Texas Smoke Management Guide

Revised January 2024

TEXAS A&M FOREST SERVICE

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Executive Statement

The Texas A&M Forest Service Smoke Management Guide (SMG) is designed to give guidance toward smoke management during prescribed burning The SMG is not expected to contain a complete set of answers to solve all smoke-related problems. Guidance in this document is designed to support burn managers decisions and actions that may reduce smoke impacts from prescribed fire. The SMG does not relieve the private landowner or company conducting the burn from liability for fines or damages that might occur or transfer any liability to the state. Texas A&M Forest Service recommends that a trained, experienced, and certified burn boss prepare the burn plan and conduct all prescribed burns. Texas A&M Forest Service prescribed fire burn managers are certified by the National Wildfire Coordinating Group (NWCG). Other agencies and burn practitioners may have different certifications or licenses according to their governing entity's protocols and guidelines."

The law in Texas related to smoke and emissions from prescribed fires can be found in Texas Commission on Environmental Quality Ch 111. 201-219. This SMG was written with these laws in mind. Prior to burning, refer to TCEQ code to ensure the burn is conducted within allowable limits.

Special thanks to Sean Luchs with the National Weather Service Houston office for providing technical guidance toward the smoke modeling section.

Introduction

Prescribed fire is recognized as an important forest and rangeland management tool in Texas and across the Southeastern United States. Prescribed burning has a positive and direct impact toward improving ecosystem health. Some specific benefits of prescribed fire include reducing invasive or competing vegetation, site preparation for planting, and forest or watershed health. Not only does prescribed fire serve as a resource management tool, but it also increases public safety by reducing fuels and the intensity of future wildfires. The application of prescribed fire reduces the density of hazardous fuel, which can lower wildfire intensity and help protect lives and property. Although prescribed fire provides many benefits to public safety and ecosystem health, it does produce a hazardous byproduct: *smoke.*

Smoke generated from prescribed fires can decrease air quality and aggravate health problems. Smoke can reduce visibility and result in dangerous roadway conditions. The general sight and smell of smoke can also be a nuisance to people with limited knowledge about prescribed fire as an important land management tool.

Texas is home to over 29 million people as of July 2021. According to the U.S. Census Bureau, the population of Texas increased by 15.9% between 2010 and 2020. A direct result of the increasing population is the increase of the wildland urban interface (WUI). The WUI is where homes and communities are adjacent or intermingle with undeveloped land and fuels. WUI areas have a high potential of being impacted by smoke as prescribed burning occurs.

Texas A&M Forest Service will use this smoke management guide (SMG) as a support document during the implementation of prescribed fire on public lands. This SMG serves as guidance for Texas A&M Forest Service burn managers and personnel when conducting burns as well as a general reference and tool for the public.

Mission Statement

The SMG establishes best management practices to limit impacts on air quality and smoke sensitive areas before, during, and after burning. The guide is also designed to provide educational material and references for proper smoke management across the state. The SMG will be reviewed periodically to refine and improve smoke management guidance.

Smoke Management Process

Prescribed fire smoke is a mixture of small particles, water vapor, carbon dioxide, ash, organic material, and other invisible gases. Composition of smoke will vary between different fuel types being consumed. Particulate Matter (PM) levels are measured in micrometers. The Environmental Protection Agency defines PM of 2.5 micrometers as the base threshold to determine respiratory and visibility impacts *(Figure 1; Environmental Protection Agency, 2017).*

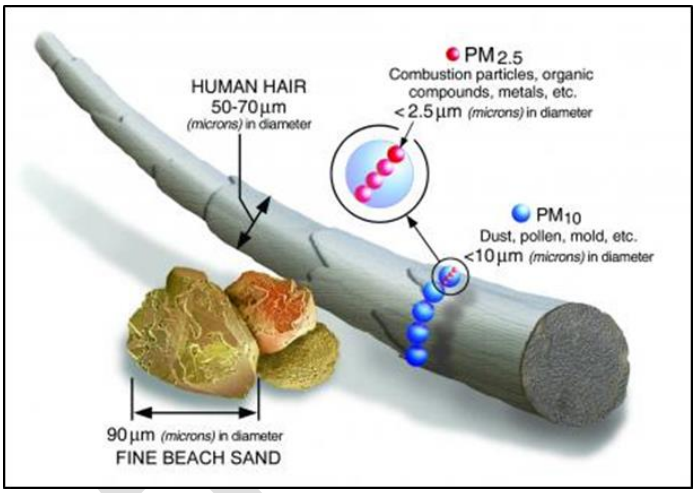

Figure 1: Particulate matter (PM) size comparison

A consistent process to best manage smoke will help prescribed fire managers complete the burn objectives and reduce smoke impacts (Table 1). The following five steps for smoke management are recommended to determine if the burn can be conducted when fuel and weather conditions are appropriate for burn objectives.

Table 1: Smoke management process to minimize prescribed fire smoke impacts

Action	Purpose	Recommended Completion
Identify Smoke Sensitive Areas	To plan for potential impacts	When writing the burn plan
Develop Smoke Contingency Actions	Have pre-determined actions known if smoke becomes hazard	When writing the burn plan
Determine Category Day	Provide guidance on smoke dispersion based on Transport Winds and Mixing Height	Day Before and Day of Burn
Configure Smoke Model	Have documented predicted movement of smoke if burn is complex or large	When writing the burn plan and Day of Burn
Check Air Quality Index	Determine if smoke will reduce air quality to high levels of health concerns	Day of the Burn
Smoke Observations	Monitoring Smoke Impacts	During the Burn and After

Smoke Sensitive Areas

Identifying smoke sensitive areas (SSA) is the first and most important step in determining potential impacts from prescribed fire smoke. A SSA contains sensitive receptors such as people, livestock or crops, as defined in the Outdoor Burning Rule, Title 30, Texas Administrative Code, Sections 111.201–221. Sensitive receptors are susceptible to negative impacts from prescribed fire smoke, as those areas with high volumes of traffic either on major roadways or airspace. SSAs should be identified while writing the burn plan and before the burn occurs. Determining the distance from the burn unit within which to identify SSAs will depend on the size of the burn, fuel type, and results of smoke model outputs.

