Air Quality Working Paper
Buttermilk Hollow - Talbott Hollow Blowdown Project

Mississippi Bluffs Ranger District
Shawnee National Forest

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Introduction

The Mississippi Bluffs Ranger District of Shawnee National Forest (Forest) proposes to burn approximately 5650 acres of private and National forest lands in the Buttermilk Hill - Talbott Hollow Blowdown Project. It also proposes about 25 acres of chipping and mastication on private land near at risk structures to reduce fuel loads prior to burning. This paper describes the expected direct, indirect, and cumulative effects to air quality of implementing the proposed action and of the no action Alternative.

Current Conditions and Affected Environment

The project area is located in western Jackson County, IL, and has climate and weather typical of the region. It generally has hot, humid summers and cool winters. Rain is normally adequate in all seasons, but the area is subject to infrequent droughts, usually occurring in late summer and early fall. Frequent frontal systems pass the area, especially in the "shoulder seasons" of spring and fall. Average wind conditions extrapolated from Regional data sources (see Appendix B) using the Ventilation Climate Information System (VCIS, available online at http://www.airfire.org/vcis) show frequent southeast, south, west and northwest winds. Prevailing burn season winds are generally thought to be south to west, with topographic winds frequently dominating local airflow, including daytime south/southwest winds up the Mississippi Valley. Mixing heights vary but average about 4000 feet in the afternoon during burn season (VCIS 2008). The ozone season for Illinois is considered April - October, outside of or on the fringe of burning season (IEPA 2007).

Projects implemented by the Forest Service must follow all State and federal regulations governing air quality, including meeting ambient air quality standards (NWCG 2001). Chief among these are the Clean Air Act (CAA) as amended in 1990, and State Implementation Plans (SIP), which are state-derived implementation documents of the CAA. The State of Illinois has not yet finalized their SIP, so only compliance with the CAA is dealt with here. The Illinois Environmental Protection Agency (IEPA) is the agency charged with regulating and monitoring air quality within the state.

The CAA prescribes National Ambient Air Quality Standards (NAAQS) for criteria pollutants (Particulate Matter less than 10 microns in diameter (PM_{10}), Particulate Matter less than 2.5 microns in diameter ($PM_{2.5}$), Total Suspended Particulate Matter (TSP), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone, Carbon Monoxide (CO), and Lead (Pb)) to limit the negative health or welfare effects from air pollution. Areas not meeting these standards are considered "non-attainment areas," and states must develop plans to improve air quality there (NWCG 2001). The only non-attainment areas in Illinois are in the Chicago Metro Area and Madison, Monroe, and St. Clair Counties in the St. Louis Metro- East Area. These nearest counties are about 40 miles northwest of the project area at the closest point. Areas in the Evansville, IN metro area are also in non-attainment status for particulate matter. These are situated about 100 miles east of the project area (USEPA 2008). Figure 3 depicts the nearest non-attainment areas for particulate matter. Figure 4 shows non-attainment areas for 8-hour ozone.

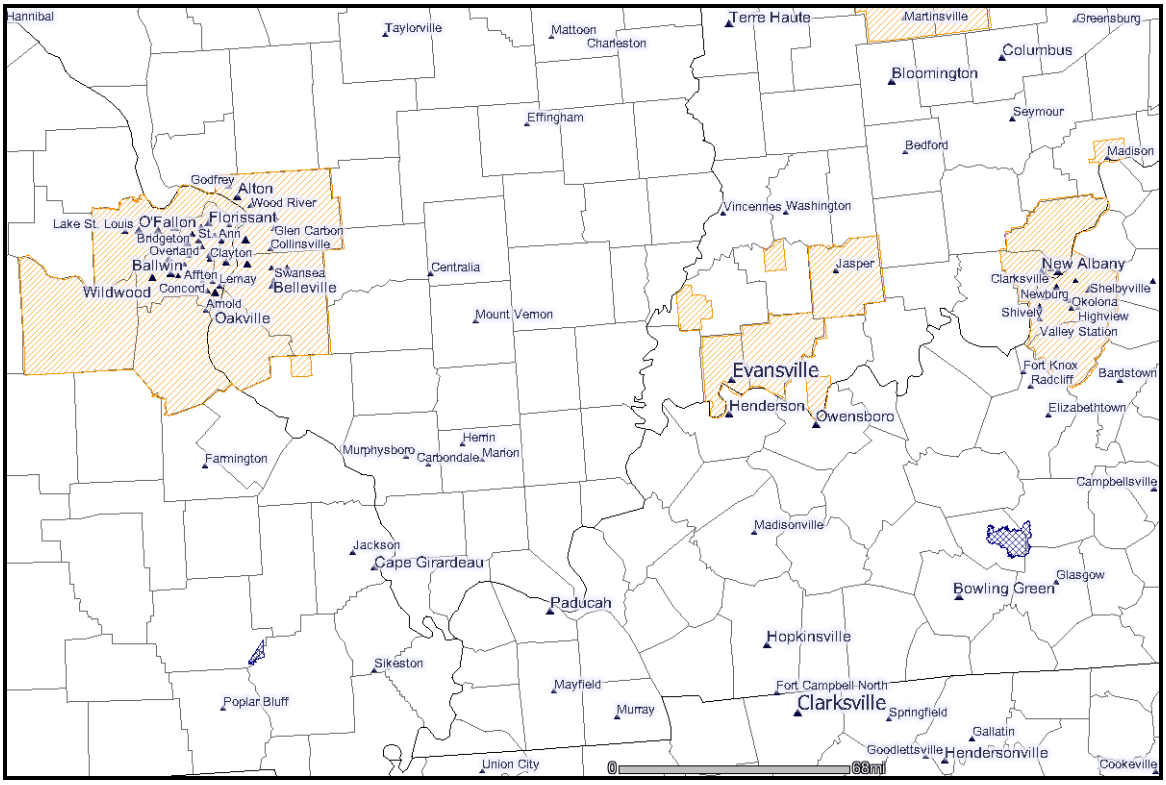


Figure 3. Non-Attainment Areas for $PM_{2.5}$ (tan hatching) and Class I Airsheds (blue cross-hatching).

Tables 1, 2, and 3 show total pollutants and certain criteria pollutants as reported in the 2005 Illinois Annual Air quality Report (IEPA 2006). In general, southern Illinois has good air quality and meets the NAAQS. Particulate matter (PM) emissions would be the pollutant of most concern to public health and safety because it is responsible for most health problems and visibility reductions. The proposed prescribed burning is located in Jackson County, considered by the EPA to meet all the ambient air quality standards designed to protect public health. According to IEPA data, emissions of pollutants including particulate matter and ozone, in Jackson and surrounding counties have been much lower than more urban locations in the state. In fact, the Carbondale monitoring station had the lowest annual average in the state for PM_{10} at 19µg/m^3 in 2003, and is among the lowest in all other years. Knight Prairie Township Monitoring Station in Hamilton County had one of the lowest annual mean $PM_{2.5}$ concentrations in 2006 (IEPA 2007). Background concentrations of particulate matter and other pollutants are thought to chiefly arise from agricultural, industrial, commercial, and residential sources. Appendix C displays maps of criteria pollutant emissions by county for Illinois with the Jackson County annual mean listed below the map for each criteria pollutant (USEPA 2008).

