follow the U.S. Forest Service voluntary decision procedure for forestry smoke management (Southern Forest Fire Laboratory Staff, 1976). This step-by-step, decision-logic framework can predict the impact of smoke to the immediate airshed, and how it will affect visibility at any point downwind.

c. Conduct all burns after the morning inversion layer has broken and before the evening inversion forms, when the mixing depth and wind is most favorable for smoke dispersal (Nikleva, 1972).

d. Burn when conditions for wind dispersal of smoke are optimum, and the wind direction will carry smoke away from population centers.

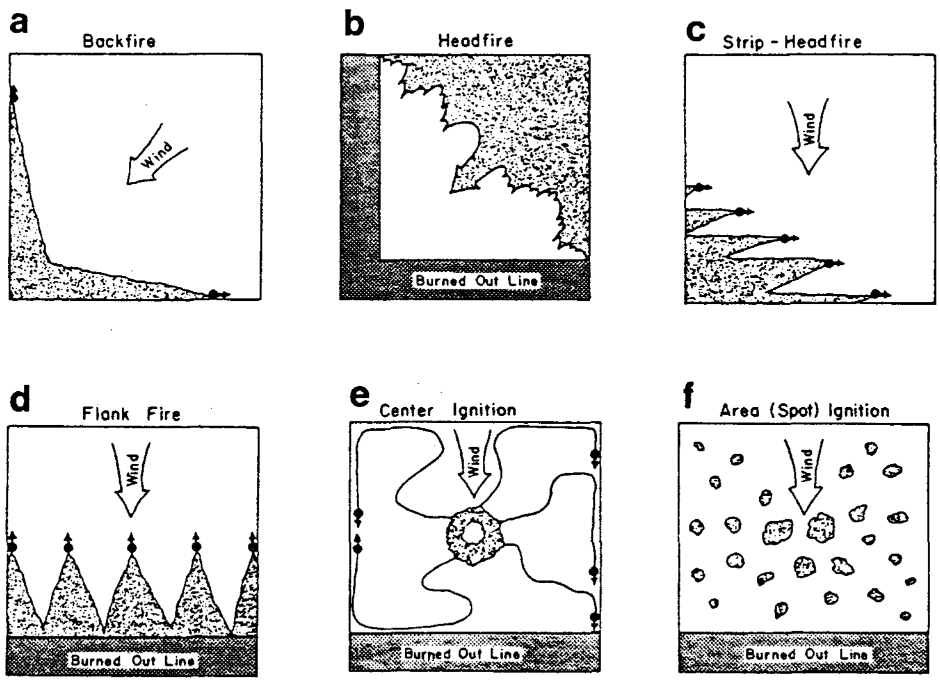
e. Conduct burns in as short a time as possible to reduce the duration of smoke problems.

Ignition Techniques

The most commonly used ignition techniques are outlined in Figure (2). These techniques are thoroughly discussed by Davis (1959), Sando and Dobbs (1970), and Mobley, et al. (1978).

Headfires (Figures 2,b) are fires that move with the prevailing wind and the flames tilt in the direction of spread. They are most effective for killing shrubs and trees (Fahnestock and Hare, 1964); achieving an effective burndown of standing trees (Britton and Wright, 1971); and successfully burning low quanti-

FIGURE 2. Firing techniques used for prescribed burning (from Wright and Bailey, 1982).



ties of fine-fuels [670 to 1125 kg/ha (600 to 1000 lb/acre)] (Heirman and Wright, 1973).

Backfires (Figure 2,a) are fires spreading against the wind, with flames tilting away from the direction of spread. These fires are most useful when fuel exceeds 2000 kg/ha (1178 lb/acre) and one wishes to maintain good control when conditions (weather and/or fuel) are not optimum. Backfires reduce heat damage to overstory vegetation (Biswell, et al., 1973). However, they are generally more destructive than headfires to understory vegetation, because they create higher temperatures for longer periods near the soil surface where seeds and perennating buds are located (Daubenmire, 1968).

Strip-headfires and flank fires (Figure 2, c,d) are most useful to control fire intensity. They are used when backfires move too slowly and headfires would be too dangerous.

Area ignition (Figure 2,f) sets the entire area on fire at once, causing the fire to move toward the center. Center ignition (Figure 2,e) is similar to area ignition although the center is lit first and the intensity is lower. Both of these fire types result in very intense burns and are most useful for slash burning, in clear-cut areas with no overstory. They are not recommended for general burning in forests and grasslands.

GUIDELINES FOR PRESCRIPTION BURNING

Low Volatile Fuel Types

a. Freshwater marsh and wet meadows (maidencane, sawgrass, beak and spike rush, arrowhead, pickerelweed, etc.)

Conditions:

Air Temperature: 4 - 24°C (40-75° F) (Wright and Bailey, 1982)

Relative Humidity: 30 - 50% (Zipprer, 1977; Wright and Bailey, 1982)

Atmospheric Stagnation Index: <9 (Maynard, 1976)

Soil Moisture: 65% ovendry weight (Wade, et al., 1980) or with 7.5 - 15 cm (3 - 6 in) of standing water on a falling water table (Zipprer, 1977, Eichholz, 1981).

Winds: 16 - 32 km/h (10 - 20 mph) from a direction which will carry smoke away from population centers (Zipprer, 1977; Wright and Bailey, 1982).

Season: December - March, winter dormant season (Givens, 1962; Craighead, 1971; Bancroft, 1977; Holland, 1982[1]; Wright and Bailey, 1982).

Interval: 3 - 5 years (Zipprer, 1977; Schroer, 1979; de la Cruz and Hackney, 1980).

Ignition Technique: Headfires or spotfires (Wade, et al., 1980); alternate burned and non-burned vegetation patches (Schroer, 1979; Hackney and de la Cruz, 1981).

Containment Precautions: Containment should not be a problem because any area of sparse fuels more than a few feet wide

[1] Holland, D. 1982. Personal Communication. Chincoteague National Wildlife Refuge, Chincoteague, VA.

should stop prescribed fire. Artificial fire breaks should be established where necessary by backfiring or if conditions are appropriate, airboat trails.

b. Forage Lands - Improved Pasture (Bahia grass, sand cordgrass, etc.)

Conditions:

<u>Air Temperature</u>: 4 - 24°C (40 - 75°F) (Wright, 1974; Wright and Bailey, 1982).

<u>Relative Humidity</u>: 30 - 50% (Wright, 1974)

<u>Atmospheric Stagnation Index</u>: <9 (Maynard, 1976)

<u>Soil Moisture</u>: within 24 hr of a rain which delivered 1.2 to 2.5 cm (0.5 to 1.0 in) (Wright, 1974; Kayll, 1979).

<u>Winds</u>: 12 - 24 km/h (8-15 mph) from a direction which will carry smoke away from population centers (Wright, 1974).

<u>Season</u>: Conduct burns when the preferred plants are dormant (Wright, 1974; Kayll, 1979); November-May (Hughes, 1975); end of dry season.

Interval: 1 - 3 years (Halls, et al., 1952; Anderson, et al., 1970)

Ignition Technique: headfires, strip-headfires, or flank fire (Wright and Bailey, 1982).

Containment: Establish boundaries to enclose the area to be burned using natural firebreaks and backfires.

<u>Moderate - to high - volatile fuel types</u>

a. Pine flatwoods (pine, saw palmetto, cabbage palm, etc.)

Conditions:

<u>Air Temperature</u>: -7°C to 10°C (20° to 50°F) (Dixon, 1965; Sackett, 1975; Mobley, et al., 1978)

Relative Humidity: 30 - 50% (Mobley, et al., 1978)

Atmospheric Stagnation Index: <9 (Maynard, 1976)

Soil/Litter moisture: Moisture content of upper litter 20 - 25% (Sackett, 1975); burn rough 24 to 48 hr. after the passage of a cold front which delivered 1.2 to 2.5 cm (0.5 to 1.0 in) of rain; duff moisture content 30 to 40% (Wright and Bailey, 1982).

Winds: 8 to 29 km/h (5 - 18 mph) within stand (Dixon, 1965; Sackett, 1975; Mobley, et al., 1978).

Season: Winter dormant season, December - March (Wade, etal., 1980; Wright and Bailey, 1982).

Interval: 2 - 5 years (Komarek, 1963; Stoddard, 1963; Sackett, 1975; Wright and Bailey, 1982).

Ignition Technique: Dictated by fuel quantity and quality.

Containment: Adequate firebreaks should be established to insure fire control; firelines should be established using methods which minimize soil disturbance; divide the proposed burn site into smaller more manageable parcels.

b. Mixed-hardwood swamp, cypress forests, and tree islands.

It is not recommended that fire be artificially introduced into these habitats (Wade, et al., 1980).

DISCUSSION OF THE ENVIRONMENTAL IMPACTS OF FIRE

ABIOTIC EFFECTS

Fire and Air Quality

A recent nationwide emission inventory made by the National Air Pollution Control Administration indicated that natural fires (prescribed and wildfires) contributed about 8% of the total annual load of pollutants to the atmosphere. Of the total pollutant load from all sources, natural fires produced approximately 24% of the total particulates, 7% of the total carbon monoxide, 7% of the total hydrocarbons, and 6% of the nitrogen oxides[2].

The range of emission for the major components of forest fire smoke and their potential environmental effects are summarized in Table 1. Water vapor and carbon dioxide comprise approximately 90% of the mass of the combustion products emitted from fire. The other 10% include virtually all of the smoke and potential problem compounds, i.e., hydrocarbons, particulates, and oxides of nitrogen and sulfur (Southern Forest Fire Laboratory Personnel, 1976).

Air-borne particulates are probably the most important single category of emissions from fire, although they are also short-lived (Dieterich, 1971). Particulates are the major cause of reduced visibility and serve as sorbtion surfaces for harmful gases. They are also a major cause of aggravated respiratory conditions in susceptible individuals, especially when in combination with sulfur oxides (Sandberg, et al., 1979).

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2 Public Health Service Consumer Protection Environmental Health Service 1970. Nationwide inventory of air pollutant emissions, 1968. National Air Pollutant Control Administration, Pub. AP-73, 63 pgs.

TABLE 1. Range of emission factors for components of forest fire smoke, with effect potentials (from Southern Forest Fire Laboratory Personnel, 1976).

Components	Range of emission factors (pounds produced per ton of fuel consumed)	Effect potentials
Carbon dioxide	1/ 2,000-3,500	No direct
Water vapor	500-1,500	Visibility
Carbon monoxide	20-500	Health
Total suspended particulate matter	20-180	Visibility & health
Total hydrocarbons	10-40	Visibility & health 2/
Other organics	Unknown	Visibility & health 2/
Nitrogen oxides	1-9	Visibility & health 2/
Sulfur oxides	Negligible 3/	Health

1/ Values higher than 1 ton occur because of the chemical combination of carbonaceous constituents with oxygen in air to produce carbon dioxide.
2/ Includes effects from secondary photochemical products.
3/ A possible exception in the high-sulfur peat or "muck" soils.

Hydrocarbons are another primary combustion product, but few if any appear in the combustion of wood products that are important in the development of photochemical smog (Fritchen, et al., 1970).

Sulfur oxides are probably produced in negligible quantities because most natural fuels contain less than 0.2% sulfur. Notable exceptions are certain organic soils in Florida of marsh origin which have a sulfur content of about 4% (Southern Forest Fire Laboratory Personnel, 1976).

Information on nitrogen oxide emissions from natural fires is scanty and inconclusive (Sandberg, et al., 1979).

Fires may also affect local climate (microclimate). Smoke may locally place too many condensation nuclei into the atmosphere, preventing precipitation. Removal of vegetation permits greater wind velocities closer to the ground, increasing erosion of exposed soils. Solar heating of burned soils may increase instability in the atmosphere, promoting the formation of convection cells (Hofstetter, 1973).

Fire Effects on Water

Mass erosion, increased turbidity levels, sedimentation, and elevated nutrient concentrations appear to be the most serious threats to water resources following fire. Reduction in plant cover generally increases erosion (Table 2), and relatively small changes in vegetation cover can greatly influence the hydrologic performance of a catchment basin. Storm events over fire-disturbed basins can have a significant impact on downstream water quality and quantity. The consequences of increased overland flow and the resultant increase in peak discharge are obvious.

TABLE 2. Effects of Fire on Sediment Delivery (from Tiedemann, et al. 1979).

Authors	Habitat	Location	Treatment	Sediment transport Pre-treatment or control	Post-treatment
					$kg \cdot ha^{-1} \cdot yr^{-1}$
DeByle and Packer (1972)	Western larch, Douglas-fir	Western Montana	Clearcut, slash burned	0[1] 0[2]	168 150
Glendening et al. (1961)	Chapparral	Central Arizona	Wildfire	175	204,000
Wright et al. (1976)	Oak-juniper steep slopes	Texas	Broadcast burn	.02	28
Biswell and Schultz (1965)	Ponderosa pine	California	Understory burn	0[3]	0
Copley et al. (1944)	Southern woodland	North Carolina	Prescribed burn	0	11,200
Meginnis (1935)	Oak-woodland	Mississippi	Harvest, Annual burning	45	740
Krammes (1960)	Chaparral	California	Wildfire	5530	55,300
Campbell et al. (1977)	Ponderosa pine	Northern Arizona	Wildfire	0-3	1-1254

[1]Snowmelt.
[2]Summer storms.
[3]No surface runoff and no erosion observed.

Fire effects on the concentration of nutrients in forest soil solution and surface runoff have received considerable attention. Nitrate-nitrogen (NO_3 - N) and cation enrichment of surface runoff and soil leachate were observed in the majority of the studies referenced (Table 3 - 6). Similar increases were observed for ammonium-nitrogen (NH^+_4 - N) (Fredriksen, 1971; Hoffman and Ferreira, 1976) and organic-nitrogen (O-N) (Hoffman and Ferreira, 1976; Tiedemann, et al., 1978).