If smoke models and weather conditions indicate that an SSA will be impacted, mitigation will be needed to reduce smoke impacts at these areas or the burn will be postponed until a time the SSA is no longer at risk of being impacted by smoke. Steps that can be taken include reducing the size of the burn, using a different burn technique (e,g,. back burn) or utilizing wind directions that will not adversely affect SSAs.

The following are examples of smoke sensitive areas:

- Nursing Homes/Hospitals
- Schools
- Designated “Class 1” areas of Texas located at Big Bend National Park and Guadalupe Mountains National Park
- Airports
- Interstate Corridors
- Chemical Emission Factories
- Livestock/Crops (nursery plants, cultivated mushrooms, plants used for pharmaceutical drugs)
- Residential Homes

Identifying Smoke Sensitive Areas

After identifying SSAs adjacent to the burn unit and a burn plan and finishing a burn plan that includes weather and fuel parameters, the burn boss should model potential smoke impacts. This can be done using the internet based Simple Smoke Screening Tool or hand-drawn 30° diagram.

The Simple Smoke Screening Tool is a web-based smoke modeling tool hosted by the Mississippi Forestry Commission that uses simple graphical smoke screening system produced in the Southern Smoke Management Guide. When utilizing the tool, a burn boss may navigate to Texas and input fuel and weather parameters to view any potential impacts on air quality for SSAs.

The first zone, (colored red in Figure 2) is used to identify *critical smoke-sensitive areas*. This is the most probable smoke impact area. If smoke-sensitive targets within this critical zone, burning is not recommended under the current prescription. The other zone (yellow) shows an area of less severe smoke impact (Figure 2). A KML file can be exported and opened in Google Earth if desired *Figure 3).*

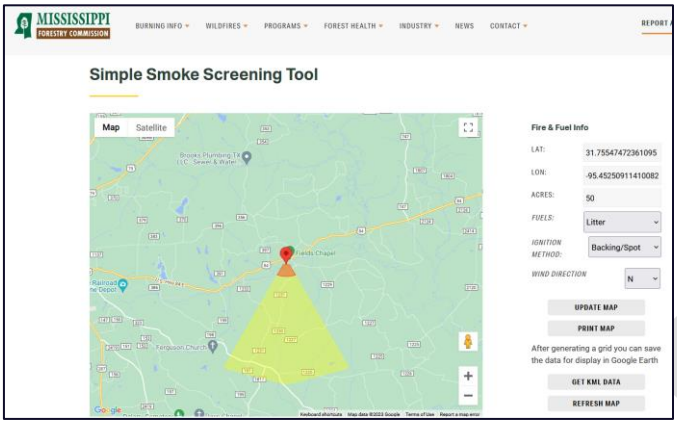

Figure 2: Determine smoke sensitive areas with Simple Smoke Screen

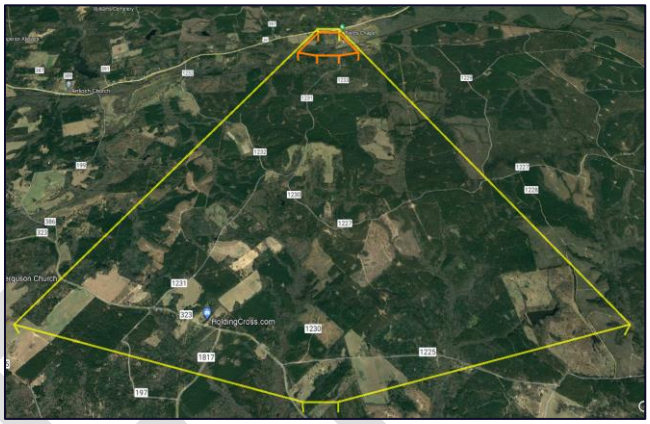

Figure 3: Simple Smoke Screen and produce a KML file to be used in Google Earth for additional planning.

A hand drawn 30° smoke diagram can also determine the general smoke path and potential impacts. Based on wind direction written in the burn plan, the burn boss can draw a line of predicted smoke trajectory for a small burn (Figure 4). Additional lines drawn 30° on both sides of the smoke trajectory provide guidance for minor shifts in general wind direction.

For large burns (Figure 5), the burn boss should draw a line from the center of the burn unit and then lines in the same direction at both ends of the unit and add the 30° vector line. Using this method, the burn boss can identify any SSA that may be impacted. If SSAs are within this vector, decisions should be made or actions completed to minimize smoke production and impacts.

