CHAPTER 8

SMOKE MANAGEMENT

OBJECTIVES

1) List major pollutants associated with wildland fire.
2) Identify smoke-sensitive areas and explain the designation of a Critical smoke –sensitive area.
3) List the current legal requirements for managing smoke produced during prescribed fires.
4) Identify situations that can lead to smoke related problems.
5) Relate the dispersion index and LVORI to smoke management for both day and night conditions.
6) Identify ignition strategies that reduce undesirable emissions.
7) Describe and implement the smoke screening system taught in this course.

References: Appendix E "*Introduction to Prescribed fire in Southern Ecosystems," 2012*

Note: This student Manual should also include a FFS smoke plotter

INTRODUCTION

Next to controlling the burn, smoke management may be considered the most critical element of using prescribed fire. The potential for smoke to create serious highway traffic hazards and public nuisances is real and must be included in prescription planning. We cannot control atmospheric conditions but we can and must control the effects of actions we initiate. If we are willing to use relatively simple guidelines that already exist and continue to seek improvements, we can demonstrate to both the public and regulatory agencies that prescribed burning can be conducted without adverse impacts to public safety or welfare.

Smoke management concerns are a major factor in determining if, when, and how to use fire to achieve resource management objectives. This is due to:

1) An increasing population that has limited knowledge of the benefits of prescribed fire
2) An increasing number of vehicles and roads
3) An increased awareness of potential deleterious health effects
4) A population that does not want to be temporarily inconvenienced
5) The increased likelihood of litigation
6) More restrictive rules and laws pertaining to the application of fire

Laws, rules, liability and operational costs are important considerations in every resource management program. Some of these issues can be resolved through better communications and education. All of these concerns deal with the safety and welfare of the public. Certified Prescribed burning is recognized by Florida Statues 590.125 as an

essential land management practice. The challenge for the prescribed burner is to maintain the benefits of prescribed fire while negating or mitigating adverse impacts. The prescribed burner must constantly review and update the process. The human habitat (rural, urban, and transportation corridors) has changed dramatically in the past 200 years. Prescribed fire practices must change and continue to change so that present day and future safety and welfare requirements are met.

Smoke management is a plan of action to conduct prescribed fires in such a way that the smoke produced is dispersed without causing a health or safety hazard. A smoke screening system should be used on every prescribed burn regardless of size or location. A commonly used system can be found in Appendix E. Proper smoke management dictates more planning, reduced burning opportunities, and more stringent mop-up requirements.

The benefits of smoke management include: the continued use of prescribed fire as a land management tool. Improved air quality through fewer smoke intrusions relating to prescribed burning which may equate to fewer complaints from the public due to the presence of smoke in the air. The reduction in litigation and associated liability costs.

DESCRIPTION OF TERMS:

Smoke Sensitive Area (SSA) are areas designated by the Florida Forest Service within which, for reasons of visibility, health or human welfare, smoke could unduly adversely impact public safety e.g., interstates/highways, urban areas, airports, schools and hospitals.

Critical Smoke Sensitive Area Critical smoke sensitive areas (CSSA) include any SSA's within the target area that have an existing or historically established problem. *Distance* to the burn makes a smoke sensitive area critical. This critical distance varies depending on fuels, conditions and firing technique. If a smoke sensitive area has demonstrated an *existing problem* under similar conditions then it is also a critical smoke sensitive area.

It also includes any SSA's that are within a 'critical' distance; which is defined as the first 10% of the impact distance as determined by fuel type and firing technique. For grass fuels the impact distance is 5 miles and therefore any smoke sensitive area within ½ mile (0.5 miles) of the burn unit is critical. For a logging debris burn the impact distance is 30 miles and any SSA within 3 miles is 'Critical.'

Mixing Height The altitude above which vertical mixing does not occur. Mixing heights below 1700 feet are often associated with pollution episodes.

Transport Wind Speed The average horizontal wind speed between the surface and the mixing height. Transport wind speeds below 9 MPH are often associated with pollution episodes.

Major Products of Rx Fire The major products of the combustion on a prescribed burn are water (H_2O) and carbon dioxide (CO_2).

Major Pollutants of Rx Fire The major pollutants are carbon monoxide (CO) and particulates.