The Clean Air Act also proscribes measures called Prevention of Significant Deterioration (PSD) to limit the impacts to visibility in certain areas. Class I areas are those with high air quality that allow only minor additional visibility reduction (NWCG 2008). The nearest Class I areas are at the Mingo Wilderness Area in southeast Missouri (approximately 75 miles to the southwest) and Mammoth Cave National Park (approximately 200 miles east-southeast in central Kentucky) (USEPA 2008). These areas are shown in Figure 3. Northeast winds are rare and are often associated with rainy conditions, rendering it unlikely that visibility in the Mingo Wilderness would be affected. Even when run for the largest units at the driest conditions, modeling data shows no chance of impacting sensitive airsheds at

Mammoth Cave. The entire Shawnee NF and surrounding counties are in a Class II area, which allows for some incremental increase in pollution, but not to the limit of the NAAQS.

Visibility is typically worst during hazy summer days under entrenched high pressure and humid conditions. Since burning usually occurs during spring and fall (dormant season), most burn emissions would not overlap with the times of worst background visibility. Other background sources of particulate matter include industrial facilities, automobiles, residential and commercial buildings, agriculture, and roads (USEPA 2008). Some of these are temporary (such as smoke from wood stoves, fireplaces, field burning, and wildfires that often coincide with prescribed burning season), while some are constant (e.g. industrial sources). Disking and harvesting activities on agricultural lands can produce copious dust and other particulates, but this action is temporary and seasonal and may overlap with prescribed burning.

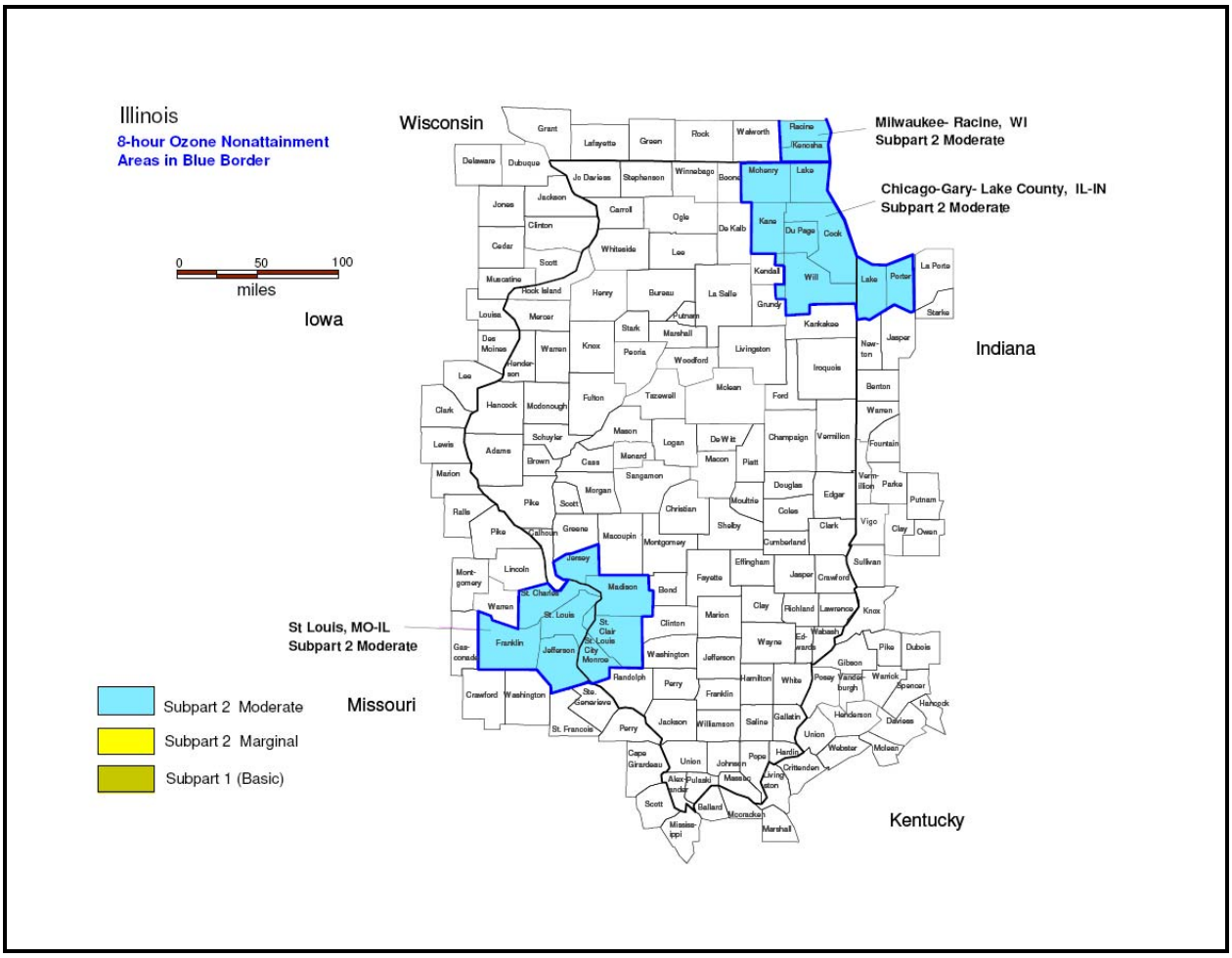


Figure 4. Non-Attainment Areas for 8 Hour Ozone concentrations for Illinois.

Table 1. Estimated County Stationary Point Sources Emissions, 2005 (Tons/Year)					
County	**Carbon monoxide**	**Nitrogen oxides**	**Particulate matter (PM)**	**Sulfur dioxide**	**Volatile organic matter**
Jackson	164.6	183.9	170.5	778	64.8
Statewide High (County)	18,165.3 (Madison)	27,531.1 (Tazewell)	9,836.4 (Cook)	80,861.9 (Will)	15,329.0 (Macon)

Table 2. 2005 Air Quality Monitoring for Air Region 74 (Southern Illinois Intrastate).							
Pollutant	Sample type	Sample Location	IEPA Standard	Readings			
Ozone	1 hour	Effingham	0.12 ppm	0.086	0.083	0.078	0.077
Ozone	1 hour	Knights Prairie	0.12 ppm	0.087	0.086	0.086	0.085
Ozone	8 hour	Effingham	0.08 ppm	0.076	0.075	0.073	0.073
Ozone	8 hour	Knights Prairie	0.08 ppm	0.081	0.081	0.080	0.077
$PM_{2.5}$	24 hour	Knights Prairie	65 ug/m3	39.1	29.3	28.0	--
PM_{10}	24 hour	Carbondale	150 ug/m3	56	42	42	--
Sulfur dioxide	3 hour	Mt.Carmel	0.5ppm	0.187	0.160	--	--
Sulfur dioxide	3 hour	Rural Wabash	0.5ppm	0.165	0.112	--	--
Sulfur dioxide	24 hour	Mt.Carmel	0.14 ppm	0.039	0.038	--	--
Sulfur dioxide	24 hour	Rural Wabash	0.14 ppm	0.038	0.024	--	--
Sulfur dioxide	Annual Mean	Mt.Carmel	0.03 ppm	0.006	--	--	--
Sulfur dioxide	Annual Mean	Rural Wabash	0.03 ppm	0.004	--	--	--