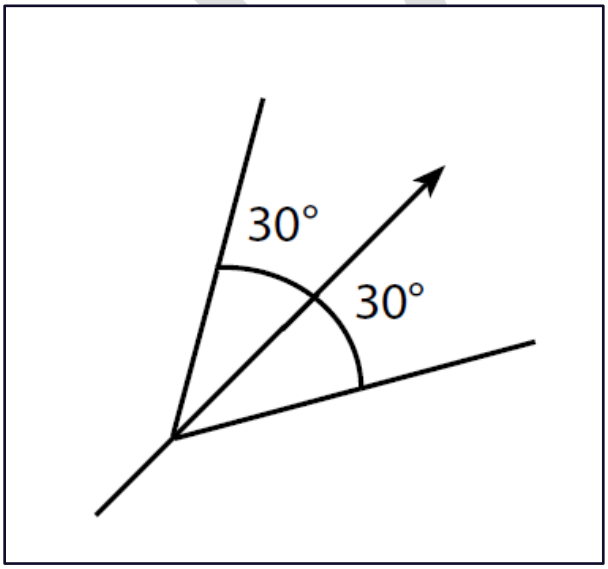

Figure 4: Determine general smoke path with wind

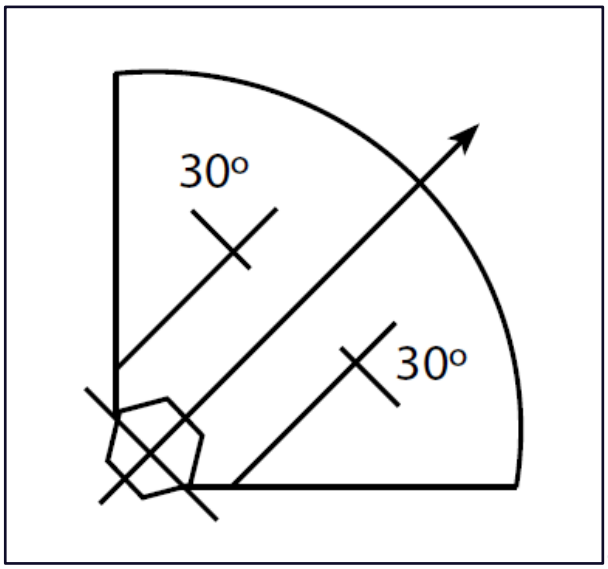

Figure 5: General smoke path for large burn

Develop Proactive Smoke Impact Actions

The burn boss should determine if any proactive actions can be completed prior to burning to limit prescribed fire smoke impacts. The following questions need to be addressed:

- What can be done prior to burning to reduce smoke production?
- Do adjacent landowners and SSAs need to be notified before burning? If so, how?
- What actions need to take place if smoke begins to affect an SSA?
- What actions need to take place if smoke starts to settle on a roadway?

Smoke Reduction

Depending on the prescribed fire objectives, actions can be taken before and during a prescribed fire to reduce the amount of smoke produced. The following are several recommended actions to consider before and during the burn to reduce smoke production:

- Thin or reduce fuel loading in the burn unit prior to burning.
- Burn unit in smaller sections over a period of time.
- Adjust firing technique to reduce amount of fuels consumed and smoke produced.
- Do not burn if smoke production will cause negative impacts toward SSAs.

Additional details about smoke reduction techniques can be found in the NWCG Smoke Management Guide for Prescribed Burning (2020) at https://www.nwcg.gov/sites/default/files/publications/pms420-3.pdf

Public Notification

The following actions are recommended for public awareness of a prescribed burn occurring in an area.

- Provide written or verbal statement of prescribed burn operation and smoke production to Texas A&M Forest Service *(Texas Administrative Code 111.217 and 111.219)*
- Post "Prescribed Fire in Progress" signs in proximity of state and interstate roadways. Signs should be posted on the morning of the burn by an individual designated by the burn boss. It is also recommended that flashing lights be fixed to the signage for nighttime viewing.
- Possible social media notifications for burn area (This will be a standardized post to cut down on the time factor and the discrepancies between different areas. Coordination with communication department needed for Texas A&M Forest Service social media accounts).

Laws specific to public notifications, written consent from neighboring landowners and flag persons posted on roadways are included in the Outdoor Burning Rule, Title 30, Texas Administrative Code, Sections 111.211 and 219 as well as the Texas Administration Code, Title 4, Part 13, 228.2.

Visibility on Roadways

The prescribed burn boss or manager is responsible for the smoke impacts on roads near the burn unit. Alerting motorists of smoke impacts from a prescribed burn may be done with the placement of prescribed burn signs along road(s) adjacent to the burn unit. Monitoring conditions and reduced visibility on roads should be done throughout the entire burn operations. Priority should be given to nighttime visibility. Based on visibility, the actions below are recommended (Table 3*)*. The NWCG Smoke and Roadway Safety Guide provides additional reference material in regards to managing prescribed fire smoke around roadways https://www.nwcg.gov/sites/default/files/publications/pms477.pdf.

Table 2: Mitigation actions associated with reduced roadway visibility from prescribed fire smoke

Visibility on Roadway (feet)	Recommended Action
300 +	Continue to monitor
< 300	Slow traffic to 25 mph (use pilot cars)
< 200	Slow traffic to 15 mph (use pilot cars)
<100	Start one-way traffic
< 50	Close the road to traffic *(Adjust burn technique to clear roadway, or shut down burn and begin mop-up)*

National Weather Service Tools

Fire Weather Forecasts

Texas is served by 13 National Weather Service (NWS) offices each with a fire weather forecast page https://www.weather.gov/srh/nwsoffices . At a minimum, prescribed fire manager should utilize NWS fire weather text forecasts the day of the planned prescribed fire (Figure 6). Spot weather forecasts are available and may be requested by government officials/burn bosses only.