Phosphorus (P) mobilization was generally less than that for NO_3 -N and most cations, because it complexes readily with organic compounds in the soil (Black, 1968). However, increases in total-phosphorus (T-P) have been reported for soil leachates after burning (Smith, 1970; Gifford, et al., 1976; McCall and Grigal, 1975), and Fredriksen (1971) and Wright (1976) observed 2 to 3 fold increases in P in surface runoff from forest soils.

Comparatively little data are available on the effects of fire on water chemistry in wetlands. Forthman (1973) followed changes in water chemistry after prescribed burning in a sawgrass marsh. Burning resulted in immediate statistically significant increases in phosphate-phosphorus (PO_4 -P) and potassium (K), while NO_3 -N increased only slightly. Concentration of all nutrients returned to preburn levels within 28 hours. Faulkner and de la Cruz (1982) observed enrichment of the sediment nutrient pool following fire in an irregularly flooded marsh. Total phosphorus (T-P) increased immediately and remained elevated for at least 68 days following fire. Phosphorus release from the sediments due to mild heating action appeared to contribute to the increased T-P levels.

TABLE 3. Effects of fire and selected treatments on maximum NO_3 -N concentration in streamflow (from Tiedemann, et al. 1979).

Author	Habitat	Location	Treatment	Maximum NO_3-N Pre-treatment or control	Maximum NO_3-N Post-treatment
					mg/liter
Brown et al. (1973)	Douglas-fir, Red alder	Western Oregon	Clearcut, slash burned	0.7	2.1
Fredriksen (1971)	Douglas-fir	Western Oregon	Clearcut, slash burned	0.1	.43
Likens et al.[1] (1970)	Eastern deciduous forest	Northern New Hampshire	Clearcut, herbicide treatment	2.5	82.0
Hibbert et al. (1974)	Chaparral	Central Arizona	Herbicide treatment	.2	56.0
Hetherington (1976)	Engleman spruce, Subalpine fir	Eastern B.C., Canada	Clearcut	.02	0.4
Johnson and Needham (1966)	White-fir, Ponderosa pine	Central California	Wildfire	.01	.01
Tiedemann et al. (1978)	Douglas-fir, Pinegrass	Eastern Washington	Wildfire	.02	.6
Tiedemann et al. (1978)	Douglas-fir, Pinegrass	Eastern Washington	Wildfire, nitrogen fertilization	.02	1.5
Hoffman and Ferreira (1976)	Mixed conifer shrub	Central Sierra Nevadas	Wildfire	.06	.3
Longstreth and Patten (1975)	Chaparral	Central Arizona	Wildfire 1959, maintained in grass cover	.1	2.0
Snyder et al. (1975)	Western white pine, Western red cedar	Northern Idaho	Clearcut burned	0.8	7.6

[1]Value expressed is for nitrate, not nitrate-N.

TABLE 4. Effects of fire and selected treatments on solution transport of nitrogen (from Tiedemann, et al. 1979).

Authors	Habitat	Location	Treatment	Solution transport of nitrogen: Pre-treatment or control	Solution transport of nitrogen: Post-treatment
				$kg \cdot ha^{-1} \cdot yr^{-1}$	
Brown et al. (1973)	Douglas-fir, Red alder	Western Oregon	Clearcut, slash burned	5.0	16.0
Fredriksen (1971)	Douglas-fir	Western Oregon	Clearcut, slash burned	.03	2.1
Likens et al. (1970)	Eastern deciduous forest	Northern New Hampshire	Clearcut, herbicide treated	3	147
Kimmins and Feller (1976)	Western Hemlock, Douglas-fir	Western B.C., Canada	Clearcut	+1.9	5.1
Tiedemann et al. (1978)	Douglas-fir, Pinegrass	Eastern Washington	Wildfire	< .01	3.0
Tiedemann et al. (1978)	Douglas-fir, Pinegrass	Eastern Washington	Wildfire, nitrogen fertilization	< .01	4.1

TABLE 5. Effects of fire and selected treatments on concentration of major cations (Ca, Mg, Na, and K) in streamflow (from Tiedemann, et al., 1979).

Authors	Habitat	Location	Treatment	Cation concentration	
				Pre-treatment or control	Post-treatment
				mg/liter	
Fredriksen (1971)	Douglas-fir	Western Oregon	Clearcut, slash burned	5.9	10.7
DeByle and Packer (1972)	Western larch, Douglas-fir	Western Montana	Clearcut, slash burned	218.0	130.0
Tiedemann et al. (1978)	Douglas-fir, pinegrass	Eastern Washington	Wildfire, nitrogen fertilization	13.0	9.0
Likens et al. (1970)	Eastern deciduous forest	Northern New Hampshire	Clearcut, herbicide treatment	3.2	13.6
Synder et al. (1975)	Western white pine, western red cedar	Northern Idaho	Clearcut, slash burned	7.4	13.2
Longstreth and Patten (1975)	Oak chaparral	Central Arizona	Wildfire maintained in grass cover	66.0	51.0

TABLE 6. Effects of fire and selected treatments on solution loss of major cations (Ca, Mg, Na, and K) in solution (from Tiedemann, et al, 1979).

Authors	Habitat	Location	Treatment	Solution transport of cation	
				Pre-treatment or control	Post-treatment
				$kg \cdot ha^{-1} \cdot yr^{-1}$	
Fredriksen (1971)	Douglas-fir	Western Oregon	Clearcut, slash burned	46	133
DeByle and Packer (1972)	Western Larch, Douglas-fir	Western Montana	Clearcut, broadcast, slash burned	1.5	8.2
Tiedemann et al. (1978)	Doublas-fir, pinegrass	Eastern Washington	Wildfire	15	63
Likens et al. (1970)	Eastern deciduous forest	Northern New Hampshire	Clearcut, herbicide treated	27	168
Kimmins and Feller (1976)	Western hemlock, Douglas-fir	Western B.C., Canada	Clearcut, calcium only	23[1]	140
DeBano and Conrad (1978)	Chaparral	Southern California	Prescribed fire	0[2]	34

[1]Calcium values only were reported.
[2]Trace.

Fire Effects on Soil

Fires influence the physicochemical properties of soils by oxidizing the standing vegetation and by igniting organic matter on and beneath the soil surface. These alterations in soil properties are directly related to the degree and duration of soil heating, and significantly influence the reestablishment and functions of the biotic/soil associations.

Soil Chemistry

Burning may significantly affect the availability of nutrients. Fires cause an abrupt release of elements bound in vegetative material that normally would only gradually become available. The quantity of nutrients released as volatiles or ash depends on the concentration of these nutrients in the above ground vegetation (Gifford, 1981).

Studies within various vegetation types indicated that the nitrogen and sulfur status of soils following fire varies greatly. These elements are volatilized at relatively low temperatures [200°C (392°F)] (Bollen, 1974; Tiedemann and Anderson, 1980; Boerner, 1982), and their losses from standing vegetation and soil can be significant. Twenty-five to 90% losses of these elements have been observed (Knight, 1966; Sharrow and Wright, 1977; Faulkner and de la Cruz, 1982), depending on the type of vegetation, localization of nutrients, and the fire intensity. Raisons (1979) found that while NO_3 - N decomposed at temperatures above 150°C (300° F), soil heating could significantly increase the concentration of $NH^{+}{}_4$ -N. All other nutrients are converted to simple salts that are water soluble and therefore readily available for uptake by plant tissue and/or microbes, litter adsorption, or lost through runoff or leaching (Tiedemann, et al., 1979).

Cations (e.g., potassium, calcium, magnesium, etc.), phosphates, and various plant micro-nutrients (e.g., iron, copper, zinc, etc.) are volatilized at significantly higher temperatures (Mueggler, 1976). Volatilization temperatures of potassium and calcium are 760°C (1400°F) and 1240°C (2264° F), respectively (Wright and Bailey, 1982). Such temperatures are seldom reached near the soil surface, and as a result, the losses of these elements are minor (Alban, 1977; Stark, 1979).

Researchers have observed a significant post-fire increase in the soil concentration of exchangeable bases (e.g., calcium, magnesium, potassium, etc.), with a concomitant increase in the hydrogen ion concentration (pH) (Kozlowski and Ahlgren, 1974). These conditions have a favorable effect on the growth of bacteria, which ultimately produce nitrogen through the mineralization of organic matter (Issac and Hopkins, 1937). Old (1969) and Sharrow and Wright (1977a) emphasized that most of the fertilizing effect after a fire comes from nitrates released when bacteria consume organic matter, not from nutrients in ash. The usual additions of some nitrogen to soil after fire (Sharrow and Wright, 1977b; DeBano and Conrad, 1978); plentiful supply of mineral nutrients (Wells, et al, 1979); increased soil temperature and ashed minerals that stimulate nitrification (Sharrow and Wright, 1977a; Raisons, 1979); and adequate soil moisture, greatly enhance soil fertility (Sharrow and Wright, 1977a).

Erosion and Soil Losses

The retention of ash-borne nutrients is largely a function of meteorological factors, tides, and topography. Smith and Bowes (1974) indicated that nutrient losses in fly ash during low-temperature fires in old-field communities may be significant, and estimated 30% losses of particulate-borne nutrients.

All studies of soil solution and runoff following fire indicated increased levels of cations (Tables 5 and 6). Soil systems, however, maintain a high degree of retention power for the great majority of cations, and their losses occur primarily through the physical removal of sediment and suspended organic material (Table 7). If post-fire revegetation is rapid or plant root systems remain viable, the soil biotic layer may retain the capacity to recover most of the available nutrients released by the dissolution of ash elements or mineralization (Vitorsek and Reiners, 1975; Woodmansee, 1978; Woodmansee and Wallach, 1981).

The effects of nutrient losses via erosion and sedimentation have not been related directly to site productivity, but do not appear to represent a significant proportion of the total site nutrient capitals (Tiedemann, et al., 1979). A possible exception may be organic peat soils. Fires during periods of drought can consume deep peat deposits (Craighead, 1971; Wade, et al., 1980), accelerating soil subsidence, and significantly reducing the available nutrient pool and concomitant site productivity. Depending on the severity of the burn, the substrate may be so altered as to delay or prevent revegetation. Obviously, the timing of fire on peat soils determines the degree of environmental perturbation.

Thermal Properties of Soil

Burning can radically alter the thermal regime of the soil surface and the adjacent layer of air. Standing vegetation and litter are partially or wholly consumed, reducing the area of soil surface shaded from direct insolation. The darkened ash layer adsorbs solar heat creating higher surface temperatures than observed on comparable unburned sites (Vogl, 1971).

TABLE 7. Sediment transport of cations after fire (from Tiedemann, et, al., 1979).

Authors	Habitat	Location	Treatment	Cation[1] transport	
				Pre-treatment or control	Post-treatment
				kg • ha⁻¹ • yr⁻¹	
Brown et al. (1973)	Douglas-fir	Western Oregon	Clearcut, slash burned	.3	5.6
DeByle and Packer (1972)	Douglas-fir	Western Montana	Clearcut, slash burned	0	37
Debano and Conrad (1978)	Chaparral	Southern California	Prescribed fire	0[2]	131

[1]Ca, Mg, Na, and K.
[2]Trace.

The effects of increased soil surface temperatures are twofold. First, evaporation is increased and continues until the humus layer dries and capillarity is broken (Viro, 1974). If the amount of organic matter in the surface layer is reduced, the water-holding ability of this layer declines, which may ultimately alter soil permeability. Second, the warmer sub-soil temperatures coupled with increased soil-water (due to decreased transpiration), increase biological and chemical reactions. Nitrogen fixation (Wells, et al., 1979), nitrification (Wright, 1974), and mineralization (Neal, et al., 1965; Christensen, 1973) are stimulated, increasing the available nutrient pool, and therefore, the potential plant productivity (Owensby and Wyrill, 1973; Christensen, 1977). Early seed germination and regrowth of surviving vegetation may also be enhanced by the generally warmer, moist soil (Vogl, 1974).

BIOTIC EFFECTS

Effects of Fire on Soil Microorganisms

Ahlgren (1974) and Wells, et al. (1979) have provided relatively complete summaries of the pertinent literature pertaining to the responses of soil microorganisims (bacteria, fungi, and actinomycetes) to fire. Microorganisms have not been investigated as extensively as larger plants and animals due to their apparent lack of direct economic importance and the inherent difficulties associated with their study (Ahlgren, 1974). Yet, ecosystem productivity is directly related to the interrelationships between climate, physicochemical, and microbial processes. Disturbance of these processes will affect soil fertility and ultimately the carrying capacity and yields (Wells, et al., 1979).

The effects of burning on soil microorganisms are variable depending on the physicochemical properties of the soil, fire intensity, and sampling methods (Wells, et al., 1979). Intense fires affect microorganisms most dramatically. Ahlgren and Alhgren (1965) and Renbuss, et al., (1973) reported that hot fires temporarily sterilized the soil. Wright and Tarrant (1957) found that burning had its greatest effect on microbes in the upper layer of the soil and only severly burned soil showed any influence of fire below 4 cm (1.5 in). They observed an increase in the number of microorganisms as a result of severe burns. Apparently a number of common soil microbes are stimulated by fire. Less intense fires usually had little effect on soil microorganisms because only slight changes in soil properties were caused by fire (Berry, 1970; Jorgensen and Hodges, 1970).

The duration of soil heating, maximum temperature, and soil moisture content appear to be the most important factors affecting microbial responses to heating (Wells, et al., 1979). Generally, bacteria are more resistant than fungi to heating in both wet and dry soils. Lethal temperatures for bacteria in chaparral soils were 210°C (410°F) in dry soil and 110°C (230°F) in wet soils (Dunn and DeBano, 1977). Ahlgren and Ahlgren (1965) reported similar lethal temperatures for bacteria in forest soils. Nitrifying bacteria, however, appear to be particularly sensitive to soil heating. These organisms are killed at temperatures as low as 100°C (212°F) in dry soil and 50°C (122°F) in wet soils (Dunn and DeBano, 1977). This sensitivity of nitrifying bacteria to heating has important implications regarding plant nutrition because nitrogen is often limiting in soils (Hellmers, et al., 1955). Saprophytic fungi in chaparral soils tolerated temperatures of only 155°C (311° F) in dry soil and 100°C (212° F) in wet soil (Dunn and DeBano, 1977).