Residual Smoke Smoke produced from smoldering combustion and not contained in a convection column. When flaming ceases, the convection dissipates and all subsequent smoke produced from smoldering combustion remains near the ground as residual smoke.

Local Viewpoint Individual land manager who is concerned about his smoke violating any regulation or creating a problem in an area sensitive to smoke.

Broad Viewpoint The viewpoint of the regulator or coordinator for a large area who must consider the collective impact of all smoke being produced by various sources.

SMOKE SENSITIVE AREAS

The definition we are using for a smoke sensitive area is 'any area where human health, visibility or welfare could be adversely impacted by smoke'. This is a broad definition. Interstate highways, hospitals, and airports are obvious examples. Others are not so obvious. Some smoke sensitive areas can tolerate significant levels of smoke while others cannot. The level of sensitivity can also vary with time and local responses.
Examples and discussion of Smoke-sensitive Areas:

1. Hospitals: Maintaining air quality around hospitals is an obvious priority. When hospitals are nearby, contact hospital managers well in advance. Establish and follow measures to prevent adverse impacts.

2. Airports: The primary concern around airports is maintaining visibility. Smoke from prescribed fires should not impair 'VFR' (visual flight rule) conditions. Visibility at major airports should be at least 5 miles.

3. Highways and public roads: Smoke related vehicle accidents and highway closures account for most of the current smoke management incidents in Florida. Proactive approaches work best. Signs and other information protocols can inform the public ahead of time. Per Florida Administrative Code 5I-2.004 (1) (f) Open burning which reduces visibility on paved public roadways to less than one thousand (1000) feet unless the regulating authorities have agreed to control traffic, or have delegated the authority to control traffic.
4. Schools: have a variety of issues unlike other sites. Society takes extra precautions to protect children. Parents, teachers and administrators will not hesitate when protecting children from real or perceived threats. Again, proactive approaches work best. Alternatives include wind directions that send the smoke

away from school and scheduling burns during periods when classes are out and no other activities are scheduled.

5. Recreation Areas: Most recreation areas are utilized on a seasonal basis. Peak use typically occurs on Holiday weekends and during special events.

6. Class I Areas: Designated federal lands where no degradation of air quality is permitted include the: Chassahowitzka National Wildlife Refuge, St. Marks Wildlife Refuge, Everglades National Park, and Bradwell Bay in the Apalachicola National Forest

7. 'Non-Attainment Areas' Areas that have been so designated for one of the criteria pollutants because the standard for that particular pollutant is being exceeded. The state is required to take additional steps to reduce the amount so the standard can be maintained. Since prescribed fire smoke is temporary, the standards might allow small amounts during periods when particulate concentration is low and dispersion is good.

8. Populated areas: There are additional areas that may be heavily populated on a seasonal or event specific basis. The prescribed burner should know when and where these events are scheduled. Both the event location and important travel arteries should be protected.

9. Special Cases: Additional areas may contain plants, animals, or other resources, which may be damaged by smoke. Orchid greenhouses, aviaries, zoos, and botanical gardens may contain plants or animals that are sensitive to smoke.

SMOKE MANAGEMENT BASICS

Smoke management incorporates three basic strategies. These strategies are avoidance, dispersion and reduction.

Avoid Smoke Sensitive Areas The burn plan should identify and map all smoke-sensitive areas that may be impacted~~,~~ burn only on days when the wind will take the smoke away from these areas. Most fires have an active burning and a residual burning period. Wind direction during both periods should be considered.

Disperse and Dilute Smoke Disperse and dilute smoke before it reaches smoke sensitive areas. Complete burning by mid afternoon. Smoke produced during active burning has several hours of robust weather to promote dispersion and dilution. It is good to dilute smoke when you prescribe burn when transport winds are greater than 9 mph and mixing heights are greater than 1700 feet. (Refer to Chapter VI and fire weather forecasts when planning and executing burns). The further the smoke travels from the burn unit the more it is dispersed even with slight changes in wind direction.

Avoid burning at night unless the predicted wind speed is greater than 5 mph and expected to blow all night and the predicted difference between the dew point and minimum temperature is 5 degrees or more.