Table 3. Air Quality Trends (for particulate matter (10 microns) and sulfur dioxide in Region 74.									
Pollutant	Sample type	Sample Location	IEPA Standard	2000	2001	2002	2003	2004	2005
PM_{10}	Annual Mean	Carbondale	50 ug/m3	23	19	19	19	20	24
Sulfur dioxide	Annual Mean	Mt. Carmel	0.03 ppm	0.005	0.005	0.004	0.004	0.004	0.006
Sulfur dioxide	Annual Mean	Rural Wabash	0.03ppm	0.006	0.005	0.003	0.003	0.003	0.004

Air Quality standards and guidelines are set forth in the Forest Plan. Forest-wide Standard FW25.8 says "Emission from Forest Service activities and related mitigation measures must comply with applicable state standards. Present and potential impairment of Forest resources attributable to air pollution are identified to the Forest Supervisor."

Effects of the Alternatives

Alternative 1 – No Action

Under this alternative there would be no likely effects to air quality since no proposed activities would take place. Current use and activities that do produce some pollutants would continue, but in the past these have not contributed to excessively degraded air quality and are not expected to do so in the future. A wildfire in the project area would produce higher emissions than a prescribed fire in the same area. Numerical values for predicted emissions for Alternatives 1 and 2 are shown in Table 4. These were derived from actual fuel inventories (see Fuels Working Paper) using the First Order Fire Effects Model (FOFEM) Version 5.2.1. Two situations were modeled: A wildfire occurring under very dry conditions (Figure 5), and a prescribed fire occurring under the driest conditions likely to be experienced during prescribed fires (Figure 6). Actual emissions would be much less if moisture conditions are higher during the burn as would normally be the case.

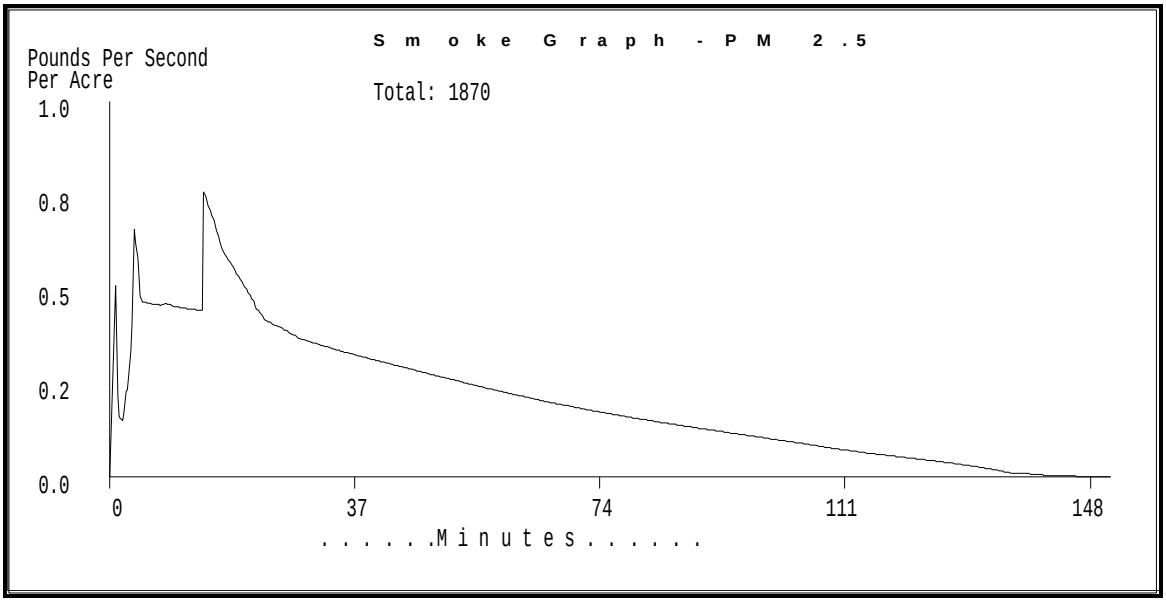


Figure 5. Predicted $PM_{2.5}$ emission from a wildfire in the Heavy Blowdown Pine Stands.

Alternative 2 – Proposed Action

Smoke from prescribed burning would temporarily reduce visibility and produce pollutants. Past experience has shown these effects are greatly diminished with increasing distance from the burn. Downwind impacts were estimated using the VSMOKE-GIS Computer model (assumptions and outputs are covered in greater detail in Appendix A). Results suggest that smoke impact levels may reach unhealthy levels for sensitive groups within 19.65 miles of the burn (Appendix A, Scenario 4), but detectable smoke may be transported much farther (estimated 40+ miles). However, at those distances it is expected that most impacts will be in the form of “nuisance” smoke and/or smell. Actual emissions are expected to be much lower than those modeled because 1) the duff layer found in the project area is much thinner and less is consumed than in the default computer model, 2) there is greater dispersion due to shifting winds that is not accounted for in the model, 3) multiple plumes are not accounted for in the model, and 4) prior experience has shown this model may considerably overestimate actual emissions. Naeher et al (2006) suggest that there would be less fuel consumption and fewer emissions in areas near certain at-risk structures where fuels have been chipped.

Most emissions would occur during active ignition phases of the burn, which would likely last 4-6 hours. Smoldering may occur for several days. In prior prescribed burns on the Shawnee National Forest the residual smoke has typically been light, possibly due to higher soil and large fuel moisture conditions than during wildfires or when compared to fires in other parts of the country. Higher moisture in duff and large logs probably limit combustion of these fuels more than during wildfires or when compared to fires in other parts of the country. Smoke may settle into low areas such as the Kinkaid Lake basin, especially at night or during times of poor dispersal.

Table 4. Emission Summary for Alternatives 1 and 2 for project area stands. Alternative 2 fuel moistures were considered "worst case." All results in lbs/acre.