Latest Fire Weather Forecast (FWFSHV)

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000
FNUS54 KSHV 221022
FWFSHV

Fire Weather Planning Forecast for Southwest Arkansas...
Northwest Louisiana...East Texas...and Extreme Southeast Oklahoma
National Weather Service Shreveport LA
422 AM CST Wed Feb 22 2023

.DISCUSSION...
Strong southerly winds expected today ahead of a dryline that will move
across the region tonight. Additionally, showers will be possible across
much of the region today with some thunderstorms possible mainly across northeast
Texas, southeast Oklahoma, and southwest Arkansas. Afternoon high temperatures today
will range from the mid 70s across the I-30 corridor to the lower 80s across deep
east Texas and north Louisiana. Otherwise, afternoon relative humidity values will
range from the mid 30s across east Texas to the mid 60s across Arkansas and Louisiana.
With strong winds and low relative humidity values, an elevated wildfire risk exists
across northeast Texas and southeast Oklahoma in advance of any rainfall that is forecast
to occur today.
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Figure 6: Example of routine NWS fire weather planning forecast

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TXZ136-149>153-222230-
Smith-Cherokee-Rusk-Panola-Nacogdoches-Shelby-
Including the cities of Tyler, Jacksonville, Rusk, Henderson,
Carthage, Nacogdoches, and Center
422 AM CST Wed Feb 22 2023