Dispersion index is a tool that measures atmospheric stability or vertical air movement. Dispersion is calculated for daytime and nighttime operations. The numbers vary due to the potential for vertical air movement due to daytime heating and nighttime cooling effects. When burning during the day dispersion should be greater than 30 to prevent smoke related issues and less than 70 to prevent fire control issues. Dispersions greater than 70 have been known to lead to erratic fire behavior. Nighttime burning on the other hand can be accomplished when the dispersion remains at a six (6) or higher. A high nighttime dispersion usually is associated with winds staying strong all night allowing for the good vertical air movement.

Mixing height and transport winds play a vital role in dispersion. Review the established criteria and local conditions. It may be necessary to set minimum standards that are significantly above those associated with smoke management problems (MH=1700 ft and transport wind = 9 mph).

LVORI-Low Visibility Occurrence Risk Index is derived from the Dispersion Index and relative humidity, which gages the probability of visibility restrictions in fog or smoke. There are 10 LVORI categories; ranging from 1 (indicating the lowest probability of visibility restrictions) to 10 (indicating the highest probability of visibility restrictions). When planning a prescribed burn that may produce residual smoke into the evening this index should be referenced to see what the potential for visibility issues are.

The combination of smoke particulates and high moisture levels can result in dense fog as the water droplets adhere to the smoke particles which may lead to visibility dropping to near zero. This index is part of the Fire Weather Forecast issued by the National Weather Service in the morning then updated during the afternoon weather. Prescribe burn when the LVORI is predicted to be less than 7 or reduce the size of the area to be burned and begin mop up quickly.

Reduce Emissions The third strategy to minimize smoke problems is to reduce emissions. There are varieties of techniques, which can help reduce emissions, but their effectiveness can vary depending on site conditions during the burn.

Uses of firing techniques such as backing fires produce fewer emissions than other techniques. Backing fires promote complete combustion, which means particulate matter is reduced and less carbon monoxide is produced. Head fires promote incomplete combustion as indicated by particulate laden black smoke. When the same fuels are consumed, backing fires produce about ½ the particulate matter of a head fire. Backing fires move slower, it takes longer to complete the burn and this increased residence time favors the consumption of more fuel.

Preparing the area prior to and during the prescribed burn can help prevent fuels from igniting. Prior to the burn, flag and fireproof large concentrations of downed woody material or snags to help prevent ignition. During the burn holding crews should be monitoring the line and prepping downed material and snags prior to the ignition team igniting the area. If material does ignite the holding crews should begin suppression actions (mop-up) as soon as the area is safe to enter.

Regardless of firing technique, the prescribed burner needs to select conditions and techniques that reduce the amount of duff consumed and larger debris ignited. Moisture content of these fuels is the key. The Keetch Byram Drought Index (KBDI) and recent rainfall are two indicators of the moisture that may be present within the unit you intend to prescribe burn. Both of these indicators are site specific and only an approximation for the burn unit. Examine onsite conditions by looking at the duff and larger fuels throughout the unit. Small isolated patches of dry duff or exposed tips of large fuels can nurture and spread ignition unless steps are taken to extinguish these burning fuels producing residual smoke. Smoldering fuels and residual smoke can be further reduced by completing the burn early and starting mop-up as soon as practical.

Smoke is monitored beginning with the test fire. If the test fire is producing hazardous conditions, the prescribed burner must shut down the burn and try again at a latter date. However, if the test fire starts out as predicted and conditions change during the course of the prescribed burn making your smoke hazardous to a smoke sensitive area it may become necessary to shut down the burn. This is not always an easy process but good contingency planning will enhance the outcome. For example, a staged ignition plan utilizing existing interior firebreaks can facilitate burning different portions of the unit in an orderly process that also facilitates shut down at specific stages.

Four Phases Of Combustion related to smoke production:

1. **Pre-ignition Phase:** As the temperature rises, the woody material decomposes releasing combustible gases and vapors (pyrolysis). Some of these materials are burned in the flaming combustion phase; others condense into particles that become visible smoke.