Heat from fires has also been found to reduce the number of mycorrhizae in forest soils. Tarrant (1956) found the number of mycorrhizae associated with Douglas-fir seedlings to be significantly reduced on burned soils, even after two years following fires.

Effects of Fire on Fauna

Micro-Macroinvertebrate Populations

The invertebrate fauna of soils and litter is important to the ecology of ecosystems. This group of organisms breakdown organic tissue into small particles prior to bacterial and fungal decomposition (Bornebush, 1930; Metz and Farirer, 1971), and increase soil permeability by mixing the soil. This incorporates organic matter, providing media and aeration necessary for bacterial decomposition (Taylor, 1935; Heyward and Tissot, 1936).

The effects of fire on soil fauna are generally greater in the forest ecosystem than in grasslands (Ahlgren, 1974). Species in grasslands are more adapted initially to xeric conditions than species in cooler, moist forest floors, and forest fires are usually more intense due to the greater accumulation of fuel.

Research has shown that where fires are moderate, heat of the fire is apparently less important than postfire environmental changes in altering soil fauna populations (Ahlgren, 1974). Buffington (1967) related declines in soil fauna to the loss of soil organic matter, which reduced food supply for the organisms, and in turn for their predators. Heyward and Tissot (1936) and Pearse (1943) suggested that transition to xeric conditions and greater temperature fluctuations following fire reduced populations, particularly in the upper 5 to 10 cm (2 to 4 in) of soil.

Other researchers have observed increases in invertebrate populations after fire (Tester and Marshall, 1961; Hurst, 1970; Van Arman and Goodrick, 1979). These observed increases were probably the result of recolonization from adjacent unburned areas. Insects in particular appear to be attracted to lush early post-fire herbaceous cover.

Vertebrate Populations

Short-term Effects

The immediate response of wildlife to fire is related to the animals size and mobility. Responses exhibited are wild panic in rodent populations (Komarek, 1969; Tevis, 1956); calm movement away from the fire in large animals (deer, racoons) (Hakala, et al., 1971; Vogl, 1973); and positive movement toward the fire by large insectivorous birds and predators (Holland, 1982[3]; Komarek,

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[3] Holland, D. 1982. Personal Communication. Chincoteague National Wildlife Refuge, Chincoteague, VA.

1969; Stoddard, 1963).

Animal mortality has been documented by some investigators (Chew, et al., 1958; Hakala, et al., 1971) while others have observed very little (Stoddard, 1963; Komarek, 1963; Simms and Buckner, 1973; and Vogl, 1973). Most fires burn unevenly providing refugia for many birds and mammals. The microclimate of places where small animals escape fire appears to be very important to their survival. The relatively low subsoil temperatures observed in surface fires suggest that, when animal mortality occurs, it is unlikely that death results directly by fire. Suffocation is the more probable cause (Lawrence, 1966; Chew, et al., 1958), when noxious gasses and smoke accumulate in tunnels and burrows. Herptile species, however, have an increased incidence of death by fire. This is attributed to their generally slow rate of movement and secretive habits (Vogl, 1973).

Long-term Effects of Fire

The principal way that fires adversely affect population densities of animals is by altering the habitat, not by killing. Habitat, more than anything, determines the species and their densities (Wright and Bailey, 1982).

The immediate postfire environment presents the terrestrial fauna with a modification of habitat structure and local microclimate (Lyons, et al., 1978). The removal of the above ground vegetation, blackening of the soil, and exposure of light colored mineral soils and rocks drastically alters the input and reflectance of light energy. Generally, higher maximum and lower minimum temperatures are observed on burned soil as compared to nonburned surfaces. The open burn is usually drier and shows greater fluctuations in relative humidity (Table

8). Fauna are generally subjected to more xeric conditions than previously existed. The frequency and intensity of winds may also increase over burns. Winds probably have their greatest effect in concert with temperature and humidity. A cold wind may greatly increase the heat loss from animals, especially if they are wet (Lyons, et al., 1978).

The pattern of the above ground cover within a burn also influences the quantity of food, predator prey relationships and interspecific competition, and ultimately determines where animals live and the densities they achieve. The quality of food resources is perhaps the most limiting factor. Bendell (1974) emphasized that the abundance of wildlife on a burn is set by the amount of nutrient release expressed through the quality of food.

Research has shown that, in general, the kinds and densities of fauna do not change or increase following fire (Table 9). More importantly, evidence suggests that food intake, the efficienty of food utilization and the resulting animal biomass may be greater on burns (Bock and Lynch, 1970).

Effects of Fire on Vegetation

Direct Effects of Fire

Vascular plant tissue is easily killed by heat, and the extent of fire damage to plants is dependent on the temperature and the time of exposure (Hare, 1961; Yarwood, 1961; Wright, 1970). A temperature of 60°C (140°F) for ten minutes is usually given as the thermal death point for most plant tissue (Hare, 1961; Kayll, 1966). However, research indicates that the lethal temperature may vary from 47°C to 75°C (117°to 165°F), depending on the plant species and its stage of development (Baker, 1929; Nelson, 1952; Jameson, 1961; Kayll, 1966).

TABLE 8. Relative humidity (%) in open burn and adjacent dense regrowth (from Bendell, 1974).

Month	Open burn			Dense regrowth		
	Mean[a] max.	Mean min.	Lowest value	Mean max.	Mean min.	Lowest value
May	96.5	21.6	4	100	60.3	34
June	95.3	23.5	3	100	68.1	38
July	99.4	26.9	9	99.9	68.3	46
August	98.9	38.9	6	99.3	80.7	55

[a] Calculated as the average of daily readings.

TABLE 9. Changes in density and trends of populations of breeding birds and mammals after burning (from Bendell, 1974).

	Density			Trend		
	Increase	Decrease	No Change	Increase	Decrease	No Change
Foraging zone	(%)	(%)	(%)	(%)	(%)	(%)
			Birds[b]			
Grassland and shrub	50(33/66)	9 (6)	41 (27)	24 (10)	10 (4)	66 (27)
Tree trunk	28 (9)	16 (5)	56 (18)	4 (1)	8 (2)	88 (21)
Tree	24 (17)	19 (14)	57 (41)	6 (3)	5 (3)	80 (41)
Totals	35 (9)	15 (25)	50 (86)	12 (14)	8 (9)	80 (89)
			Mammals[c]			
Grassland and shrub	24 (9)	13 (5)	63 (24)	20 (4)	5 (1)	75 (15)
Forest	23 (6)	42 (1)	35 (9)	0 (0)	11 (1)	89 (8)
Totals	23 (15)	25 (16)	52 (33)	14 (4)	7 (2)	80 (23)

[a] Numbers of species are in parentheses.

[b] Sources: Biswell et al. (1952); Bock and Lynch (1970); Emlen (1970); Ellis et al. (1969); Hagar (1960); Kilgore (1971); Lawrence (1966); Michael and Thornburgh (1971); Tester and Marshall (1961); Vogl (1973).

[c] Sources: Alhgren (1966); Beck and Vogl (1972); Biswell et al. (1952); Cook 1959); Gashwiler (1970); Keith and Surrendi (1971); Lawrence (1966); Sims and Buckner (1973); Tester and Marshall (1961); Tester (1965); Vogl (1973).

Phenological characteristics of plants at the time of burning are important determinants of the extent of fire damage (Daubernmire, 1968). Wright and Bailey (1982) have shown that the death of plant tissue is an exponential function between temperature and the time of exposure, if the moisture content is constant (Figure 3). Plant moisture, which is related to the phenological stage of herbaceous vegetation, generally increases the susceptibility of plants to heat (Figure 3).

The position of growing points (meristems) and seeds also determine the resistance of plants to fire damage (Hopkins, et al., 1948; Lemon, 1949), and therefore, the potential for post-fire recovery. Systems with a preponderance of biomass and nutrients in below ground organs are less severly disturbed by fire than those having a large proportion of aerial biomass (Woodmansee and Wallach, 1981). Fire destroys a population of herbaceous perennials only when lethal temperatures descend to the level of the perennating buds, at or below the soil surface (Daubenmire, 1968). Among populations of annuals, however, fire sensitivity is a matter of seed survival, which are located on or below the soil surface exposed directly to heating. Many seeds are very tolerant to heat, and if they are slightly covered by soil they can survive a relatively intense fire. However, if the fire consumes plants during flowering, continuation of the species in the post-fire environment may be jeopardized. Trees also show varied resistance to fire depending on the depth of the bud zone. If the crown bud zone is close to the soil, the plant is more susceptible to fire destruction of growing points and reproductive structures (Wright, 1980).

Plant vigor and vitality are also affected by fire. These plant activities may be increased or decreased depending on the season in which burning occurs (Daubenmire, 1968). Generally, burning results in increased yields as decadent plant biomass is removed (Vogl, 1973), and new growth responds to increased

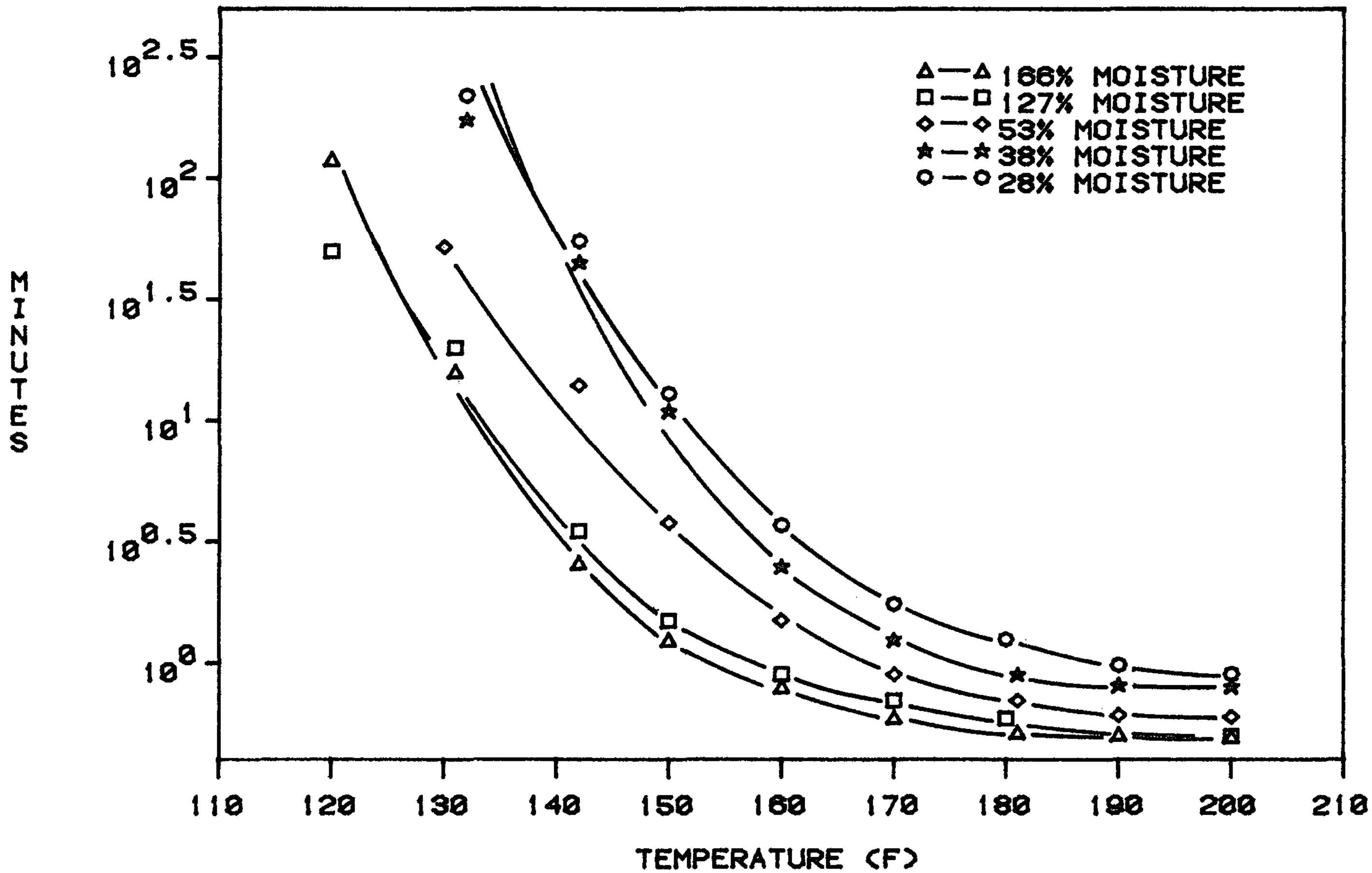

FIGURE 3. Time required to kill tissue of needle-and-thread (<u>Stipa comata</u>) for five moisture contents in relation to temperature (from Wright and Bailey, 1982).

nutrient concentrations and optimum growing temperatures (Sharrow and Wright, 1977a). Research indicates that plants recovering from fire damage often respond by reducing vegetative growth and increasing sexual reproduction (seed production) (Curtis and Portsch, 1950; Dix and Butler, 1954; Ehrenreich, 1959). Seeds harvested from recently burned grasslands had a higher percentage germination than those from unburned lands, reflecting the greater vigor and vitality of burned plants (Ehrenreich and Aikman, 1957; Grant, et al., 1963). Fire may also increase the total seed germination, the rate of germination, and the establishment of seedlings (Vogl, 1974). Plants within burns have been noted to initiate spring regrowth prior to the emergence of plants in unburned plots (Faulkner and de la Cruz, 1982). This may have the disadvantage, however, of making seedlings more susceptible to frost damage (Stoddard, 1935).