Scenario	PM_{10}	$PM_{2.5}$	CH_4	CO	CO_2	NO_X	SO_2
Alternative 1	0	0	0	0	0	0	0
Alternative 1 – Wildfire (Heavily Damaged Hardwoods)	430	364	209	4403	45752	51	30
Alternative 1 – Wildfire (Heavily Damaged Pine)	2207	1870	1108	23905	160726	116	105
Alternative 1 – Wildfire (Lightly Damaged Areas)	289	245	134	2752	42913	58	27
Alternative 1 – Wildfire (No Damage Oak-Hickory)	225	190	106	2181	31386	41	20
Alternative 1 – Wildfire (No Damage Mesophytic)	225	190	106	2179	30903	40	20
Alternative 2 – (Heavily Damaged Hardwoods)	413	350	201	4238	43384	48	29
Alternative 2 – (Heavily Damaged Pine)	1944	1648	973	20946	148199	115	114
Alternative 2 – (Lightly Damaged Areas)	281	238	130	2665	42258	57	26
Alternative 2 – (No Damage Oak-Hickory)	217	184	102	2089	30526	40	20
Alternative 2 – (No Damage Mesophytic)	216	183	102	2088	30348	40	19

Based on these emissions rates, total $PM_{2.5}$ emissions for the first prescribed burn entries would be about 764 tons if every acre within the burn units was blackened, which is quite unlikely (50-80% burn coverage is more likely). These would likely be spread over two years or an estimated 40 total burn days. On average, 19 tons per burn day would be produced. By contrast, the annual $PM_{2.5}$ emissions for Jackson County are estimated at 2175 tons (USEPA 2008). Subsequent burns should produce fewer emissions since fuel loads would be reduced via consumption in the first burn or decay in subsequent years, and would be spread over 2-5 years. Actual emissions from this project would vary based on factors such as transport winds, mixing heights, fuel moisture, and unit size.

Burning would likely occur fall through early spring, mostly outside of the typical "ozone season" in Illinois. Mixing heights average around 4000 feet above ground level in these months, helping

disperse smoke away from ground level. Frontal systems tend to pass the area frequently during these months, helping to "scour out" residual smoke.

Still, several sensitive receptors (e.g. homes, hospitals, highways, schools, airports) are potentially affected by these emissions. In the theoretical "typical burn scenario" residents within 7.82 miles may experience a few hours of elevated concentrations (greater than 175 $\mu g/m^3$) but overall 24-hour averaged concentrations should still be within the National Ambient Air Quality Standard for particulate matter 2.5 microns in diameter ($PM_{2.5}$). Within 19.65 miles, those sensitive to smoke (potentially children at school, the elderly or sick in nursing facilities or hospitals) may be affected temporarily. The greatest concentrations of these individuals are in Murphysboro (approximately 10 miles east-southeast of the project) and Carbondale (approximately 15 miles east-southeast of the project), though smaller towns such as Ava, Vergennes, and De Soto may also have sensitive receptors. Figures 7 and 8 show potential sensitive receptors from the project (VCIS 2008).

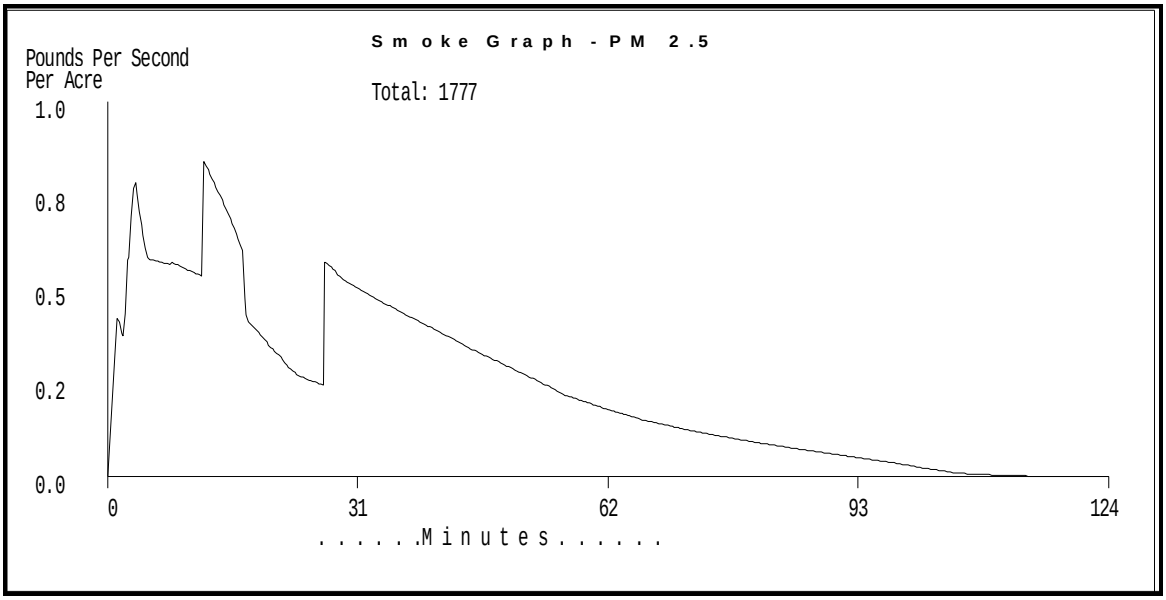


Figure 6. Emissions for a Prescribed Fire in Heavy Damage Pine Stands.

Visibility may be reduced at the Southern Illinois Airport (approximately 12 miles east of the project area) but not to the level of impacting aviation operations. Cross-plume visibility is predicted to be at least 0.25 miles at all distances greater than 0.25 miles from the fire. The greatest potential for visibility reductions is in the Kinkaid Lake basin and major valleys such as Logan and Austin Hollow and the Mississippi River floodplain as smoke settles into low spots at night. These are of particular concern since State Highways 3 and 151 run through these areas.

Design criteria such as timing burns to coincide with good smoke dispersion, public notification, highway signing, and potentially 24-hour monitoring have been included in the project to alleviate most of these impacts. Since a fairly large population in Murphysboro and Carbondale could be impacted by smoke transported by a west-northwest wind, it would be prudent to burn only smaller units or under higher moisture conditions with these winds. Similarly, southeast winds could theoretically transport emissions into non-attainment areas in the Metro East (St. Louis) area. However, the wind required to transport smoke that far very rarely occurs during otherwise good burning conditions. Prevailing winds are frequently from the west, southwest, and south, especially

during warm dry days favored for prescribed burning. Any east wind component is frequently accompanied by precipitation or very humid air. Non-attainment areas in Evansville, IN area are predicted to be beyond the maximum range of impact of criteria pollutants for these burns.