2. **Flaming Phase:** The major products of flaming combustion are predominantly carbon dioxide and water vapor. Some of the organic compounds produced cool and condense into tar droplets and solid soot particles as they move away from the heat of the fire. These particles make up the visible smoke component with which we are primarily concerned. The more inefficient the burning, the more soot and tar produced.

3. **Smoldering** Phase (slow flameless combustion): NOTE: This phase of combustion is the most critical in terms of its potential for causing serious

injuries, deaths and property damage. Emissions from a smoldering fire are at least twice that for flaming fire.

Residual smoke is defined as the smoke produced from smoldering combustion and not contained in a convection column. When flaming ceases, the convection dissipates and all subsequent smoke produced from smoldering combustion remains near the ground as residual smoke.

RESIDUAL SMOKE: SPECIAL PROBLEMS ARISE FROM A PRESCRIBED FIRE IF RESIDUAL SMOKE PERSISTS INTO THE NIGHT OR FOR MULTIPLE DAYS. In flat terrain, wind usually is minimal at night, causing smoke density to build up in the vicinity of the burn area. Even in apparently flat areas, smoke will follow the same contours (drainages) that water travels and 'settle' in low areas. If residual smoke settles over a public highway and the wind speed is less than 5 mph and the relative humidity is high, you have ideal conditions for a dense fog with close to zero visibility to form over the highway.

4. **Glowing Phase:** The glowing phase is a relatively rapid but flameless combustion process. Those familiar with grilling with charcoal know this phase well. This is the phase when the charcoal briquettes are red hot. This phase is an efficient combustion process and produces virtually no smoke.

Background Before starting the smoke screening process two types of maps are required. The first map is a smoke screening map that covers the general vicinity. These maps should be able to cover a 30-mile radius surrounding the burn unit. Locate and mark all smoke sensitive areas (SSA) on these maps. If you are aware of areas that are prone to fog these areas should be indicated on the map as well.
The second is a map of the burn unit. Use this map to identify potential smoke hazards within the burn unit ie. Debris piles, large number of dead standing snags, possible blown down timber.

Once you have identified smoke sensitive areas the next step is to determine the acceptable level of smoke impact for each SSA. Later in this chapter we will discuss a five step process for smoke screening that will help you plan a course of action for successfully conducting a prescribe burn in close proximity to smoke sensitive areas.

SMOKE SCREENING A FIVE-STEP PROCESS

Refer to the smoke screening process described in Appendix E. The following is only a brief overview. To complete the process you must refer to and follow the instructions in Appendix E.

1) Plot Probable Smoke Impact Area

Use a smoke plotter and your desired wind direction plot the smoke impact area. Use an administrative map that allows you to identify smoke sensitive areas. An example of an administrative map includes: DOT county highway map, Florida Gazetter, Map Source maps, or some form of electronic mapping program. The smoke plotter allows you to plot the impact area with an allowance for minor wind shifts. This is accomplished by including the area within a 30^{o} arc in either direction from the desired wind. It is important to position the plotter in a manner that encompasses the entire burn unit.

2) Identify Smoke Sensitive Areas

Once the smoke impact area has been delineated, all smoke sensitive areas should be identified and marked.

A. If there are no smoke sensitive areas in the impact zone then you may burn as planned.

B. If there are smoke sensitive areas in the impact zone and if the burn unit contains organic soils that are likely to ignite then do not burn.

C. If any smoke sensitive areas are found continue screening.

3) Identify Critical Smoke Sensitive Areas

Determine the primary impact zone downwind:
Distance based on fuel and firing technique and mark on map.

Fuel Types	Smoke Sensitive Area (SSA) Distance	Critical Smoke Sensitive Area (CSSA) Distance
Grass		
All firing techniques	5 miles	½ mile
Palmetto/gallberry		
Backing fire or spot ignition	10 miles	1 mile
Heading Fire	20 miles	2 miles
Logging Slash		
All firing techniques	30 miles	3 miles
Other fuel types		
Backing fires	5 miles	½ mile
Heading fires	10 miles	1 mile
Fires of 250 acres or more	10 miles	1 mile

Remember to look down drainage ½ the Smoke Sensitive distance and mark the impact zone on the map. This is the night time impact area with light winds.