                    Today       Tonight     Thu

Cloud Cover         Pcldy       Mclear      Pcldy
Precip Type         Showers     None        None
Chance Precip (%)   50          0           0
Temp (24h trend)    82 (-2)     56 (-11)    79
RH % (24h trend)    36 (-15)    100 (+14)   35
Wind 20ft/early(mph) S 19 G34   S  9        W  5
Wind 20ft/late(mph) SW 14 G24   S  9        NE  6
Precip Amount       0.03        0.00        0.00
Precip Duration     2                       
Mixing Hgt(m-agl/msl) 1570                  1090
Mixing Hgt(ft-agl/msl)5140                  3570
Transport Wnd (m/s) SW 11                   NE  4
Transport Wnd (mph) SW 24                   NE  8
Vent Rate (m/s-m)   17270                   4360
Vent Rate (mph-ft)  123360                  28560
Category Day        5                       3
Dispersion          Excellent               Good
Mix Hgt 500         68                      68
Stability Class     D           F           C
```

Figure 7: Zone fire weather forecast information

Reference conversions: 1 meter (m) = 3.28 feet (ft) / 1 knot (kt) = 1.15 miles per hour (mph)

Mixing Height and Transport Wind Reference

The **mixing height**, given in feet, is defined as the height to which pollutants are transported vertically due to turbulent or mechanical mixing. In other terms, it is the height that wildfire smoke will readily reach through convection (Figure 8). The layer of air between the surface and the mixing height is known as the mixing layer or well-mixed layer.

Days with high mixing heights allow the smoke plume to be transported high vertically. Nights typically have very low mixing heights and tend to trap smoke in the near-surface layer. This situation may bring hazardous air quality. Like temperature, the mixing height will vary significantly across regions. And like temperature, you may want to know what the average mixing height is for your location and time of year. Days with above-average mixing heights tend to be warmer, drier, and gustier than days with below average mixing height. These are the types of conditions can lead to an increase in fire behavior. Additional information can be found in NWCG Guide to Fire Weather Forecasts, 2021,PMS 425, https://www.nwcg.gov/publications/pms425.

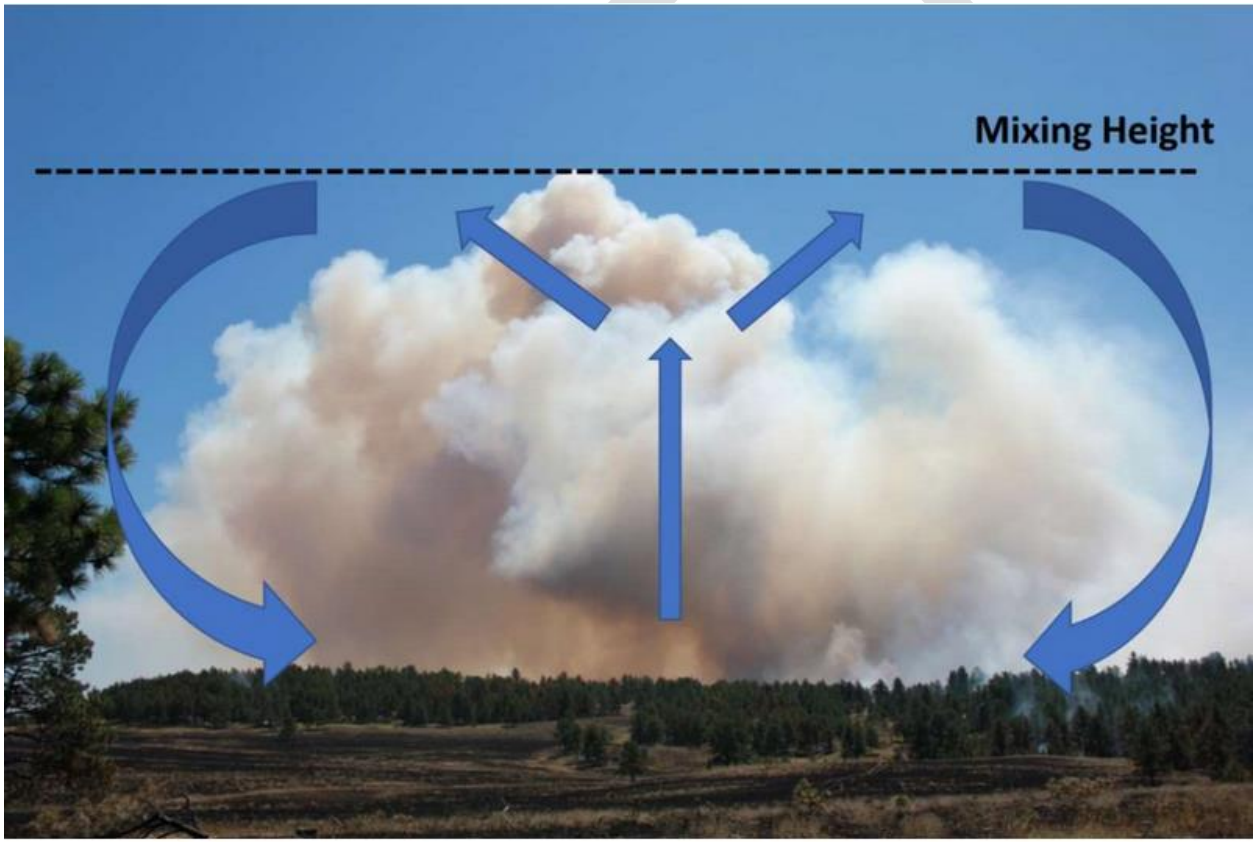

Figure 9: Example of smoke's vertical motion and mixing in the lower atmosphere

The **transport wind**, (Figure 10) is defined as the average wind speed, in knots, and wind direction through the depth of the mixing layer. This is the wind that will directly impact the smoke plume and has serious implications to smoke management. It is used in calculations for smoke dispersion. The transport wind may also give you an indication of the direction of potential long-range spotting. Additional information can be found in NWCG Guide to Fire Weather Forecasts, 2021,PMS 425, https://www.nwcg.gov/publications/pms425).

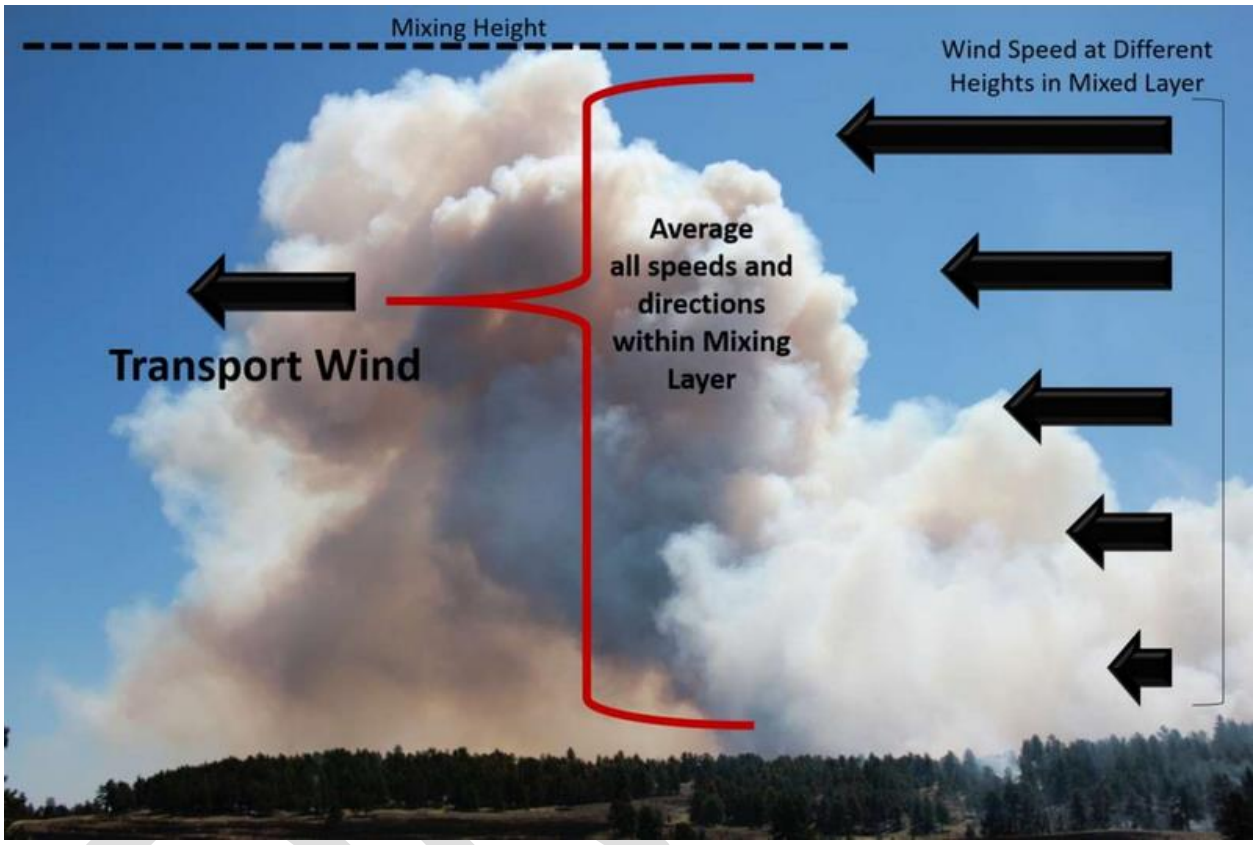

Figure10: Example of how wind speeds throughout the mixing height contribute to the transport of smoke horizontally