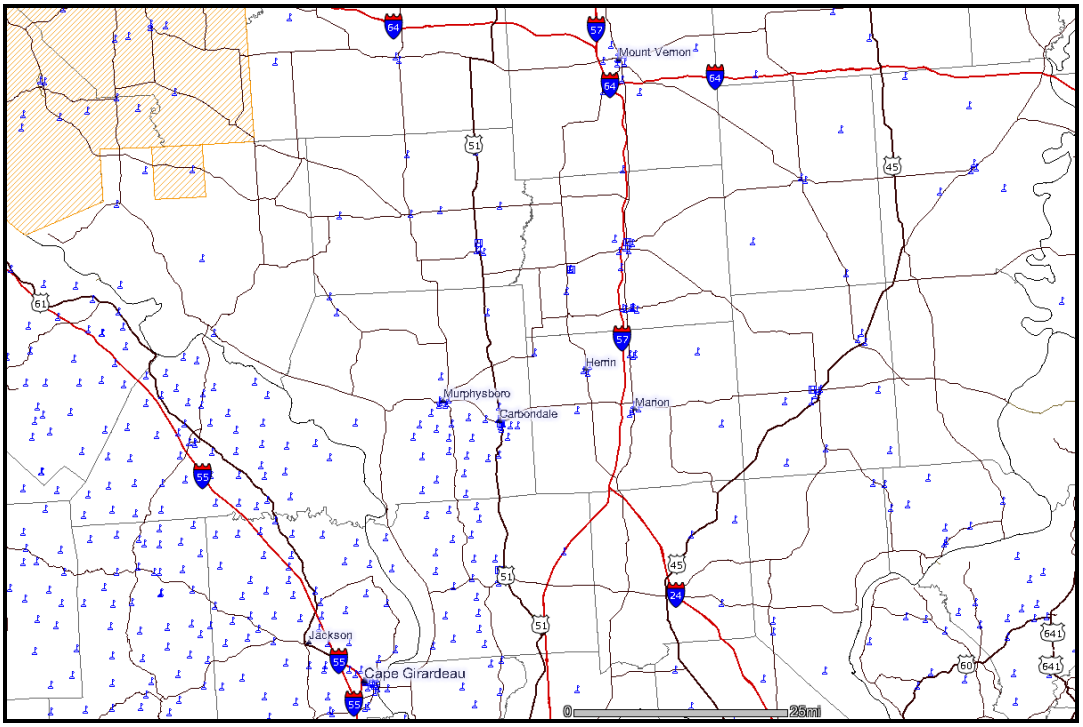


Figure 7. Potential sensitive receptors (schools, health care facilities, etc) in the vicinity of southern Illinois.

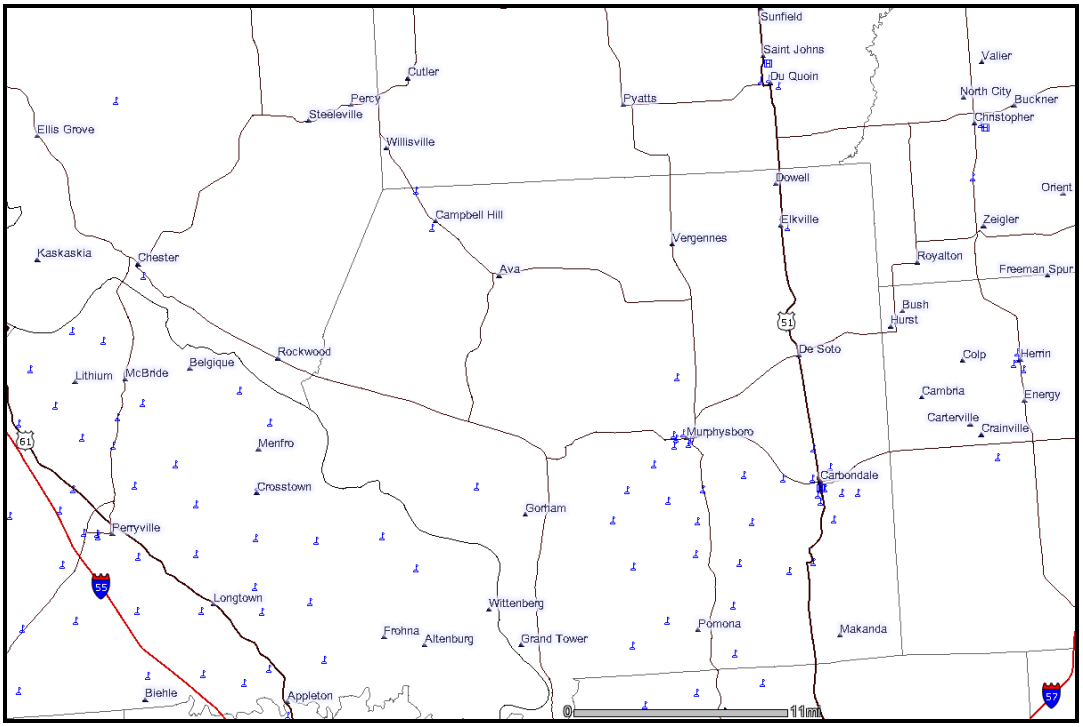


Figure 8. Potential Sensitive Receptors in Jackson County, IL.

Cumulative Effects Rationale – Air Quality

Smoke from fires may travel long distances, and direction is determined by transport winds. Maximum detectable smoke transport from the project may be greater than 30 miles (Appendix A). Most burning is done with south, southwest, west, northwest, and north winds, so areas downwind of the project to the south, southeast, east, northeast, and north within this distance are considered for potential cumulative effects. Since air quality data is readily available for counties, the spatial boundary of analysis is the southern Illinois counties of Perry, Franklin, Jackson, Williamson, Union, and Johnson.

Emissions from prescribed fires are predicted to occur over approximately 20 days per year, in the spring and fall, for 10 years. Each burn (a single unit or combined units) would likely take 1-2 days to ignite, and smoldering emissions may continue for another 1-2 days. About 6-10 units would likely be burned each year, and some of the emissions from these units may temporally overlap. Since county emissions data is listed per year, yearly burn totals will be used for the comparative analysis. The temporal boundary for effects to air quality is the duration of predicted smoke production from prescribed burning. Instantaneous emissions maxima for various scenarios are estimated in Appendix A. Fireline construction, transport to and from the site, and other activities involving internal combustion engines may produce some pollutants, but the amount is negligible so the timing of these activities is not considered.

Many other activities will occur in the analysis area in the analysis timeframe (see Table 5 and Cumulative Effects Checklist), but only the most important sources were considered for cumulative effects analysis. These were separated into Agricultural, Industrial/Commercial, Other, and Other Rx Burns. The "Industrial/Commercial" category includes fuel combustion and various industrial processes, while the "Other Uses" category is mostly transport and storage, but includes waste disposal/recycling, fugitive dust, and all other sources. All data comes from the USEPA AirData website for year 2001 except for prescribed burn emissions, which were predicted separately.

Table 5. Particulate Matter ($PM_{2.5}$) Emissions Analysis (Tons)

	Particulate Source					
County	**Agriculture**	**Industrial/ Commercial**	**Other**	**Other Rx Fires**	**Blowdown Rx**	**Total**
Jackson	417	910	848	354	382	**2868**
Perry	284	75	382	0	0	**741**
Franklin	286	164	635	0	0	**1085**
Williamson	224	875	835	28	0	**1962**
Johnson	119	57	371	56	0	**603**
Union	117	50	449	125	0	**741**
Totals	**1447**	**2131**	**3520**	**563**	**382**	**8043**
Percent of Total	**18%**	**27%**	**44%**	**7%**	**5%**	**100%**

Past and Future Agriculture (Hundreds of thousands of acres/year)

Row crop agriculture is heavily mechanized and widespread in the southern Illinois counties comprising the analysis area. Farm production activities in dry soil can release substantial dust and other particulate matter into the atmosphere and reduce visibility. Mechanized equipment also

produces pollutants from internal combustion engines. There would be overlap in time as farming may occur during both spring and fall burn seasons. Estimates for particulate matter produced from agricultural sources are found in Table 5. These include agriculture and forestry but not fugitive dust, though much of it likely comes from agriculture outside the county. The effects from agriculture are expected to far outweigh any from burning.