A. If any Critical Smoke Sensitive Areas are found within the probable smoke impact area do not burn.

B. If no critical smoke sensitive areas are found continue screening.

4) Determine Fuel Type and Loading

Determine the fuel type based on the list provided (Appendix E). Determine the approximate fuel loading and follow the procedures indicated. If all criteria have been met then proceed to step 5.

5) Minimize Risk Checklist

If any smoke sensitive areas may be affected by the proposed burn then these additional steps are required.

- Mixing Height 1700 feet or more
- Transport wind speed 9 mph or more
- Background visibility at least 5 miles within plotted area
- If rough is older than 2 years, use a backing fire. Other firing techniques may be used if the burn can be completed at least *3 hours before sunset* or if *no sensitive areas are located in the first half of the impact area.*
- Promptly mop-up and monitor to minimize smoke hazards.
- If a smoke sensitive area is in the overlapping trajectory of two smoke plumes, it should be 1 mile from either source (two miles if one is logging debris).
- For night burns, backing fires with surface wind speed greater than 4 mph and relative humidity under 80 % should be prescribed.
- If it appears that stumps, snags, or logs may cause a residual smoke problem, take steps to keep them from burning. If they do ignite, extinguish them.
- Daytime value of the Dispersion Index between 30 and 70 is adequate for small fire and low levels of burning activity. As either size of individual fires or level of burning activity increases, the lower limit of the Dispersion Index value should also increase.

Many variables affect the behavior and resulting smoke from a prescribed burn. This system works best in flat terrain and is not designed for mountainous country. It does not consider all variables: it only offers broad guidelines. If your prescribed burn complies with all conditions in this process you should be able to safely burn without causing a smoke problem. If you have any marginal answers, areas that are especially sensitive to smoke, heavy fuel loadings or wet fuels use a more suitable prediction system in conjunction with state and federal agencies.

Additional Considerations

1) Patrol and monitor Critical SSA's
2) Check the moisture condition of duff or peat in all fuel types prior to test fire
3) Have informational signs ready for deployment
4) Request law enforcement and suppression assistance in a timely manner (Advance notification)
5) Be prepared to put fire out
6) Have access to updated weather forecasts including
7) Before leaving the burn site check the entire burn unit for smoldering fires
8) Monitor residual smoke as required (see note below)
9) If residual smoke is excessive initiate action plan and call FFS
10) Avoid burning into dry swamps

NOTE The majority of automobile accidents in Florida where smoke is listed as a contributing factor involve a combination of smoke and fog. The majority of theses accidents occur between 10 PM and 9 AM. Consider this before you leave your burn site. The smoke involved in these accidents is usually residual smoke and quite often the residual smoke is from muck fires, in dry swamps, excessive duff burning, or from burning piles. Checking the fire after 9:00 AM the day after the burn is too late to determine if residual smoke is going to be a problem.

. State Laws and Rules Concerning Smoke

1. Authorization required from Florida Forest Service.
    a. FLORIDA FOREST SERVICE may restrict burning or cancel authorization if burning under 51-2.06 creates a condition that is deleterious to health, safety or general welfare.
    b. FLORIDA FOREST SERVICE authorizations generally require burning to be done between 8 am Central 9 am Eastern and one hour after sunset for a certified prescribed burn manager.
    c. Burning at other times may be allowed when certain conditions are met.

2. Smoke from the burn must not reduce visibility on public roadways to less than 1000 feet.

3. Burns must not violate local laws, rules, regulations, or ordinances.

Smoke Screening Example

Examples of the smoke screening process will be reviewed during the class session and during field exercises.

SUMMARY

Try and reduce or dilute your smoke. Burn when weather conditions favor good smoke dispersal, Mixing heights of 1700 feet or greater, transport winds at 9 mph, and a dispersion above 30. Identify all known smoke sensitive areas within you impact zone and take precautions to minimize smoke intrusions into these areas.

The potential for smoke to create serious highway traffic hazards and public nuisances is real and therefore, smoke management must be included in prescription planning. We cannot control atmospheric conditions, but we can and must control the effect of actions that we initiate. If we are willing to use relatively simple guidelines that have already been developed, and continue to search for better ones, we can demonstrate to regulatory agencies and the public that we act responsibly and will avoid adverse impacts on public safety and welfare.