Burning also alters plant community structure, species succession, and diversity. Fire generally acts as a retrogressive agent in returning plant succession to earlier and less stable conditions, and in fire-adapted communities, fire arrests succession. Repeated burning in forests tends to simplify species composition and stand structure, often producing monotypes of a fire-resistant species (Vogl, 1974). Burning of grasslands, however, generally does not reduce species diversity and may even increase it by promoting growth of additional grasses, legumes and forbes (Vogl, 1974). This is particularly true in dense culms of a monotype, in which burning may open areas for colonization by invader species.

Indirect Effects of Fire

In addition to the obvious direct physical damage caused by heat to vegetation, emissions from fires may also seriously impact vegetation. Smoke contains or results in the formation of a number of compounds, notably sulfur oxides and oxides of nitrogen, which are known toxicants to vegetation at relatively low concentrations (Cramer, 1974; Evans, et al., 1977). The effects of smoke components on physiological processes range from reduced photosynthetic efficiency at low concentrations to accute toxicity and tissue necrosis at high concentrations. There is also convincing evidence that oxidants affect several stages of the reproductive process in some plant species (Houston and Dochinger, 1977).

Physical damage to vegetation may reduce host vigor, which predioposes vegetation to insect attack and/or disease. Davis (1959) suggested that fire contributes to rot-caused defects in standing timber which in its cumulative effect may outweigh in importance the more obvious tree mortality.

ADVANTAGES AND DISADVANTAGES OF PRESCRIBED BURNING AS A MANAGEMENT PRACTICE

ADVANTAGES

1) Prescribed burning reduces the likelihood of damaging wildfires by eliminating heavy fuel accumulations. Reduction of fuel levels along boundaries of management zones can decrease the probability of wildfires crossing into or out of the zone.

2) Burning causes an abrupt release of elements bound in vegetative material which normally would only gradually become available for microbial and plant growth.

3) Fire may increase the soil concentration of exchangeable bases with a concomitant increase in pH. These conditions coupled with warm, moist soil provide a favorable environment for microbial nitrification, mineralization, and nitrogen fixation which may significantly enhance soil fertility.

4) Prescribed fire can increase the edge effect and browse material thereby improving conditions for wildlife.

5) Fire generally stimulates wildlife food plants, and seeds become more plentiful and accessible. Unpalatable brush and litter are removed improving forage quality and accessibility.

6) In environments where man's activities (e.g., drainage enhancement) have artifically accelerated plant community succession, prescribed burning can be utilized to "restore" the vegetation to an earlier successional stage.

7) Fire maintains the species composition in plant communities that develop and survive because of periodic fire.

8) Fire sanitizes and eradicates disease. It eliminates sporulation in many disease fungi, insect vectors of disease, and diseased plant tissue.

9) Prescribed burning increases plant productivity. Regrowth plants are nutritionally superior; sexual reproduction is enhanced; seeds generally have a higher percent and total germination and rate of germination; and the success of seedling establishment is often increased.

DISADVANTAGES

1) Prescribed fire causes a temporary deterioration of local air quality and visibility through increased emissions of particulates, hydrocarbons, and nitrogen and sulfur oxides, and contributes to the total annual pollutant load of the atmosphere.

2) Fire alters basic hydrologic processes increasing the sensitivity of the soil to eroding forces. The potential results are increased overland flow; greater peak and total discharges; and increased turbidity and sedimentation in receiving waters.

3) Volatilization of some nutrients during a fire can limit their availability for biological incorporation.

4) Fires cause rapid mineralization and mobilization of nutrient elements that may be manifested in increased levels of nutrients in overland flow and in soil solution.

5) Burning temporarily alters the microclimatology (insolation, temperature, evaporation, moisture, etc.) of a site, which may affect the function, structure, and distribution of biota.

6) Fire may injure or kill biota. Wounding may make the organism more susceptible to pathogens.

7) Heat from fire may have a temporary sterilizing effect on soils, eliminating microbial processes important to soil integrity.

8) Fire may alter the habitat, disrupting normal usage by fauna. Structures and sites necessary for territorial display, mate selection, and nesting may be destroyed.

9) Heat from fire can stimulate spore germination, growth, and fruiting in some disease producing fungi.

10) Fire alters plant community structure and the processes of natural plant succession. It is a retrogressive agent, setting plant community structure back to earlier successial stages.

11) Burning impacts the aesthetic properties of the environment.

SUMMARY AND CONCLUSIONS

From a review of the literature, it is apparent that fire is a natural and important factor in southeastern ecosystems, and it is increasingly recognized that land and fire management are synonymous in this region of North America. Scientific evidence suggests that the reintroduction of fire into ecosystems can be beneficial when conscientiously applied. There are inherent environmental impacts associated with any fire. However, when prescribed burning is conducted in a scientific manner by experienced professionals, perturbations are minimized and the habitat is only temporarily altered.

The land management alternatives available to the SJRWMD regarding fire are: (1) use fire to achieve one or more clearly defined management objectives and control all unwanted fires (2) let all fires burn (3) exclude all fires or (4) some combination of the above. A large percentage of fires in Florida are caused by lightning and man's activities (Tables 10 and 11), and there is no reason to expect a decrease under any management program. However, the environmental impact caused by these fires can be minimized through the implementation of a comprehensive land management program which includes provisions for prescribed burning. The objectives of this program should be (1) to protect and enhance the natural ecosystems of these lands and the habitat for wildlife production and diversity (2) to protect human life and (3) to prevent damage to cultural or physical facilities.

In meeting these objectives, it is appropriate that:

(1) The SJRWMD inventory all properties under its jurisdiction to:

- (a) establish land management planning units
- (b) determine the status of existing plant communities
- (c) identify sensitive environments and provide for their protection
- (d) determine what land uses are appropriate for the individual properties.

(2) The District develop land management programs for each planning unit which will optimize for the intended land uses, while at the same time insuring environmental integrity. These programs should establish

TABLE 10. Number of fires and acres burned by lightning fires, prescribed fires, man-caused, and all fires within Everglades National Park, for the years 1948 - 1979 (from Taylor, 1981).

Type of Fire	Number of Fires		Acres Burned	
	No.	%	acres	%
lightning fires	190	28	81,293	18
man-caused	246	36	280,622	62
prescribed fires	246	36	89,167	20
TOTAL FIRES	682	100	451,082	100

TABLE 11. Categories of man-caused fires within Everglades National Park, from 1948 - 1979. Values are number of fires and percentages (from Taylor, 1981).

MAN-CAUSED FIRES							
Smoking	Camper	Hunter	Farming	Debris Burn	Arson	Other	Total
49 (20%)	23 (9%)	8 (3%)	19 (8%)	9 (4%)	105 (43%)	33 (13%)	246 (100%)

management zones within each planning unit, delineated by perimeter firebreaks, which will eliminate the threat of wildfire coming into or out of the property.

(3) Prescribed burning be employed whenever it is the most appropriate management practice for District owned properties, in accordance with the procedure and guidelines presented in this report.

(4) All prescribed fires be contained to predetermined fire management zones.

(5) Every wildfire on District lands be aggressively suppressed unless its nature and character are such that it qualifies under an approved fire management plan either (a) as a prescribed fire or (b) for modified suppressive action.

(6) Fire suppression and firebreak establishment methods used on District lands should be those causing the least resource damage, commensurate with effective fire control.

(7) For specific habitat types:

   (a) Periodic fire be introduced into upland areas (pine flatwoods, cabbage palm-pine-mixed hardwood forests, and forage lands) to remove accumulated fuels and effectively eliminate the threat of catastrophic fires.

   (b) Exclude all unnatural fires from cypress and mixed-hardwood swamps, tree islands, hammocks, sites with archeological significance and areas occupied by endangered plant or animal species, unless it is determined that periodic fire is required to restore or maintain these sites or species.

   (c) Exclude all unnatural fires from freshwater marshlands and wet meadows unless after an evaluation of the environment significant modification of the preferred vegetation structure has occurred or is imminent. Under these circumstances fire would be introduced in order to restore and maintain the desired plant communities.

REFERENCES

Ahlgren, C. E. 1966. Small mammals and reforestation following prescribed burning. J. Forest. 64: 614-618.

Ahlgren, C. E. 1974. The effect of fire on soil organisms. In: Kozlowski T. T. and Ahlgren, C. E. (eds.) Fire and Ecosystems. Academic Press, N.Y., pp. 47-72.

Ahlgren, I. F. and Ahlgren, C. E. 1965. Effect of prescribed burning on soil microorganisms in a Minnesota jack pine forest. Ecology 46: 304-310.

Alban, D. H. 1977. Influence on soil properties of prescribed burning under mature red pine. USDA For. Serv. Res. Paper NC-139, North Central For. Exp. Stn., St. Paul, Minn.

Anderson, K. L., Smith, E. F., and Owensby, C. E. 1970. Burning bluestem range. J. Range Manage. 23: 81-92.

Baker, F. S. 1929. Effect of excessively high temperatures on coniferous reproduction. J. For. 27: 949-975.

Bancroft, L. 1977. Fire prescriptions for FY 77 prescribed burns. Mimeo. Rep. USDI Everglades Natl. Park, Homestead, Fla., 5 pp.

Beardall, L. E. and Sylvester, V. E. 1976. Spring burning for removal of sagebrush competition in Nevada. Proc. Tall Timbers Fire Ecol. Conf. 14: 539-547.

Beck, A. M. and Vogl, R. J. 1972. The effects of spring burning on rodent populations in a brush prairie savanna. J. Mammal. 53: 336-346.

Bendell, J. F. 1974. Effects of fire on birds and mammals. In: Kozlowski, T. T. and Ahlgren C. E. (eds.) Fire and Ecosystems. Academic Press, N.Y., N.Y., pp. 73-138.

Berry, C. W. 1970. Enumeration and identification of the microbial populations from burned and unburned pine forest soil. M. S. thesis La. Tech. University, Ruston, La., 48 pp.

Biswell, H. H. and Schultz, A. M. 1957. Surface runoff and erosion as related to prescribed burning. J. For. 55: 372-374.

Biswell, H. H., Taber, R. D., Hedrick, D. W., and Schultz, A. M. 1952. Management of chamise brushlands for game in the north coast region of California. Calif. Fish & Game 38: 453-484.

Biswell, H. H., Kallander, H. R., Komarek, R., Vogl, R. J., and Weaver, H. 1973. Ponderosa fire management. A task force evaluation of controlled burning in Ponderosa pine forests in central Arizona. Misc. Pub. No. 2, Tall Timbers Res. Stn., Tallahassee, Fla.

Black, C. A. 1968. Soil-plant Relationships. John Wiley and Sons, Inc. New York., 792 pp.

Bock, C. E. and Lynch, J. F. 1970. Breeding bird populations of burned and unburned conifer forests in the Sierra Nevada. Condor 72: 182-189.

Boerner, R. E. J. 1982. Fire and nutrient cycling in temperate ecosystems. BioScience 32(3): 187-192.

Bollen, W. B. 1974. Soil microbes. In: Environmental effects of forest residues management in the Pacific Northwest - a state of knowledge compendium. USDA For. Serv. Gen. Tech. Rep. PNW-24, Pac. Northwest For. and Range Exp. Stn., Portland, Ore., pp. B1-B41.

Bornebush, C. H. 1930. The fauna of forest soil. Proc. Int. Congr. Forest Exp. Sta., 1st, 1929. pp. 541-545.

Britton, C. M. and Wright, H. A. 1971. Correlation of weather and fuel variables to mesquite damage by fire. Range Manage. 23: 136-141.

Brown, G. W., Gahler, A. R., and Marston, R. B. 1973. Nutrient losses after clear-cut logging and slash burning in the Oregon Coast Range. Water Resources Res. 9: 1450-1453.

Buffington, J. D. 1967. Soil arthropod populations of the New Jersey pine barrens as affected by fire. Am. Entomol. Soc. Amer. 60: 530-535.

Bunting, S. C. and Wright, H. A. 1974. Ignition capabilities on nonflaming firebrands. J. For. 72: 646-649.

Campbell, R. E., Baker, M. B. Jr., Ffolliott, P. F., et al., 1977. Wildlife effects on a ponderosa pine ecosystems: An Arizonna case study. U. S. Department Agric. For. Serv. Res. Pop. RM-191, Rocky Mt. For. and Range Exp. Stn. Fort Collins, Colo., 12 pp.

Chew, R. M., Butterworth, B. B. and Grechman, R. 1958. The effects of fire on the small mammal populations of chaparral. J. Mammal. 40: 253.

Christensen, N. L. 1973. Fire and the nitrogen cycle in California chaparral. Science 181: 66-68.

Christensen, N. L. 1977. Fire and soil plant nutrient relations in a pine-wiregrass savanna on the coastal plain of North Carolina. Oecologia (Berl.) 31: 27-44.

Cook, S. F., Jr., 1959. The effects of fire on a population of small rodents. Ecology 40: 102-108.

Copley, T. L., Forrest, L. A., et al. 1944. Investigations in erosion control and reclamation of eroded land in the Central Piedmont Conservation Experimental Station, Statesville, North Carolina. U. S. Dep. Agric. Tech. Bull. 873., 66 pp.

Countryman, C. M. 1976. Radiation and wildland fire: Heat - It's role in wildland fire. Part 5. USDA Forestry Service, Pacific Southwest For. and Range Exp. Stn., Berkley, California.

Countryman, C. M. 1978. Radiation: Heat - Its role in wildland fire. Part 4. USDA For. Ser., Pacific Southwest For. and Range Exp. Stn., Berkley, California.

Craighead, F. C., Sr. 1971. The trees of south Florida, Vol. 1. The natural environments and their succession. University of Miami Press, Coral Gables, Florida, 212 pp.

Cramer, O. P. 1974. Air quality influences. In: Environmental effects of forest residues management in the Pacific Northwest. USDA Forest Service Gen. Tech. Rep. PNW-24.

Curtis, J. T. and Partsch, M. L. 1950. Some factors affecting flower production in Andropogon gerardi. Ecology 31: 488-489.