Industrial/Commercial and Other Activities
These include point and non-point source emissions for industrial, commercial, and other uses. These are considered essentially "fixed" and are not considered elsewhere.

Past and Future Wildfires (tens to hundreds of acres/year)
In general wildfires produce more pollutants than prescribed fires. The amount depends on the amount of fuel consumed, fuel qualities, and emission rates. The lift, dispersal, and transport of these pollutants are dependent on atmospheric conditions. Past wildfire amounts have been variable in the analysis area but have only contributed temporarily to decreased air quality. Due to the unpredictable nature of these events and the lack of data outside Shawnee National Forest boundaries, these events have not been included separately in the numeric analysis, other than being part of the background particulate matter in burn areas, and as part of the miscellaneous "Other" emissions.

Past and Future Prescribed Fires (thousands of acres/year)
Past prescribed fires in southern Illinois have not produced many negative impacts; however, since other prescribed fires are foreseeable in the analysis area and time period, some analysis is warranted. Another burn project (Kinkaid Lake Prescribed Fire Project) has been proposed on Forest Service land just north of the project area, and other prescribed fires on Forest Service lands and other ownerships are likely in these counties. Further, several of these burns may occur simultaneously since many people may choose to burn on the same day.

Written burn plans are required for every prescribed fire. These plans outline the specific conditions in which a prescribed fire may be ignited. These conditions are limited in the prescribed fire burn plan to minimize impacts to human health and safety, including those from smoke. Typically, allowable winds and dispersal conditions are those that will lift smoke away from the surface and transport it away from potentially impacted areas such as hospitals, nursing homes, and highways. Standard measures are taken to minimize smoke impacts where they cannot be avoided through timing or atmospheric conditions, including prior public notification and traffic management if necessary.

As stated earlier, if every acre of the project was blackened, approximately 764 tons of $PM_{2.5}$, the pollutant of greatest concern for health and visibility reasons, would be produced. Though it may take three years or more to implement burns on the entire project and fewer acres would actually be burned, for analysis purposes, it is assumed that half of the blowdown project would be burned in one year, producing 382 tons of $PM_{2.5}$. Estimates for other burns were made by multiplying an emissions factor specific to the predominant fuel type of the burn by the number of acres anticipated to be burned in any upcoming fiscal year. For all fuel beds the D2L2 moisture scenario was used since it is used for comparing fire behavior outputs in the Standard Fire Behavior Fuel Models (Scott and Burgan 2005) and was also used to obtain fuel consumption levels for the Fuel Analysis (Fire and Fuels Working Paper). White Oak - Black Oak - Red Oak was chosen as the fuel bed for upland forest since it comprises upwards of 80% of the Forest. FOFEM 5.2.1 (Keane et al 2004) predicts emissions of 189

lbs/ac for this fuel type and fuel moisture combination. Measured fuel load values were used for Pin Oak- Sweet Gum to represent burns in the Big Muddy Bottoms (383 lbs/ac), and default values for Missouri Prairie (12 lbs/ac) were used to simulate warm season grass burns. Multiple burns in the same season were modeled to represent the worst case scenario for air quality since other emission statistics are averaged for the year, though it is unlikely all these burns would be conducted in the same year. The burns include several landscape scale Forest Service burns in the analysis area, including one in the same watershed; several small-scale Forest Service burns; one US Fish and Wildlife Service (USFWS) mid-scale burn in the analysis area, one small-scale Illinois Department of Natural Resources (IDNR) burn, and one small-scale burn on private land all in the same county. For private land, IDNR, and Forest Service small-scale burns a warm season grass fuel model (Missouri Prairie) was used. The results are shown below.

Table 6. Emissions from Foreseeable Future Prescribed Burns in Analysis Area

Burn	**Location**	**$PM_{2.5}$ Produced (Tons)**
Buttermilk Hill – Talbott Hollow Blowdown Rx	Kinkaid Lake watershed, Jackson County	382
Kinkaid Lake Rx – 900 acres	Kinkaid Lake watershed, Jackson County	85.1
TPL Tract – 45 acres	Western Jackson County	0.3
Oakwood Rx – 1400 acres	Southern Jackson County	268.1
Atwood Ridge Rx – 1323 acres	Union County	125.0
Pennant Bar Rx – 75 acres	Johnson County	0.5
Johnson County Landfill Rx – 55 acres	Johnson County	0.3
West Tract – 103 acres	Johnson County	0.6
Simpson – 576 acres	Johnson County	54.4
USFWS Burn – 300 ac	Williamson County	28.4
IDNR Burn – 60 acres	Kinkaid Lake watershed, Jackson County	0.4
Private Burn – 25 acres	Eastern Jackson County	0.2
Total		**945.1**

The combined effects of these burns are still expected to be far outweighed by the effects of agriculture, industry, and widespread automobile use, and are not expected to collectively diminish air quality of the region. These burns combined would comprise only 12% of the total $PM_{2.5}$ emissions (8043 Tons) for the analysis area for the year.

Determination

The upper estimate of $PM_{2.5}$ produced in the first year of the Buttermilk Hill – Talbott Hollow Blowdown Project is 382 Tons. This represents approximately 5% of the total emissions predicted for the analysis area. Past experience suggests that actual emissions would be much lower. In future years there would likely be less particulate matter produced as fuel loads diminish and fewer acres are burned per year, so this percentage would decrease even further.

The combined impact of all activities has been small enough to be acceptable for all criteria pollutants and visibility in the past. The temporary production of smoke would yield a short term increase in

some pollutants, especially near the fire, but would not be enough to negatively impact air quality as a whole. No days in 2007 had an Air Quality Index Rating over 100 in Jackson County, and this is predicted to continue even with the additive effects of the proposed action and other emissions (Appendix C).

Monitoring

Three monitoring stations are located in the region that can be used for regional air quality monitoring. Readings from these stations contribute to the AirData website and are available online. An IEPA monitoring station (PM_{10} only) is maintained in Carbondale and can also be accessed online. Local monitoring would be accomplished through standard (visual) procedures during the prescribed burns, or may be supplemented by the use of DataRAMS or other monitoring devices. All burns would be monitored for smoke impacts.