Category Day

A Category Day (Table 3) forecast can provide a burn manager guidance toward the dispersion and movement of smoke. The National Wildfire Coordinating Group (NWCG) defines category day as a numerical index related to the atmosphere ability to disperse smoke typically using ranges 1 (poor) to 5 (excellent). Due to the large geography of Texas and varying climate, there is no single standard Category Day calculation using mixing height and transport wind speeds. Burn managers should be aware that not all National Weather Service offices that serve Texas provide Category Day forecasts in a spot weather forecast or daily fire weather text forecast.

Table 3: Category Day and relation to smoke dispersion

Category Day	*Recommended Guidelines*
1	**No Burning, Mixing Height and Transport Winds too low to disperse smoke**
2	**No burning until after 10 AM and not before surface inversion has lifted. Recommended fire operations near completion by 4 PM for sufficient ventilation**
3	**Daytime burning only,but not before surface inversion has lifted**
4	**Burning Anytime**
5	**Unstable and Windy, Excellent smoke dispersal, burn with caution**

Supplemental Weather Forecast Products

A supplemental tool for prescribed burn managers and smoke management planning is the NWS Activity Planner tool. The Activity Planner provides a 48-hour graphical display of several meteorological conditions (Figure 11) from a selected latitude and longitude. Forecast data can be used for planning purposes before, during, and after the prescribed fire.

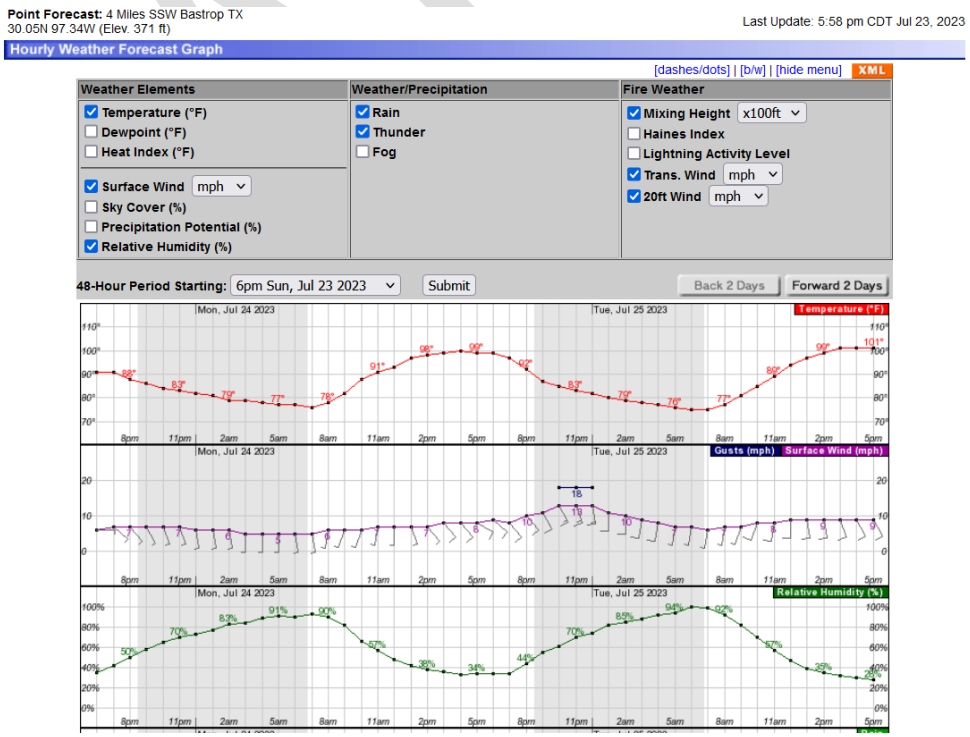

Figure 12: NWS Activity Planner tool can provide 48-hr forecast guidance for specific location

Configure a Smoke Model

The National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory has developed the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) and dispersion models for point source emissions of potentially harmful materials emitted and transported into the atmosphere using gridded weather data. The HYSPLIT is limited in scope as the user is unable to incorporate fuels and burn duration into the model. This is an advanced modeling tool that may have application for smoke management on complex prescribed burns or larger burn units (> 2,000 acres) in Texas. A HYSPLIT smoke model is only a recommendation if the burn boss feels a model is needed. The following are the basic HYSPLIT model outputs from a NWS Spot Weather Request in either a stand along map or KML file able to be loaded into Google Earth.

Trajectory Model

Colored arrows/lines (Figure 12) represent single air parcel movement over a default 72-hour period at different heights Above Ground Level (AGL). The time frame is set and cannot be changed.

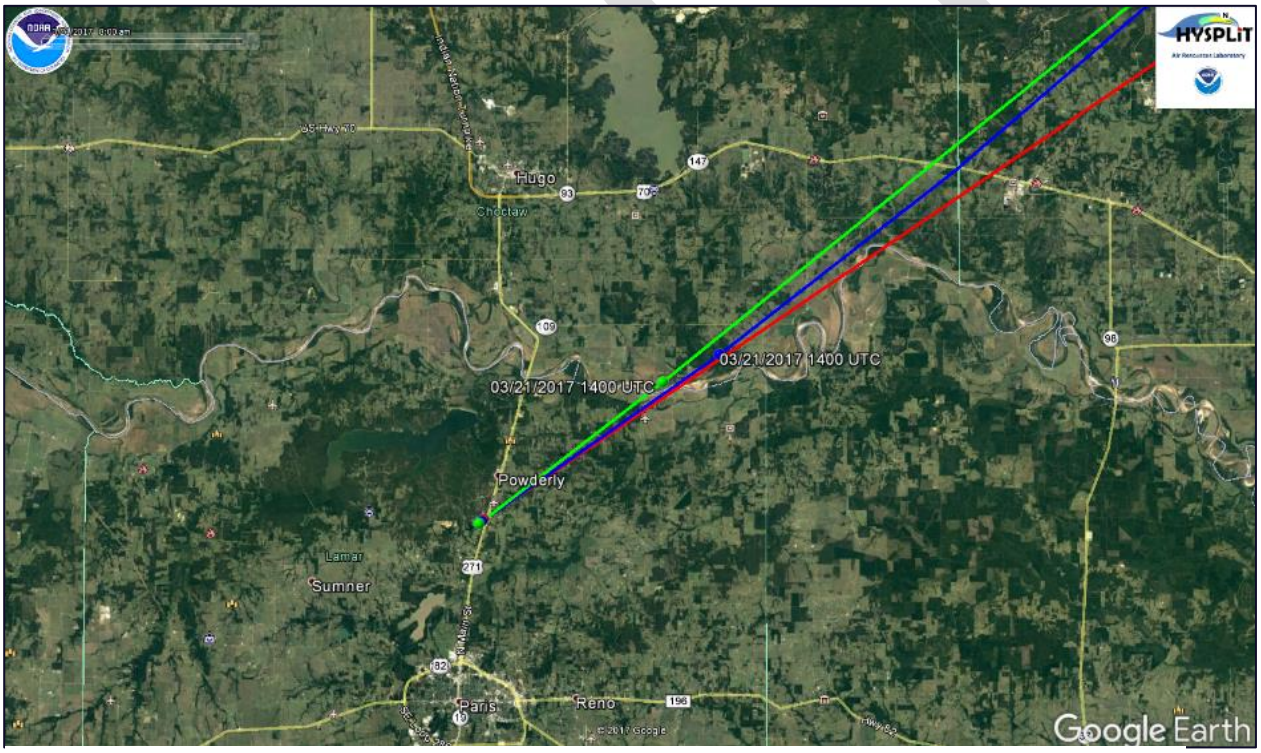

Figure 12: Trajectory HYSPLIT model for a point source emission

Dispersion and Particle Cross Section Models