Czuhai, E. and Cushwa, C. T. 1968. A resume' of prescribed burnings on the piedmont National Wildlife Refuge. Southeastern Forest Exp. Stn., USDA Forest Service Research Note SE-86, 4 pp.

Daubenmire, R. 1968. Ecology of fire in grasslands. Adv. Ecol. Res. 5: 209-266.

Davis, K. P. 1959. Forest Fire: Control and Use. McGraw-Hill, N.Y., N.Y. 584 pp.

DeBano, L. F. and Conrad, C. E. 1978. Effects of fire on nutrients in a chaparral ecosystem. Ecology 59: 489-497.

DeByle, N. V. and Packer, P. E. 1972. Plant nutrient and soil losses in overland flow from burned forest clearcuts. In: Watersheds in Transition. Proc. Symposium sponsored by the American Water Resources Association and Colorado State University, pp. 296-307.

de la Cruz, A. A. and Hackney, C. T. 1980. The effects of winter fire and harvest on the vegetational structure and primary productivity of two tidal marsh communities in Mississippi. Mississippi-Alabama Sea Grant Consortium Pub. No. M-ASGP-80-013, Ocean Springs, Mississippi, 111 pp.

Dieterich, J. H. 1971. Air quality aspects of prescribed burning. In: USDA Forest Service Prescribed Burning Symposium Proc., Southeastern Forest Exp. Stn., Ashville, North Carolina, 160 pp.

Dix, R. L and Butler, J. E. 1954. The effects of fire on a dry, thin-soil prairie in Wisconsin. J. Range Mgt. 7: 265-268.

Dixon, M. J. 1965. A guide to fire by prescription. USDA For. Serv., Southern Reg. Atlanta, Georgia.

Dube', D. 1977. Prescribed burning in Jasper National Park. For. Rep. 5 (2): 4-5, Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta.

Dunn, P.. H. and DeBano, L. F. 1977. Fire's effect on the biological properties of chaparral soils. In: Intern. Symp. Environ. Conseq. Fire and Fuel Mangt. in Mediterranean-climate ecosystems.

Ehrenreich, J. H. 1959. Effect of burning and clipping on growth of native prairie in Iowa. J. Range Mgmt. 12: 133-137.

Ehrenreich, J. H. and Aikman, J. M. 1957. Effect of burning on seedstalk production of native prairie grasses. Iowa Aca. Sci. Proc. 64: 205-212.

Eichholz, N. 1981. How do you manage a damaged marsh? Florida Wildlife, Jan-Feb. 1981: 26-29.

Ellis, J. A., Edwards, W. R. and Thomas, K. P. 1969. Responses of bobwhites to management in Illinois. J. Wildl. Manage. 33: 749-762.

Emlen, J. T. 1970. Habitat selection by birds following a forest fire. Ecology 51: 343-345.

Evans, L. F., Weeks, I. A., Eccleston, A. J., and Packham D. R., 1977. Photochemical ozone in smoke from prescribed burning of forests. Environ. Sci. Tech. 11: 896-900.

Fahnestock, G. R. and Hare, R. C. 1964. Heating of tree trunks in surface fires. J. For. 62: 799-805.

Faulkner, S. P. and de la Cruz, A. A. 1982. Nutrient mobilization following winter fires in an irregularly flooded marsh. J. Environmental Quality 11 (1): 129-133.

Forthman, C. A. 1973. The effects of prescribed burning on sawgrass (Cladium jamaicense Crantz) in south Florida. M. S. Thesis, University of Miami, Coral Gables, Florida, 70 pp.

Fredriksen, R. L. 1971. Comparative chemical water quality - natural and disturbed streams following logging and slash burning. In: A Symposium for Land Uses and Stream Environ. [October 19-21, 1970], Oregon State University, Corvallis, Oregon, pp. 125-137.

Fritchen, L. J., Bovee, H., Buettner, K., Charlson, R., Monteith, L., Pickford, S., and Murphy, J. 1970. Slash fire atmosphere pollution. USDA For. Serv. Res. Paper PNW-97, Northwest For. and Range Exp. Stn., Portland, Oregon.

Gashwiler, J. S. 1970. Plant and mammal changes on a clearcut in west-central Oregon. Ecology 51: 1018-1026.

Gifford, G. F. 1981. Impact of burning Pinyon-Juniper debris on select soil properties. J. Range Management 34 (5): 359-359.

Gifford, G. F., Buckhouse, J. C., and Busby, F. E. 1976. Hydrologic impact of burning and grazing on a chained pinyon juniper site in southeastern Utah. Center for Water Resor. Res., Utah Water Res. Lab., Utah State University, Logan, Utah, 22 pp.

Gill, A. M. 1977. Plant traits adaptive to fires in Mediterranean land ecosystems. In: Proc. Sympos. Envir. Conseq. of Fire and Fuel Mgmt. in Mediterranean Ecosystems, FS GTR WO-3, 1977.

Givens, L. S. 1962. Use of fire on southeastern wildlife refuges. 1st Annual Proc. Tall Timbers Fire Ecol. Conf. 1: 121-126.

Glendening, G. E., Pase, C. P. and Ingebo, P. 1961. Preliminary hydrologic effects of wildfire in chaparral. In: Modern Techniques in Water Management. Proc. Fifth Ann. Arizona Watershed Symp., 4 pp.

Grant, S. A., Hunter, R. F. and Cross, C. 1963. The effects of muirburning Molinia-dominant communities. J. Br. Grassld. Soc. 18: 249-257.

Green, L. R. 1977. Fuel breaks and other fuel modifications for wildland fire control. USDA Handbook No. 499, Washington, D. C.

Hackney, C. T., and de la Cruz, A. A. 1981. Effects of fire on brackish marsh communities: Management implications. Wetlands 1: 75-86.

Hagar, D. 1960. The interrelationships of logging, birds, and timber regeneration in the Douglas-fir region of northwestern California. Ecology 41: 116-125.

Hakala, J. B., Seemel, R. K., Richney, R. A. and Kurtz J. E., 1971. Fire effects and rehabilitation methods - Swanson - Russian Rivers fires. In: Slaughter, C. W., Barney, R. J. and Hansen, G. M. (eds.) Fire in the Northern Environment. U. S. Pac. Northwest Forest Range Exp. Sta., Portland, Oregon, pp.87-99.

Halls, L. K., Southwell, B. L. and Knox, F. E. 1952. Burning and grazing in coastal plain forests. Georgia Coastal Plain Exp. Stn. Bull. 51, 33 pp.

Hardison, J. R. 1976. Fire and disease. In: Proc. 15th Annual Tall Timbers Fire Ecology Conf. [October 16-17, 1974], Portland, Oregon, pp. 223-234.

Hare, R. C. 1961. Heat effects on living plants. USDA For. Serv. Occas. Paper S-183, Southern For. Exp. Stn., New Orleans, La.

Heirman, A. L. and Wright, H. A. 1973. Fire in medium fuels of west Texas. J. Range Manage. 26: 331-335.

Hellmers, H., Bonner, J. F. and Keleher, J. M. 1955. Soil fertility: A watershed management problem in the San Gabriel Mountains of Southern California. Soil Sci. 80 (3): 189-197.

Hetherington, E. D. 1976. Dennis Creek - A look at water quality following logging in the Okanogan Basin. Environ. Can., For. Serv., 31 pp.

Heyward, F. and Tissot, A. N. 1936. Some changes in soil fauna associated with forest fires in the long leaf pine region. Ecology 17: 659-666.

Hibbert, R., Davis, E. A. and Scholl, D. G. 1974. Chaparral conversion potential in Arizona. Part 1: Water yield response and effects on other resources. USDA For. Serv. Res. Pap. RM-126,. Rocky Mountain For. and Range Exp. Stn., Fort Collins, Colorado, 36 pp.

Hoffman, R. J. and Ferreira, R. F. 1976. A reconnaissance of effects of a forest fire on water quality in Kings Canyon National Park. USDI Geol. Survey Open File Report 76-497. Menlo Park, California, 17 pp.

Holechek, J. L. 1981. Brush control impacts on rangeland wildlife. J. Soil Water Conservation 36 (5): 265-269.

Hofstetter, R. H. 1973. Appendix K. Part 1. Effects of fire in the ecosystem: an ecological study of the effects of fire on the wet prairie, sawgrass glades, and pineland communities of south Florida. Final Rep. Mimeo Rep. (EVER-N-48) USDI Natl. Park Serv. NTIS No. PB 231940, 156 pp.

Hopkins, H. H., Albertson, F. W. and Riegel, A. 1948. Some effects of burning upon a prairie in west-central Kansas. Kans. Acad. Sci. Trans. 51: 131-141.

Houston, D. B. and Dochinger, L. S. 1977. Effects of ambient air pollution on cone, seed, and pollen characteristics in eastern white and red pines. Environ. Pollut. 12: 1-5.

Hughes, R. H. 1975. The native vegetation in south Florida related to month of burning. USDA Forest Service Research Note SE-222, Southeast Forest Exp. Stn., 8 pp.

Hurst, G. A. 1970. The effects of controlled burning on arthropod density and biomass in relation to bobwhite quail brood habitat on a right-of-way. Proc. Tall Timbers Conf. Ecol. Anim. Control Habitat Management 2: 173-183.

Isaac, L. A. and Hopkins, H. G. 1937. The forest soil of the Douglas-fir region, and changes wrought upon it by logging and slash burning. Ecology 18: 264-279.

Jameson, D. A. 1961. Heat and desiccation resistance of important trees and grasses of the pinyon-juniper type. Bot. Gaz. 122: 174-179.

Johnson, C. M. and Needham, P. R. 1966. Ionic composition of Sagehen Creek, California, following an adjacent fire. Ecology 47: 636-639.

Jorgensen, J. R. and Hodges, C. S. Jr., 1970. Microbial characteristics of a forest soil after twenty years of prescribed burning. Mycologia 62 (4): 721-726.

Jorgensen, J. R. and Hodges, C. S. Jr., 1971. Effects of prescribed burning on the microbial characteristics of soil. In: Proc. Prescribed Burning Symposium [April 14-16, 1971], Charleston, S. C., USDA Forest Service, Southeastern For. Expt. Station, pp. 107-111.

Kayll, A. J. 1966. A technique for studying the fire tolerance of living tree trunks. Can. Dept. For. Pub. No. 1012 Ottawa, Ontario.

Kayll, A. G. 1974. Use of fire in land management. In: Kozlowski, T. T. and Ahlgren, C. E. (eds.) Fire and Ecosystems, Academic Press, N.Y., N.Y. pp. 483-511.

Keith, L. B. and Surrendi, P. C. 1971. Effects of fire on a snowshoe hare population. J. Wildl. Manage. 35: 16-26.

Kilgore, B. M. 1971. Response of breeding bird populations to habitat changes in a giant sequoia forest. Amer. Midl. Natur. 85: 135-152.

Kimmins, J. P. and Feller, M.C. 1976. Effect of clear cutting and broadcast slashburning on nutrient budgets, streamwater chemistry and productivity in western Canada. Proc. 16th IUFRO World Conf., Div. 1, Oslo, Norway, pp.186-197.

Knight, H. 1966. Loss of nitrogen from the forest floor by burning. For. Chron. 42: 149-152.

Komarek, E. V. 1969. Fire and animal behavior. Proc. 9th Ann. Tall Timbers Fire Ecol. Conf. pp. 161-207.

Komarek, E. V. 1974. Effects of fire on temperate forests and related ecosystems: southeastern United States. In: Kozlowski, T. T. and Ahlgren, C. E. (eds.) Fire and Ecosystems. Academic Press, N.Y., N.Y., pp. 251-277.

Komarek, R. 1963. Fire and the changing wildlife habitat. Proc. Tall Timbers Fire Ecol. Conf. 2: 35-43.

Kozlowski, T. T. and Ahlgren, C. E. 1974. Fire and Ecosystems. New York: Academic Press, N. Y., N. Y., 542 pp.

Krammes, J. S. 1960. Erosion from mountain side slopes after fire in southern California. U. S. Dept. Agric. For. Serv. Res. Note No. 171. Pacific Southwest For. and Range Exp. Stn., Berkley, California,8 pp.

Krueger, D. W. and Pachence, A. M. 1961. Wind directions for prescribed burning in southeastern United States. USDA Forest Service, Southeast Forest Exp. Sta. Paper No. 131.

Launchbaugh, J. L. 1972. Effects of early spring burning on yields of native vegetation. J. Range Manage. 17: 5-6.

Lawrence, G. E. 1966. Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills. Ecology 47: 278-291.

Lemon, P. C. 1949. Successional response of herbs in the longleaf-slash pine forest after fire. Ecology 30: 135-145.

Leopold, A. J., Cain, S. A. Cottam, C. M., Gabrielson, I. N. and Kimball, T. L. 1963. Wildlife management in the national parks. Amer. For. 69 (4): 32-35, 61-63.

Lewis, C. E. 1964. Forage response to month of burning. U. S. Forest Service Research Note SE-35, Southeast Forest Exp. Stn., Ashville, N. C.

Likens, G. E., Bormann, F. H., Johnson, N. M., et al. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol. Memo. 40: 23-47.

Lindenmuth, A. W., and Davis, J. R. 1973. Predicting fire spread in Arizona oak chaparral. USDA For. Serv. Res. Paper RM-101, Rocky Mtn. For. and Range Exp. Stn., Fort Collins, Colorado.

Longstreth, D. J. and Patten, D. T. 1975. Conversion of chaparral to grass in Central Arizona: Effects on selected ions in watershed runoff. Am. Midland Natur. 93 (1): 25-34.

Lotan, J. E., et al., 1981. Effects of fire on flora. A state-of-knowledge review. USDA Forest Service Gen. Tech. Rept. WO-16, prepared for the Forest Service National Fire Effects Workshop, Denver, Colorado, April 10-14, 1978.

Lynch, J. J. 1941. The place of burning in management of the Gulf Coast wildlife refuges. J. Wildlife Management 514: 454-457.