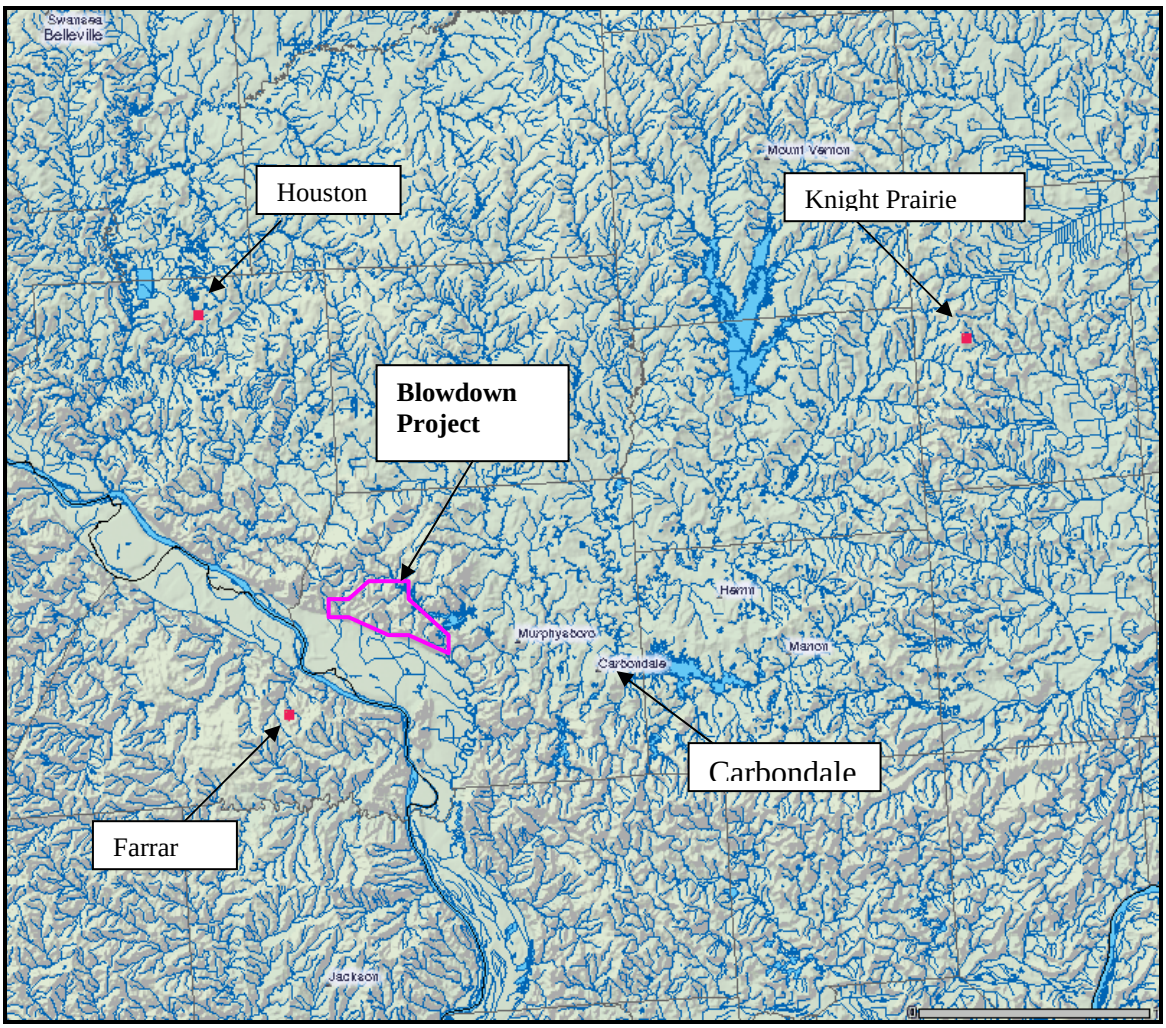


Figure 9. Air quality monitoring locations.

Appendix A – Assumptions and Results from VSmoke/VSmoke-GIS Modeling

Maximum emissions were calculated for the largest group of units (Units 4,5,6,7 – 1420 acres) and the largest unit (Unit 4 – 746 acres) that would be burned concurrently. Since the desired burn mosaic should cover 50-90% of the unit(s), actual emissions would come from 671 acres and 1278 acres at 90% burn coverage.

The VSMOKE model uses the values for the 1-hour concentrations for fine particulate matter (see table right) to color code the results following the EPA's Air Quality Index (AQI).

PM2.5 Concentration (µg/m3)
41-80 Moderate
81-175 Unhealthy for Sensitive Groups
176-300 Unhealthy
300-500 Very Unhealthy
501+ Hazardous

Scenario 1: Largest Acreage, Combination of Units 4-7, Aerial Ignition, Low Mixing Height.
The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This represents the maximum one-hour concentrations of emissions from the largest collective burn (i.e. a group of burn units) in the blowdown project. Units 4-7 are a combined 1420 acres, but the expected burn pattern would be a mosaic of 50-90% of the area burned. 90% of the area is 1278 acres. I used unrealistically high consumption percentages to model maximum emissions, while I used a low mixing height (2200 ft) and conservative values for the Pascal Index to simulate "worst case" dispersion. I used a combined ground and aerial ignition pattern to model the burn. If blacklining of the unit started in the 1000 hour, small acreage would be burned each hour until sufficient black is established. Then at the 1200 hour aerial ignition begins, burning a few hundred acres per hour until the unit is mostly lit, then finishing with ground ignition only by the 1600 hour. To estimate percentages of the various fuelbeds I assumed the ignition pattern as starting in the northeast portion of the unit on Dry Hill Rd, proceeding along the perimeter simultaneously west along Dry Hill Rd and south along the fields/firelines, eventually meeting with the other ignition group.

This time period (1500) has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 37.805 degrees latitude and -89.538 degrees longitude (-94695.134 meters east and 1538659.764 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 8909 grams/second and carbon monoxide was 108459 grams/second. The heat release rate was 16459560 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 15 micrograms/cubic meter and 3 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.

The meteorological conditions used in this model run were:

1.) Mixing height was **2200** feet above ground level (AGL).
2.) Transport wind speed, and surface wind speed were 15 and 5 miles per hour, respectively.
3.) The sky had 20 percent cloud cover, and the clouds were located 10000 feet above the ground.
4.) Surface temperature was 65 degrees Fahrenheit, and the relative humidity was 30 percent.
5.) The calculated stability class from VSmoke was slightly unstable.

The VSmoke model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.

The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an area of approximately

1000 square miles under uniform weather conditions. Typically, the Dispersion Index value should be greater than 30 when igniting a large number of acres within an area. The calculated Dispersion Index value was 38, which predicts the atmosphere has a fair to good capacity to disperse smoke.
Combining the Dispersion Index and relative humidity values provide an estimate (like is used in insurance actuary tables) of the likelihood of the smoke contributing to fog formation. The Low Visibility Occurrence Risk Index (LVORI) ranges from 1 (lowest risk) to 10 (greatest risk) and usually you want the value to be less than 4. The base line risk of having low visibility as a result of smoke contributing to fog formation is about 1 in 1000 accidents. The Low Visibility Occurrence Risk Index value for this VSmoke analysis was 1 and this is equal to the base line.