The Dispersion Model is a single air parcel plume showing the concentration of emissions over a period of time (Figure 13). This output does not take into account continued emissions that occur during a prescribed fire. There is no guarantee that smoke will be located in area based of model output. Several dilution factor maps are generated showing differences in time, but of the default single parcel. The Particle Cross Section model provides a vertical profile (Figure 14) of potential smoke concentrations based on a default single emission. This output may be used for long range impacts on larger (> 2,000 acres) burn units. Several particle cross-section maps are generated showing differences in time, but of the single emission.

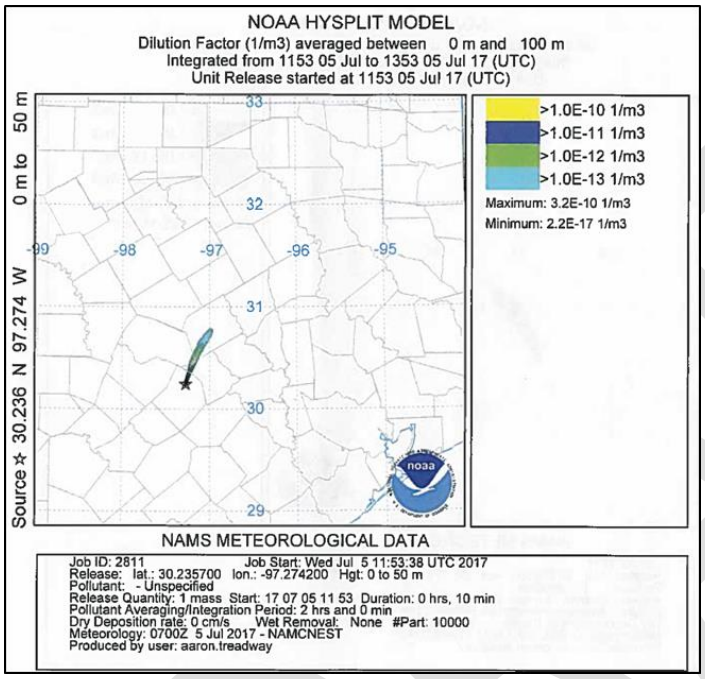

Figure 12: HYSPLIT Dispersion Model for single point emission

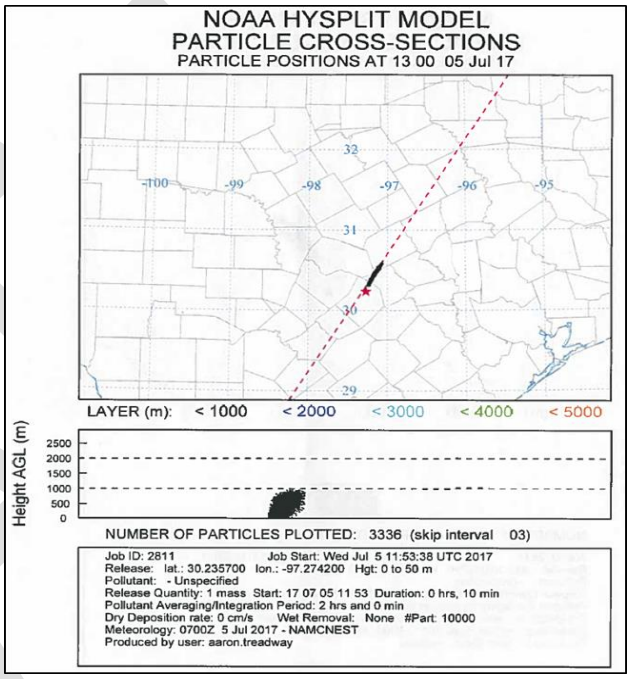

Figure 13: HYSPLIT Particle Cross Section Model

With a National Weather Service spot weather forecast or general zone fire weather forecast, a burn boss may default to a simple smoke screen or 30° map diagram to determine smoke impacts on day of the prescribed burn.

Check Forecasted Air Quality

AirNow is a web based index that surveys the daily air quality index (AQI) for the United States. This webpage provides six color coded air quality index values. The EPA has assigned a specific color to each AQI category to make it easier for people to understand quickly whether air pollution is reaching unhealthy levels in their community. Referencing this index (Table 5) is recommended to check forecasted air quality conditions before adding more particulates into the air from the prescribed fire. The burn boss should use caution if attempting to burn at moderate (51-100) AQI and hold off from burning when Unhealthy for Sensitive Groups (101-150) is forecasted.

Additional information about the air quality index can be found at www.airnow.gov

Table 5: Air Quality Index Description

Air Quality Index Levels of Health Concern	Numerical Value	Description
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects.
Hazardous	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected.

Smoke Observations

Potential Use of a Field Evaluator

The burn boss is responsible for observing and documenting smoke production from the burn unit. Depending on the complexity of the burn, delegation of smoke observations may be given to a field evaluator or, if available, fire effects monitor (FEMO) to assist the burn boss during low or moderate complexity prescribed fires. During a high complexity burn, a field evaluator or FEMO will be used to assist the burn boss with the overall observation of the fire.
This observer will be monitoring:

- Smoke dispersion (making sure roadways are clear, monitoring SSAs)
- Fire behavior
- Are burn and smoke objectives being met?
- Checking weather (Every Hour or 30-minutes, use of belt weather kit, Kestrel, RAWS, Quick Deploy RAWS)
- Recording information on significant events
- Potential use of UAS/Drone with licensed Remote Pilot in Command (RPIC).

Special Considerations

Nighttime smoke dispersion and Super Fog