Lyon, L. J., et al., 1978. Effects of fire on fauna. A state-of-knowledge review. USDA Forest Service General Technical Report WO-6, prepared for the Forest Service National Fire Effects Workshop Denver, Colorado, April 10-14, 1978.

Martin, R. E., et al., 1979. Effects of fire on fuels. A state-of-knowledge review. USDA Forest Service Gen. Tech. Rept. WO-13, prepared for the Forest Service National Fire Effects Workshop, Denver, Colorado April 10-14, 1978.

Maynard, C. 1976. Stagnation index. FDACS Tech. Info. Paper Vol. 1, No.2, Tallahassee, FL., 3 pp.

McColl, J. G. and Grigal, D. F. 1975. Forest fire: Effects on phosphorus movement to lakes. Sci. 188: 1109-1111.

Meginnis, H. G. 1935. Influence of forest litter on surface run-off and soil erosion. Amer. Soil Surv. Assn. Bull. 16: 115-118.

Metz, L. J. and Farrier, M. H. 1971. Prescribed burning and soil mesofauna on the Santee Experimental Forest. U. S. Forest. Serv., Southeast. Forest Exp. Stn., Prescribed Burning Sumposium, pp. 100-105.

Michael, E. O. and Thornburg, P. 1971. Immediate effects of hardwood removal and prescribed burning on bird populations. Southwest Natur. 15: 359-370.

Mobley, H. E., Jackson, R. S., Balmer, W. E., Ruziska, W. E. and Hough, W. A. 1978. A guide for prescribed fire in southern forests. USDA For. Serv., Southern Reg. Atlanta, Georgia, 41 pp.

Mueggler, W. F. 1976. Ecological role of fire in western woodland and range ecosystesm. In: Use of Prescribed Burning in Western Woodland and Range Ecosystems, a Symposium, Utah State University, Logan, Utah, pp.1-9.

Mutch, R. W. 1970. Wildland fires and ecosystems - a hypothesis. Ecology 51 (6): 1046-151.

Neal, J. L., Wright, E. and Bollen, W. B. 1965. Burning Douglas-fir slash: physical, chemical, and microbial effects in the soil. Oregon State University; For. Res. Lab. Res. Pap. 1, Corvallis, Oregon, 32 pp.

Nelson, R. M. 1952. Observations on heat tolerance of southern pines. USDA For. Serv. Res. Paper SE-14, Southeastern For. Exp. Stn., Ashville, North Carolina.

Nikleva, S. 1972. The air pollution potential of slash burning in southwestern. British Columbia. For. Chron. 48: 187-189.

Old, S. M. 1969. Microclimate, fire and plant production in an Illinois prairie. Ecol. Monogr. 39: 355-384.

Owensby, C. E. and Wyrill, J. B. 1973. Effects of range burning on Kansas Flint Hills soil. J. Range Manage. 26: 185-188.

Pearse, A. S. 1943. Effects of burning over and raking off litter on certain soil animals in the Duke Forest. Amer. Midl. Natur. 29: 406-424.

Perkins, C. J. 1968. Controlled burning in the management of muskrats and water fowl in Louisiana Coastal Marshes. Proc. Tall Timbers Fire Ecol. Conf. 8: 269-280.

Quintilio, D. 1972. Fire spread and impact in lodgepole pine slash. M. S. Thesis. University of Montana, Missoula.

Raisons, R. J. 1979. Modification of the soil environment by vegetation fires, with particular reference to nitrogen transformation: A review. Plant and Soil 51: 73-108.

Renbuss, M., Chilvers, G. A. and Pryer, L. D. 1973. Microbiology of an ashbed. Proc. Linn. Soc. N. S. W. 97: 302-310.

Sackett, S. S. 1975. Scheduling prescribed burns for hazard reduction in the southeast. J. For. 73: 143-147.

Sackett, S. S. 1979. Natural fuel loadings in ponderosa pine and mixed conifer forests of the southwest. USDA For. Serv. Res. Paper RM-213, Rocky Mtn. For. and Range Stn., Fort Collins, Colorado.

Sackett, S. S. 1980. An instrument for rapid, accurate, determination of fuel moisture content. Fire Manage. Notes 41 (2): 17-18.

Sandberg, D. V., et al. 1979. Effects of fire on air. A state-of-knowledge review. USDA Forest Service Gen. Tech. Report WO-9, prepared for the Forest Service National Fire Effects Workshop, Denver, Colorado April 10-14, 1978.

Sando, R. W. and Dobbs, R. C. 1970. Planning for prescribed burning in Manitoba and Saskatchewan. Liaison and Serv. Note MS-L-9, Can. Dept. Fish and For., Winnipeg, Manitoba.

Schroer, J. D. 1979. Fire Management Plan. Blackwater National Wildlife Refuge. U. S. Fish and Wildlife Serv., Cambridge, Md., 14 pp.

Sharrow, S. H. and Wright, H. A. 1977a. Effects of fire, ash and litter on soil nitrate, temperature, moisture and tobosagrass production in rolling plains. J. Range. Manage. 20: 266-270.

Sharrow, S. H. and Wright, H. A. 1976b. Proper burning intervals for tobosagrass in West Texas based on nitrogen dynamics. J. Range Mange. 30: 343-346.

Simms, P. H. and Buckner, C. H. 1973. The effect of clear cutting and burning of Pinus banksiana forests on the populations of small mammals in southeastern Manitoba. Amer. Midl. Natur. 90: 228-231.

Smith, D. W. 1970. Concentrations of soil nutrients before and after fire. Can. J. Soil Sci. 50: 17-29.

Smith, D. W. and Bowes, G. C. 1974. Loss of some elements in fly-ash during old-field burning in southern Ontario. Can. J. Soil Sci. 54: 215-224.

Snyder, G. G., Haupt, H. F. and Belt, G. H. Jr., 1975. Clear cutting and burning slash alter quality of stream water in northern Idaho. USDA For. Serv. Res. Pap. INT-168, Intermountain For. and Range Exp. Stn., Ogden, Utah, 34 pp.

Society of American Foresters. 1958. Forestry terminology. SAF, Washington, D. C.

Southern Forest Fire Laboratory Staff. 1976. Southern forestry smoke management guidebook. USDA For. Serv. Gen. Tech. Rep. SE-10, Southeast For. Exp. Stn., Ashville, North Carolina, 140 pp.

Stark, N. M. 1979. Nutrient losses from timber harvesting in a larch/Douglas-fir forest. USDA For. Serv. Res. Paper INT-231, Intermt. For. and Range Exp. Stn., Ogden, Utah.

Stoddard, H. L. 1935. Use of fire on southeastern game lands. Tall Timbers Res. Sta. Misc. Publ. 1: 47-63.

Stoddard, H. L. 1963. Bird habitat and fire. Proc. 2nd Tall Timbers Fire Ecol. Conf. 2: 163-175.

Swanson, R. J. 1976. Hazard abatement by prescribed underburning west-side Douglas-fir. Proc. Tall Timbers Fire Ecol. Conf. 15: 235-238.

Tarrant, R. F. 1956. Effects of slash burning on some soils of the Douglas-fir region. Soil Sci. Soc. Am. Proc. 20: 408-411.

Taylor, D. L. 1981. Fire history and fire records for Everglades National Park: 1948-1979. Report T-619, National Park Service, South Florida Research Center, Everglades National Park, Florida, 121 pp.

Taylor, W. P. 1935. Some animal relations to soils. Ecology 16: 127-136.

Tester, J. R., 1965. Effects of a controlled burn on small mammals in a Minesota oak-savanna. Amer. Midl. Natur. 74: 240-243.

Tester, J. R. and Marshall, W. H. 1961. A study of certain plant and animal interrelationships on a prairie in northwestern Minnesota. University of Minnesota, Mus. Natur. Hist., Occas. Pap. No. 8.

Tevis, L. Jr., 1956. Effect of slash burn on forest mice. J. Wildl. Manage. 20: 405-409.

Tiedemann, A. R. and Anderson, T. D. 1980. Combustion losses of sulfur from native plant materials and forest litter. In: Proc. 6th Conf. on Fire and Forest Meterology, April 22-24, 1980, Soc. Amer. For., Mills Building, Washington, D. C. , pp 220-227.

Tiedemann, A. R., et al., 1978. Effects of fire on water. U. S. Dept. Agriculture Forest Service General Tech. Report WO-10.

Ursic, S. J. 1969. Hydrologic effects of prescribed burning on abandoned fields in northern Mississippi. USDA For. Serv. Res. Pap. 50-46, Southern For. Exp. Sta., 20 pp.

Ursic, S. J. 1970. Hydrologic effects of prescribed burning and deadening upland hardwoods in northern Mississippi. USDA For. Serv. Res. Pap. SO-54., Southern For. Exp. Sta., 15 pp.

Van Arman, J. and Goodrick, R. 1979. Effects of fire on a Kissimmee River marsh. Florida Scientist 42 (4): 183-195.

Viosca, P. 1931. Spontaneous combustion in the marshes of southern Louisiana. Ecology 12 (2): 439-442.

Viro, P. J. 1974. Effects of forest fire on soil. In: Kozlowski, T. T. and Ahlgren, C. E. (eds.) Fire and Ecosystems. Academic Press, N.Y., N.Y.

Vitousek, P. M. and Reiners, W. A. 1975. Ecosystem succession and nutrient retention: A hypothesis. Bio Science 25: 376-381.

Vogl, R. J. 1970. Fire and Plant Succession. In: Symposium on the Role of Fire in the Intermountain West. Oct. 27-29, 1970 Missoula, Mt., pp. 65-75.

Vogl, R. J 1971. Smokey: A bearfaced lie. Ecol. Today 1 (3): 14-17.

Vogl, R. J. 1973. Effects of fire on the plants and animals of a Florida wetland. Am. Midl. Nat. 89: 334-347.

Vogl, R. J. 1974. Effects of fire on grasslands. In: Kozlowski T. T.,and Ahlgren, C. E. (eds.), Fire and Ecosystems. Academic Press, New York, N. Y., pp. 139-194.

Vogl, R. J. 1977. Fire Frequency and Site Degradation. In: Proc. Sympo. Environ. Conseq. of Fire and Fuel Mgmt. in Mediterranean Ecosystems, Forest. Service, General Tech. Rept. WO-3, pp. 193-201.

Wade, D., Ewel, J. and Hofstetter, R. 1980. Fire in South Florida Ecosystems. U. S. Department Agriculture Technical Report SE-17, Southeast For. Exp. Stn. Ashville, North Carolina, 125 pp.

Ward, P. 1968. Fire in relation to waterfowl habitat of the Delta marshes. Proc. Tall Timbers Fire Ecol. Conf. 8: 255-267.

Wells, C. G., et al 1979. Effects of fire on soil. A state-of-knowledge review. USDA Forest Service, General Tech. Rept. WO-7, prepared for the Forest Service National Fire Effects Workshop, Denver, Colorado, April 10-14, 1978.

Williams, W., Bailey, A. W. McLean, A. and Kalnin, C., 1981. Effects of fall clipping or burning on the distribution of chemical constituents in bluebunch wheatgrass in spring. J. Range Management 34 (4): 267-269.

Woodmansee, R. G. 1978. Additions and losses of nitrogen in grassland ecosystems. Bio Science 28: 448-453.

Woodmansee, R. G. and Wallach, L. S. 1981. Effects of fire regimes on biogeochemical cycles. Reprinted from: Clark, E. F. and Rosswll, T. (eds.) Terrestrial Nitrogen Cycles. Ecol. Bull. (Stockholm) 33: 649-669.

Wright, H. A. 1970. A method to determine heat-caused motality in bunchgrass. Ecology 51: 582-587.

Wright, H. A. 1974. Range Burning. J. Range Management 27 (1): 303-308.

Wright, H. A. 1980. The role and use of fire in the semidesert grass-shrub type. USDA For. Serv. Gen. Tech. Rep. INT-85, Intermt. For. and Range Exp. Stn., Ogden, Utah.

Wright, H. A. and Bailey, A. W. 1982. Fire Ecology: United States and Southern Canada. John Wiley and Sons, New York, N. Y., 501 pp.

Wright, H. A., Churchill, F. M. and Stevens, W. C. 1976. Effect of prescribed burning on sediment, water yield, and water quality from dozed juniper lands in central Texas. J. Range Manage. 29: 294-298.

Wright, E. and Tarrant, R. F. 1957. Microbial soil properties after logging and slash burning. Pacific Northwest Forest and Range Exp. Stn., USDA Forest Serv. Res. Note 157, 5 pp.

Wright, R. F. 1976. The impact of forest fire on the nutrient influxes to small lakes in northeastern Minnesota. Ecology 57: 649-663.

Yarwood, C. E. 1961. Translocated heat injury. Plant Physiol. 36: 721-726.

Yates, S. A. 1974. An antecological study of sawgrass, Cladium jamdicense Crantz, in southern Florida. M. A. Thesis, University of Miami, Coral Gables, FL, 117 pp.

Zipprer, D. G. 1977. Fire management plan: Everglades conservation area. [unpublished mimeo.], Fla. Div. For., 19 pp.

Zontek, F. 1966. Prescribed burning on the St. Marks National Wildlife Refuge. Proc. Tall Timbers Fire Ecol. Conf. 5: 195-201.

APPENDIX A

FLORIDA ADMINISTRATIVE CODE ANNOTATED

The Official Compilation of the Rules and
Regulations of Florida Regulatory Agencies
filed with the Department of State under
the Provisions of Chapter 120, Florida Statutes

COMPILED BY
THE EDITORIAL STAFF OF THE PUBLISHER

VOLUME 2

Title 4 Department of Insurance
5 Department of Agriculture and
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RULES OF THE DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

DIVISION OF FORESTRY

CHAPTER 5I-2 RURAL OPEN BURNING

5I-2.01 General.

(1) Pursuant to the Florida Environmental Reorganization Act of 1975, Section 8, Chapter 75-22, Laws of Florida, 1975, all powers, duties and functions of the Department of Pollution Control relating to the regulation of open burning connected with rural land clearing, agricultural or forestry operations (except fires for cold or frost protection) are transferred by a type four transfer, as defined in Section 20.06(4), Florida Statutes, to the Department of Agriculture and Consumer Services. This rule chapter, except where specifically amended by the Department, is the transferred Rules of the Florida Department of Pollution Control as previously promulgated in Chapter 17-5, Florida Administrative Code.

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

5I-2.02 Declaration and Intent. The Department finds and declares that the open burning of materials outdoors and the use of outdoor heating devices result in or contribute to air pollution. The Department further finds that regulation of open burning and outdoor heating devices will reduce air pollution significantly.

It is the intent of the Department to require that open burning be conducted in a manner, under conditions, and within certain periods that will reduce or eliminate the deleterious and noisome effect of air pollution caused by open burning.

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

5I-2.03 Definitions. The following words, phrases, or terms when used in this chapter shall, unless the content otherwise indicates have the following meanings:

(1) "Air pollution" is the presence in the outdoor atmosphere of the state of any one or more substances or contaminants in quantities which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property, or unreasonably interfere with the enjoyment of life or property, including outdoor recreation.

(2) "Department" is the Department of Agriculture and Consumer Services.

(3) "Open burning" means any outdoor fire or open combustion of material which produces or may produce air pollution.

(4) "Outdoor heating device" means any apparatus, machine, equipment, or other contrivance in which is burned any type of fuel capable of producing air pollution, used outdoors for the purpose of giving protection from cold or frost.

(5) "Land clearing operation" means the uprooting or clearing of vegetation in connection with construction for buildings and rights-of-way, mineral operations, control of weeds, or enhancement of property value, but does not include site preparation; i.e., fires for the growing, raising, or harvesting of crops, timber, or wildlife.

(6) "Forced draft" is an adequate current of air, blown or forced by a fan or other mechanical means, which is directed or arranged in relation to the open burning in such a manner as to increase the temperature of the fire and to reduce or minimize the resultant pollution.

(7) "Excessive visible emissions" are air pollutants emitted in such quantity as to obscure an observer's view to a degree equal to or greater than Number Two (or 40% opacity) on the Ringelmann Smoke Chart as published in the U. S. Bureau of Mines Information Circular No. 7718.

(8) "Sunset" is official sunset as set forth by the U. S. Naval Observatory (tables are available at National Weather Services offices).

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

5I-2.04 Prohibitions. Any open burning not specifically allowed by this chapter is prohibited. No person shall ignite, cause to be ignited, permit to be ignited, suffer, allow, burn, conduct or maintain any prohibited open burning.

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

5I-2.05 Limitations. Nothing in this chapter may be construed to allow open burning which causes or constitutes a hazard to air traffic, which artificially reduces visibility on public roadway to less than 500 feet, or which violates other laws, rules, regulations, or ordinances.

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

5I-2.06 Agricultural and Silvicultural Fires.

(1) Open burning between the hours of 9:00 A.M. (standard time) and one hour before sunset (except fires for cold or frost protection) in connection with agricultural, silvicultural or forestry operations related to the growing, harvesting or maintenance of crops or in connection with wildlife management is allowed, provided that permission is secured from the Division of Forestry of the Department of Agriculture and Consumer Services prior to burning. The Division of Forestry may allow open burning at other times when there is reasonable assurance that atmospheric and meteorological conditions in the vicinity of the burning will allow good and proper diffusion and dispersement of air pollutants, and ready control of such fires within the designated boundaries.

(2) The Division of Forestry may suspend after reasonable notice any such permission whenever atmospheric or meteorological conditions change so that there is improper diffusion and dispersion of air pollutants which create a condition deleterious to health, safety, or general welfare, or which obscure visibility of vehicular or air traffic.

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

5I-2.07 Rural Land Clearing.

(1) Pursuant to the Florida Environmental Reorganization Act of 1975, Chapter 75-22, Section 8, Laws of Florida, 1975, this section applies to rural land clearing. See Section 17-5.07, Florida Administrative Code, for nonrural land clearing.

(2) Open burning of wooden material or vegetation generated by a land clearing operation (except for agricultural, silvicultural, or forestry operations) or the demolition of a structure is allowed provided one of the following alternatives is satisfied:

(a) The open burning is fifty yards or more from any occupied building or public highway and is performed between 9:00 A.M. (standard time) and one hour before sunset;

(b) At other times when:

1. The open burning is fifty yards or more from any occupied building or public highway and a forced draft system is used; or

2. The open burning if five-hundred yards or more from any occupied building or a public highway and the Department has given permission because of reasonable assurance that atmospheric and meteorological conditions in the vicinity of the burning will allow good and proper diffusion and dispersement of air pollutants, or

(c) The burning is conducted under the supervision of the Department of Transportation, a forced draft is used, and visibility on roadways is not artificially reduced to less than 500 feet.

(3) If the burning site is situated in a rural area or is adjacent to or near forest, grass, woods, wild lands or marshes, the Division of Forestry shall be notified and consulted prior to any burning.

(4) All open burning under this section shall be conducted in the following manner:

(a) The piles of material to be burned shall be of such size that the burning will be completed within the designated time given in paragraph 5I-2.07(2)(a).

(b) The moisture content and composition of the material to be burned shall be favorable to good burning which will minimize air pollution.

(c) The starter fuel and materials to be ignited shall not emit excessive visible emission where burned.

Specific Authority Section 8, Chapter 75-22, Laws of Florida, 1975, 403.061 FS. Law Implemented Section 8, Chapter 75-22, Laws of Florida, 1975, 403.021, 403.031, 403.061 FS. History—New 7-1-71, transferred from 17-5, 7-1-75.

APPENDIX B

FLORIDA ADMINISTRATIVE CODE ANNOTATED

The Official Compilation of the Rules and Regulations of Florida Regulatory Agencies filed with the Department of State under the Provisions of Chapter 120, Florida Statutes

COMPILED BY
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emissions shall be minimized.

(3) Excess emissions from existing fossil fuel steam generators resulting from boiler cleaning (soot blowing) and load change shall be permitted provided the duration of such excess emissions shall not exceed 3 hours in any 24-hour period and visible emissions shall not exceed Number 3 of the Ringelmann Chart (60 percent opacity), and providing (1) best operational practices to minimize emissions are adhered to and (2) the duration of excess emissions shall be minimized.

A load change occurs when the operational capacity of a unit is in the 10 percent to 100 percent capacity range, other than startup or shutdown, which exceeds 10 percent of the unit's rated capacity and which occurs at a rate of 0.5 percent per minute or more.

Visible emissions above 60 percent opacity shall be allowed for not more than 4, six (6)-minute periods, during the 3-hour period of excess emissions allowed by this subparagraph, for boiler cleaning and load changes, at units which have installed and are operating, or have committed to install or operate, continuous opacity monitors.

Particulate matter emissions shall not exceed an average of 0.3 lbs. per million BTU heat input during the 3-hour period of excess emissions allowed by this subparagraph.

(4) Excess emissions which are caused entirely or in part by poor maintenance, poor operation, or any other equipment or process failure which may reasonably be prevented during startup, shutdown, or malfunction shall be prohibited.

(5) Considering operational variations in types of industrial equipment operations affected by this rule, the Department may adjust maximum and minimum factors to provide reasonable and practical regulatory controls consistent with the public interest.

(6) In case of excess emissions resulting from malfunctions, each source shall notify the Department or the appropriate Local Program in accordance with Section 17-4.13, Florida Administrative Code. A full written report on the malfunctions shall be submitted in a quarterly report, if requested by the Department.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.05(14), Amended 8-26-81.

17-2.260 Air Quality Models. For any provision of Chapter 17-2 which requires that an estimate of concentrations of pollutants in the ambient air be made, the estimates shall be based on the applicable air quality models, data bases, and other requirements approved by the Department and specified in the Guideline on Air Quality Models (OAQPS 1.2-080 U. S. Environmental Protection Agency, April 1978). Any substitution for or modification of a model specified in the Guideline on Air Quality Models shall be approved in writing by the Department and the Administrator of EPA, and shall be subject to the public comment procedures contained in Section 17-2.220(1). Substitutions or modifications shall be justified in a manner consistent with the Workbook for the Comparison of Air Quality Models (OAQPS 1.2-097, U. S. Environmental Protection Agency, May, 1978). Copies of the above referenced documents may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., and may be inspected at the Department's Tallahassee office.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Amended 8-26-81.

17-2.270 Stack Height Policy. The degree of emission limitation required for control of any air pollutant for which a permit limitation or an emission limiting standard is established pursuant to Part V or Part VI of this chapter, shall not be affected by

(1) So much of a stack height, not in existence before December 31, 1970, as exceeds good engineering practice, or

(2) Any other dispersion technique not implemented before December 31, 1970.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Amended 8-26-81.

17-2.280 Severability. The provisions of this entire rule are severable. If one or more of the provisions should be invalidated, the Department intends that the other portions should become effective or remain in effect.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Amended 8-26-81, Previously 17-2-24.

17-2.290 Effective Date. The effective date of this rule shall be November 1, 1981.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Amended 8-26-81.

PART III AMBIENT AIR QUALITY

17-2.300 Ambient Air Quality Standards.

(1) The air quality of the State's atmosphere is determined by the presence of

specific pollutants in certain concentrations. Human health and welfare is affected and known or anticipated adverse results are produced by the presence of pollutants in excess of the certain concentrations. It is therefore, established that maximum limiting levels, Ambient Air Quality Standards, of pollutants existing in the ambient air are necessary to protect human health and public welfare.

(2) Air Quality Maintenance — Air Quality Standards Violated — No person shall build, erect, construct, or implant any new source or operate, modify or rebuild an existing source or by any other means release or take action which would result in release of air pollutants into the atmosphere of any region, which will, as determined by the Department, result in, including concentrations of existing air pollutants, ambient air concentrations greater than Ambient Air Quality Standards, except as provided in Sections 17-2.510 and 17-2.650, Florida Administrative Code. Ambient air quality monitors used to establish a violation of an ambient air quality standard shall meet the requirements of 40 CFR Part 58. A copy of the above referenced document is available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., and may be inspected at the Department's Tallahassee office.

(3) Ambient Air Quality Standards Established.

(a) Sulfur Dioxide.

1. Maximum three hour concentration not to be exceeded more than once per year — 1300 micrograms per cubic meter (0.5 ppm).

2. Maximum 24-hour concentration not to be exceeded more than once per year — 260 micrograms per cubic meter (0.1 ppm).

3. Annual arithmetic mean — 60 micrograms per cubic meter (0.02 ppm).

(b) Particulate Matter.

1. Maximum 24-hour concentration not to be exceeded more than once per year — 150 micrograms per cubic meter.

2. Annual geometric mean — 60 micrograms per cubic meter.

(c) Carbon Monoxide.

1. Maximum one hour concentration not to be exceeded more than once per year — 40 milligrams per cubic meter (35 ppm).

2. Maximum eight hour concentration not to be exceeded more than once per year — 10 milligrams per cubic meter (9 ppm).

(d) Photochemical Oxidants (measured and corrected for interference due to nitrogen oxides and sulfur dioxide).

1. Maximum one hour concentration not to be exceeded more than once per year — 160 micrograms per cubic meter (0.08 ppm).

(e) Nitrogen Dioxide.

1. Annual arithmetic mean — 100 micrograms per cubic meter (0.05 ppm).

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.06, Amended 8-26-81.

17-2.310 Maximum Allowable Increases (Prevention of Significant Deterioration Increments). In any area designated as attainment or unclassifiable pursuant to Sections 17-2.420 or 17-2.430, increases in pollutant concentrations over the baseline concentration shall be limited to the amounts set forth below. For any averaging period other than an annual period, the applicable maximum allowable increase may be exceeded during one such period per year at any one location.

(1) Class I Area Increments

(a) Particulate Matter

1. Annual geometric mean — 5 micrograms per cubic meter.

2. Twenty-four hour maximum — 10 micrograms per cubic meter.

(b) Sulfur Dioxide

1. Annual arithmetic mean — 2 micrograms per cubic meter.

2. Twenty-four hour maximum — 5 micrograms per cubic meter.

3. Three hour maximum — 25 micrograms per cubic meter.

(2) Class II Area Increments

(a) Particulate Matter

1. Annual geometric mean — 19 micrograms per cubic meter.

2. Twenty-four hour maximum — 37 micrograms per cubic meter.

(b) Sulfur Dioxide

1. Annual arithmetic mean — 20 micrograms per cubic meter.

2. Twenty-four hour maximum — 91 micrograms per cubic meter.

3. Three hour maximum — 512 micrograms per cubic meter.

(3) Class III Area Increments

(a) Particulate Matter

1. Annual geometric mean — 37 micrograms per cubic meter.

2. Twenty-four hour maximum — 75 micrograms per cubic meter.

(b) Sulfur Dioxide

1. Annual arithmetic mean — 40 micrograms per cubic meter.

2. Twenty-four hour maximum — 182 micrograms per cubic meter.

3. Three hour maximum — 700 micrograms per cubic meter.
Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.04(1), Amended 8-26-81.

17-2.320 Air Pollution Episodes. An episode describes a condition which exists when meteorological conditions and rates of discharge of air pollutants combine to produce pollutant levels in the atmosphere which, if sustained, can lead to a substantial threat to the health of the people. In order to prevent episode conditions from continuing or from developing into more severe conditions, positive action and a rapid abatement response is necessary. An air episode shall be classified as an air alert, warning or emergency depending on the severity of the episode, based on the criteria levels established in Sections 17-2.330, 17-2.340 and 17-2.350, below.

(1) Due to the exigent nature of named episodes the Secretary, pursuant to Subsection 120.59(3), Florida Statutes, shall determine and declare that an air pollution episode exists. The determination shall be in accordance with the following criteria:

(a) Air Pollution Forecast — The existence or forecast of a stagnant atmospheric condition as advised by a National Weather Service Advisory or by an equivalent state or local determination.