Once prescribed burn operations are finished, the burn boss is still responsible for the smoke generated during the smoldering phase of operations. Smoldering may continue throughout the overnight hours. At night, surface temperatures cool with the loss the solar radiation and low level atmospheric stability normally occurs. Winds typically decrease and less mixing occurs, therefore there is less smoke dispersion and transport decreases. Colder air at the surface is denser and will pool in lower areas such as valley or river drainages. Smoke can settle in these lower topographic features and impact SSAs and roadways. Super fog is a condition where fog develops and mixes with remnant smoke and can greatly reduce visibility on roadways (Figure 14). There have been documented super fog events that have caused multiple fatalities on roadways in the Southeastern United States

Figure 14: Formation and impacts of super fog

It is recommended that the burn boss or manager consult the local National Weather Service for fog potential. Mitigation measures and decisions should be made if fog development is forecasted. The Low Visibility Occurrence Risk Index (LVORI) can be a tool to indicate reduced nighttime visibility (Figure 15). The range of 1-10 is used to determine the likelihood of smoke or fog contributing to motor vehicle accidents. A LVORI of 10 is the highest likelihood. The Atmospheric Dispersion Index can be requested by the local National Weather Service office.

	Atmospheric Dispersion Index (ADI)											
RH	1	2	3-4	5-6	7-8	9-10	11-12	13-16	17-25	26-30	31-40	> 40
< 55	2	2	2	2	2	2	2	2	2	2	1	1
55-59	3	3	3	3	3	2	2	2	2	2	1	1
60-64	3	3	3	3	3	3	2	2	2	2	1	1
65-69	4	3	3	3	3	3	3	3	3	3	3	1
70-74	4	3	3	3	3	3	3	3	3	3	3	3
75-79	4	4	4	4	4	4	4	4	3	3	3	3
80-82	6	5	5	4	4	4	4	4	3	3	3	3
83-85	6	5	5	5	4	4	4	4	4	4	4	4
86-88	6	6	6	5	5	5	5	4	4	4	4	4
89-91	7	7	6	6	5	5	5	5	4	4	4	4
92-94	8	7	6	6	6	6	5	5	5	4	4	4
95-97	9	8	8	7	6	6	6	5	5	4	4	4
> 97	10	10	9	9	8	8	7	5	5	4	4	4

Table of LVORI values as a function of Atmospheric Dispersion Index and Relative Humidity. Green = Conditions with lowest proportion of accidents. White = proportion of accidents increased by a factor of 2-10 over green. Yellow = proportion of accidents increased by a factor of 10-40 over green. Orange = proportion of accidents increased by a factor of 40-150 over green.

Figure 15: Low Visibility Occurrence Risk Index

Super Fog Watch Out Situations

The burn boss should monitor forecasted weather conditions for the evening and night time hours after the burn. Meteorological factors that contribute to super fog formation (Table 6) can be found in the Spot Weather Request or directly from the National Weather Service.

Table 6: Factors that contribute to super fog formation

Factor	*Watch Out Thresholds*
Surface Temperature	***≤70°, Critical ≤55°***
Relative Humidity	***Critical >90%***
Surface Wind speed	***Critical ≤ 4 mph***
Cloud Cover	***Critical < 40%***
Stability Class	***E or F***
Atmospheric Dispersion Index	***Critical ≤ 6***
Low Visibility Occurrence Risk Index	***≥7, Critical ≥ 9***
Transportation Corridor	***≤ 3 miles from burn site***

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