(b) Area of Episode — The Secretary shall, when declaring any episode level, declare the counties in which the episode exists.

(c) Termination — Once declared, any episode level will remain in effect until the pollutant concentration increases to meet the next higher level criteria or decreases to a point below the declared criteria level.

(2) Emission Reduction Plans and Actions — Upon a declaration by the Secretary than an episode level exists (alert, warning, or emergency) any person responsible for the operation or conduct of activities which result in emission of air pollutants shall take actions as required for such source or activity for the declared episode level as set forth in Sections 17-2.330, 17-2.340 and 17-2.350.

(3) Preplanned Abatement Strategies — Any person responsible for one or more air pollutant sources shall prepare and submit upon written request from the Department a standby plan which describes the action which will be taken by that person to reduce emissions when an episode is declared. The plan shall be submitted within 30 days of the request and will be subject to approval, modification or rejection by the Department. The plan shall be in writing and shall include but not be limited to:

(a) Identity and location of pollutant sources and of pollutants discharged.

(b) Approximate amount of normal emission and of reduction of emission expected.

(c) A brief description of the manner in which reduction will be achieved, for each of the episode levels, alert, warning and emergency.

(4) During an episode (alert, warning, or emergency) whenever any person responsible for the operation of a source or conduct of activities which result in emission of air pollutants does not take actions as required for the source or activity for the declared episode level or put into effect the Preplanned Abatement Strategy, the Secretary shall immediately institute proceedings in a court of competent jurisdiction for injunctive relief to enforce this chapter.
Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.07, Amended 8-26-81.

17-2.330 Air Alert.

(1) Alert Level Criteria — An "ALERT" shall be declared when any one of the pollutant concentration levels is reached at any monitoring site and with meteorological conditions such that this condition can be expected to continue for twelve (12) or more hours:

(a) Sulfur Dioxide (24 hour average) — 800 micrograms per cubic meter (0.3 ppm).

(b) Particulate Matter (24 hour average) — 375 micrograms per cubic meter or 3.0 COH_5.

(c) Sulfur Dioxide and Particulate Matter combined (24 hour average) — Product of SO_2 ppm, 24 hour average, and COH_5 equal to 0.2 or product of SO_2 micrograms per cubic meter, 24 hour average and particulate micrograms per cubic meter, 24 hour average equal to 65 X 10^3 .

(d) Carbon Monoxide (8 hour average) — 17 milligrams per cubic meter (15 ppm).

(e) Ozone (one hour average) — 200 micrograms per cubic meter (0.1 ppm).

(f) Nitrogen Dioxide

1. One hour average — 1130 micrograms per cubic meter (0.6 ppm).

2. 24 hour average — 282 micrograms per cubic meter (0.15 ppm).

(2) Curtailment Actions

(a) Generally

1. All forms of open burning are prohibited.

2. The use of incinerators for disposal of any form of solid waste or liquid waste is

prohibited.

3. Persons operating fuel-burning equipment which requires boiler lancing or soot blowing shall perform such operations only between the hours of 12 noon and 4 p.m.

4. Persons operating motor vehicles should eliminate all unnecessary operations.

(b) Fossil Fuel Steam Electric Generators—

1. Substantial reduction by utilization of fuels having low ash or sulfur content.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

3. Substantial reduction by diverting electric power generation to facilities outside of alert area.

(c) Process Steam Generating Facilities Burning Fossil Fuel —

1. Substantial reduction by utilization of fuels having low ash and sulfur content.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

3. Substantial reduction of steam demands consistent with continuing plant operations.

(d) Process Steam Generating Facilities Which Fire Wood, Bark or Bagasse; Totally or in Combination with Other Fuels.

1. Substantial reduction by switching to fossil fuels with low ash and sulfur content or by diverting steam demands to steam generators utilizing low ash and sulfur content fuels.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

3. Substantial reduction of steam demands consistent with continuing plant operations.

(e) Manufacturing Industries of the Following Classifications: Pulp and paper industry, Citrus processing industry, Mineral processing industry, Phosphate processing and allied chemical industry, Secondary metal industry, Petroleum operations.

1. Substantial reduction of air pollutants from manufacturing operations by enacting preplanned abatement strategies including curtailing, postponing or deferring production and all operations.

2. Curtail trade waste disposal operations which emit air pollutants.

(f) Bulk Handling Operations Which Transfer, Handle or Store the Following Materials: Cement, Fertilizer, Phosphate Rock, Grain or Feed, Run-of-Pile Triple Super Phosphate, Lime, Sand and Gravel, Dolomite.

1. Maximum reduction of fugitive dust by curtailing, postponing or deferring bulk handling operations.

(g) Any other industrial or commercial establishments which emit air pollutants.

1. Substantial reduction of air pollutants by curtailing, postponing or deferring operations.

2. Curtail trade waste disposal operations which emit air pollutants.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.07, Amended 8-26-81.

17-2.340 Air Warning.

(1) Warning Level Criteria — A "WARNING" shall be declared when any one of the following pollutant concentration levels is reached at any monitoring site and with meteorological conditions such that this condition can be expected to continue for twelve (12) or more hours.

(a) Sulfur Dioxide (24 hour average) — 1600 micrograms per cubic meter (0.6 ppm).

(b) Particulate Matter (24 hour average) — 625 micrograms per cubic meter or 5.0 COH_5.

(c) Sulfur Dioxide and Particulate Matter Combined (24 hour average) — Product of SO_2 ppm, 24 hour average, and COH_5 equal to 0.8 or product of SO_2 micrograms per cubic meter, 24 hour average and particulate micrograms per cubic meter, 24 hour average, equal to 261×10^3.

(d) Carbon monoxide (eight hour average) — 34 milligrams per cubic meter (30 ppm).

(e) Ozone (one hour average) — 800 micrograms per cubic meter (0.4 ppm).

(f) Nitrogen Dioxide

1. One hour average — 2260 micrograms per cubic meter (1.2 ppm).

2. Twenty-four hour average — 565 micrograms per cubic meter (0.3 ppm).

(2) Curtailment Actions

(a) Generally

1. All forms of open burning are prohibited.

2. The use of incinerators for disposal of any form of solid waste or liquid waste is prohibited.

3. Persons operating fuel burning equipment which requires boiler lancing or soot blowing shall perform such operations only between the hours of 12 noon and 4 p.m.

4. Persons operating motor vehicles must reduce operations by the use of car pools, increased use of public transportation and elimination of unnecessary operation.

5. Unnecessary space heating or cooling is prohibited.

(b) Fossil Fuel Steam Electric Generators—

1. Maximum reduction by utilization of fuels having lowest ash and sulfur content.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

3. Maximum reduction by diverting electric power generation to facilities outside of warning area or to generating stations emitting less pollutants per kilowatt generated.

(c) Process Steam Generating Facilities Burning Fossil Fuel —

1. Maximum reduction by utilization of fuels having the lowest available ash and sulfur content.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

3. Standby to enact preplanned emergency action plan.

(d) Process Steam Generating Facilities That Fire Wood, Bark or Bagasse; totally or in Combination With Other Fuels.

1. Maximum reduction by reducing heat and steam demands to absolute necessities consistent with preventing equipment damage.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

(e) Manufacturing Industries of the Following Classifications: Pulp and paper industry, Citrus processing industry, Mineral processing industry, Phosphate processing and allied chemical industry, Secondary metal industry, Petroleum operations.

1. Commence preplanned abatement strategies for the elimination of all air pollutants.

2. Elimination of air pollutants from trade waste disposal operations which emit air pollutants.

(f) Bulk Handling Operations Which Transfer, Handle or Store the Following Materials: Fertilizer, Phosphate Rock, Grain or Feed, Run-of-Pile Triple Super Phosphate, Cement, Lime, Sand and Gravel, Dolomite.

1. Elimination of fugitive dust by ceasing, curtailing, postponing or deferring transfer or storage of material.

(g) Any other industrial or commercial establishments that emit air pollutants.

1. Maximum reduction by curtailing, postponing or deferring operations.

2. Eliminate trade waste disposal operations which emit air pollutants.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.07, Amended 8-26-81.

17-2.350 Air Emergency.

(1) Emergency Level Criteria — An "EMERGENCY" shall be declared when any one of the following pollutant concentration levels is reached at any monitoring site and with meteorological conditions such that this condition can be expected to continue for twelve (12) or more hours.

(a) Sulfur Dioxide (24 hour average) — 2100 micrograms per cubic meter (0.8 ppm).

(b) Particulate Matter (24 hour average). 875 micrograms per cubic meter or 7.0 COH_5.

(c) Sulfur Dioxide and Particulate Matter Combined (24 hour average) — Product of SO_2 ppm, 24 hour average, and COH_5 equal to 1.2 or product of SO_2 micrograms per cubic meter, 24 hour average and particulate micrograms per cubic meter, 24 hour average equal to 393×10^3.

(d) Carbon Monoxide (eight hour average) — 46 milligrams per cubic meter (40 ppm).

(e) Ozone (one hour average) — 1200 micrograms per cubic meter (0.6 ppm).

(f) Nitrogen Dioxide

1. One hour average — 3000 micrograms per cubic meter (1.6 ppm).

2. Twenty-four hour average — 750 micrograms per cubic meter (0.4 ppm).

(2) Curtailment Actions

(a) Generally

1. All forms of open burning are prohibited.

2. The use of incinerators for disposal of any form of solid or liquid waste is prohibited.

3. All places of employment described below shall immediately cease operations.

a. Mining and quarrying of nonmetallic minerals.

b. All construction work except that which must proceed to avoid emergency physical harm.

c. All manufacturing establishments except those required to have in force an air pollution emergency plan.

d. All wholesale trade establishments; i.e., places of business primarily engaged in selling merchandise to retailer or industrial, commercial, institutional or professional users, or to other wholesalers, or acting as agents in buying merchandise for or selling merchandise to such persons or companies, except those engaged in the distribution of drugs, surgical supplies and food.

e. All offices of local, county and State government including authorities, joint meeting, and other public bodies except such agencies which are determined by chief administrative officer of local, county, or State government, authorities, joint meetings and other public bodies to be vital for public safety and welfare and the enforcement of the provisions of this order.

f. All retail trade establishments except pharmacies, surgical supply distributors, and stores primarily engaged in the sale of food.

g. Banks, credit agencies other than banks, securities and commodities brokers, dealers, exchanges and services, offices of insurance carriers, agents and brokers, real estate offices.

h. Wholesale and retail laundries, laundry services, cleaning and dyeing establishments, photographic studios, beauty shops, barber shops, shoe repair shops.

i. Advertising offices; consumer credit reporting, adjustment and collection agencies; duplicating, addressing, blueprinting; photocopying, mailing, mailing list and stenographic services; equipment rental services, commercial testing laboratories.

j. Automobile repair, automobile services, garages.

k. Establishments rendering amusement and recreational services including motion picture theaters.

l. Elementary and secondary schools, colleges, universities, professional schools, junior colleges, vocation schools, and public and private libraries.

4. All commercial and manufacturing establishments not included in this section will institute such actions as will result in maximun reduction of air pollutants from their operation by ceasing, curtailing or postponing operations which emit air pollutants to the extent possible without causing injury to person(s) or damage to equipment.

5. The use of motor vehicles is prohibited except in emergencies with the approval of local or state police.

6. Unnecessary lighting, heating, or cooling in unoccupied structures is prohibited.

(b) Fossil Fuel Steam Electric Generators

1. Maximum reduction by utilization of fuels having lowest ash and sulfur content.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing or soot blowing.

3. Maximum reduction by diverting electric power generation to facilities outside of emergency area or to generating stations emitting less pollutants per kilowatt generated.

(c) Steam Generating Facilities That Fire Coal, Oil, Natural Gas, Wood, Bark, or Bagasse.

1. Maximum reduction by reducing heat and steam demands to absolute necessities consistent with preventing equipment damage.

2. Maximum utilization of midday (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing or soot blowing.

3. Taking the action called for in preplanned emergency action plan.

(d) Manufacturing Industries of the Following Classifications: Pulp and paper industry, Citrus processing industry, Mineral processing industry, Phosphate processing and allied chemical industry, Secondary metal industry, Petroleum operations.

1. Continuation of preplanned abatement strategies for the elimination of air pollutants.

2. Elimination of air pollutants from trade waste disposal operations which emit air pollutants.

(e) Bulk Handling Operations That Transfer, Handle or Store the Following Materials: Cement, Fertilizer, Phosphate Rock, Grain, Run-of-Pile Triple Super phosphate, Lime, Sand and Gravel, Dolomite.

1. Elimination of fugitive dust by ceasing, curtailing, postponing or deferring transfer or storage of material.

(f) Any other industrial or commercial establishments which emit air pollutants.

1. Elimination of air pollutants by ceasing, curtailing, postponing or deferring operations.

2. Elimination of air pollutants from trade waste disposal operations which emit air pollutants.

Specific Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 FS. History—New 11-1-81, Previously 17-2.07, Amended 8-26-81.

PART IV AREA DESIGNATION AND ATTAINMENT DATES

17-2.400 Procedure for Designation and Reclassification of Areas.

(1) Designation or Redesignation of Attainment, Nonattainment, and Unclassifiable Areas.

(a) General Procedure (Reserved).

(b) Limitations on Redesignation — Areas redesignated as attainment or unclassifiable under this section and Section 107 (d), (1) of the Clean Air Act cannot intersect or be smaller than the area of impact of any facility or modification which:

1. Establishes a baseline date; or

2. Is subject to 40 CFR 52.21 or to Section 17-2.500, and would be constructed anywhere in the State.

(2) Designation and Reclassification of Class I, Class II, and Class III Areas.

(a) Designation and reclassification of an area may be proposed by filing a petition for Rulemaking with the Environmental Regulation Commission showing sufficient justification for such action provided that lands within the exterior boundaries of Indian