High concentrations of particulate matter, especially fine particles (PM2.5), and carbon monoxide can have a negative impact on people's health. The Environmental Protection Agency has developed a color coding system called the Air Quality Index (AQI) to help people understand what concentrations of air pollution may impact their health. When the AQI value is color code orange then people who are sensitive to air pollutants, or have other health problems, may experience health effects. This means they are likely to be affected at lower levels than the general public. Sensitive groups of people include the elderly, children, and people with either lung disease or heart disease. The general public is not likely to be affected when the AQI is code orange. Everyone may begin to experience health effects when AQI values are color coded as red. People who are sensitive to air pollutants may experience more serious health effects when concentrations reach code red levels. This analysis shows the air quality at downwind distances less than 49.36 miles from the edge of the fire may have a 1-hour particulate matter concentrations predicted to be code red or worse, while distances less than 62.14 miles are predicted to be code orange or worse. At distances less than 6.21 miles from the edge of the fire the one-hour carbon monoxide concentrations are predicted to be code red or worse, and distances less than 9.85 miles from the fire are predicted to be code orange or worse.

Distance from fire	PM2.5 (ug/m3)	CO (ppb)	Distance from fire	PM2.5 (ug/m3)	CO (ppb)
317 ft	19,921.98	204.25	2.47 mi	2,029.87	23.37
422 ft	17,587.59	180.65	3.11 mi	1,698.85	20.02
528 ft	15,390.52	158.44	3.92 mi	1,395.35	16.95
634 ft	13,367.31	137.99	4.94 mi	1,133.41	14.31
845 ft	11,540.77	119.52	6.21 mi	922.15	12.17
1056 ft	9,920.63	103.14	7.82 mi	758.94	10.52
0.25 mi	8,505.57	88.84	9.85 mi	629.98	9.22
0.31 mi	7,285.95	76.51	12.40 mi	523.29	8.14
0.39 mi	6,246.52	66.00	15.61 mi	433.90	7.23
0.49 mi	5,369.01	57.13	19.65 mi	359.49	6.48
0.62 mi	4,633.97	49.70	24.74 mi	297.96	5.86
0.78 mi	4,022.21	43.51	31.14 mi	247.32	5.35
0.98 mi	3,515.20	38.39	39.21 mi	205.74	4.93
1.24 mi	3,091.78	34.10	49.36 mi	171.66	4.58
1.56 mi	2,721.80	30.36	62.14 mi	143.75	4.30
1.96 mi	2,372.95	26.84			

Figure 10. Downwind PM2.5 Concentrations from burning Units 4-7 combined in one day with 2200' mixing height.

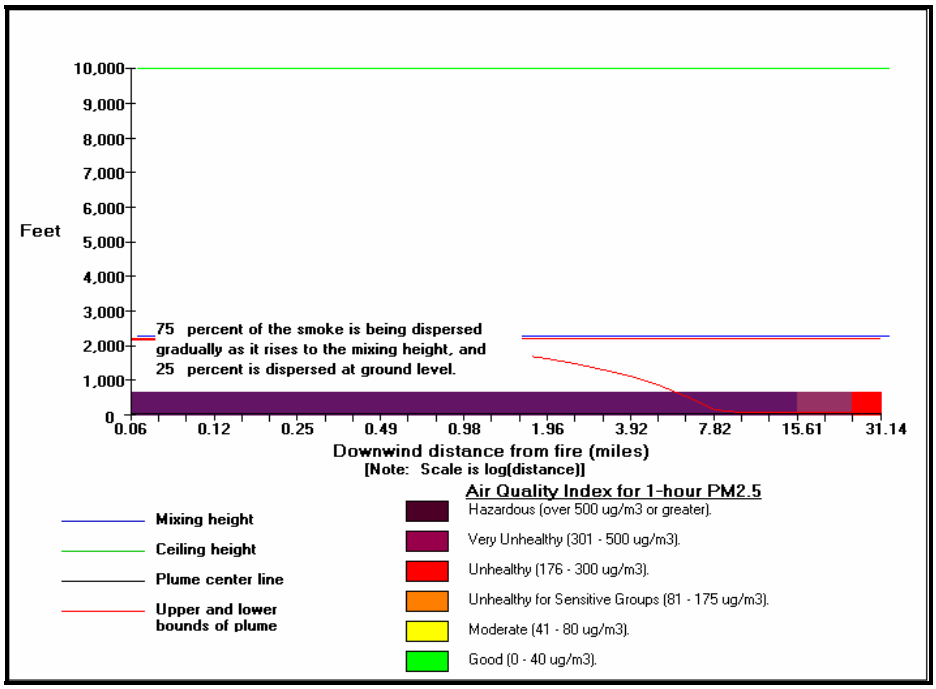


Figure 11. Atmospheric cross-section showing emissions from burning Units 4-7 combined in 1 day.

Smoke can also have an impact on how far and how clearly we can see on a highway or in viewing scenery. The fine particles in the smoke are known to be able to scatter and absorb light, which can reduce visibility conditions. The visibility estimates from VSmoke are valid only when the relative humidity is less than 70 percent. Also, the visibility estimates assume the smoke is passing in front of a person who is looking through the plume of smoke. The visibility thresholds used for this modeling analysis were to maintain a contrast ratio of greater than 0.05 and a visibility distance of 0.25 miles. Visibility conditions may exceed the threshold less than 2.47 miles from the edge of the fire.

Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)	Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)
317 ft	0.03	0.00	2.47 mi	0.28	0.07
422 ft	0.03	0.00	3.11 mi	0.34	0.11
528 ft	0.04	0.00	3.92 mi	0.42	0.16
634 ft	0.04	0.00	4.94 mi	0.51	0.22
845 ft	0.05	0.00	6.21 mi	0.63	0.29
1056 ft	0.06	0.00	7.82 mi	0.77	0.36
0.25 mi	0.07	0.00	9.85 mi	0.93	0.43
0.31 mi	0.08	0.00	12.40 mi	1.11	0.49
0.39 mi	0.09	0.00	15.61 mi	1.34	0.56
0.49 mi	0.10	0.00	19.65 mi	1.61	0.61
0.62 mi	0.12	0.00	24.74 mi	1.94	0.67
0.78 mi	0.14	0.00	31.14 mi	2.32	0.71
0.98 mi	0.16	0.01	39.21 mi	2.77	0.75
1.24 mi	0.18	0.02	49.36 mi	3.30	0.79
1.56 mi	0.21	0.03	62.14 mi	3.91	0.82
1.96 mi	0.24	0.04			

Figure 12. Visibility from burning Units 4-7 combined in one day.

The VSmoke-GIS model estimates where for the pre-selected fine particulate matter concentrations (41, 81, 176, 301, and 501 micrograms per cubic meter) to be predicted downwind of the fire. The VSmoke-GIS analysis had daytime dispersion characteristics to disperse the pollutants from the fire and this is the same as the VSmoke analysis. The downwind spacing interval was set at 0.025 kilometers, and the model ceased making downwind estimates at 30 miles from the edge of the fire. The stability class used for the VSmoke-GIS analysis was slightly unstable and this is the same as the calculated stability from VSmoke.

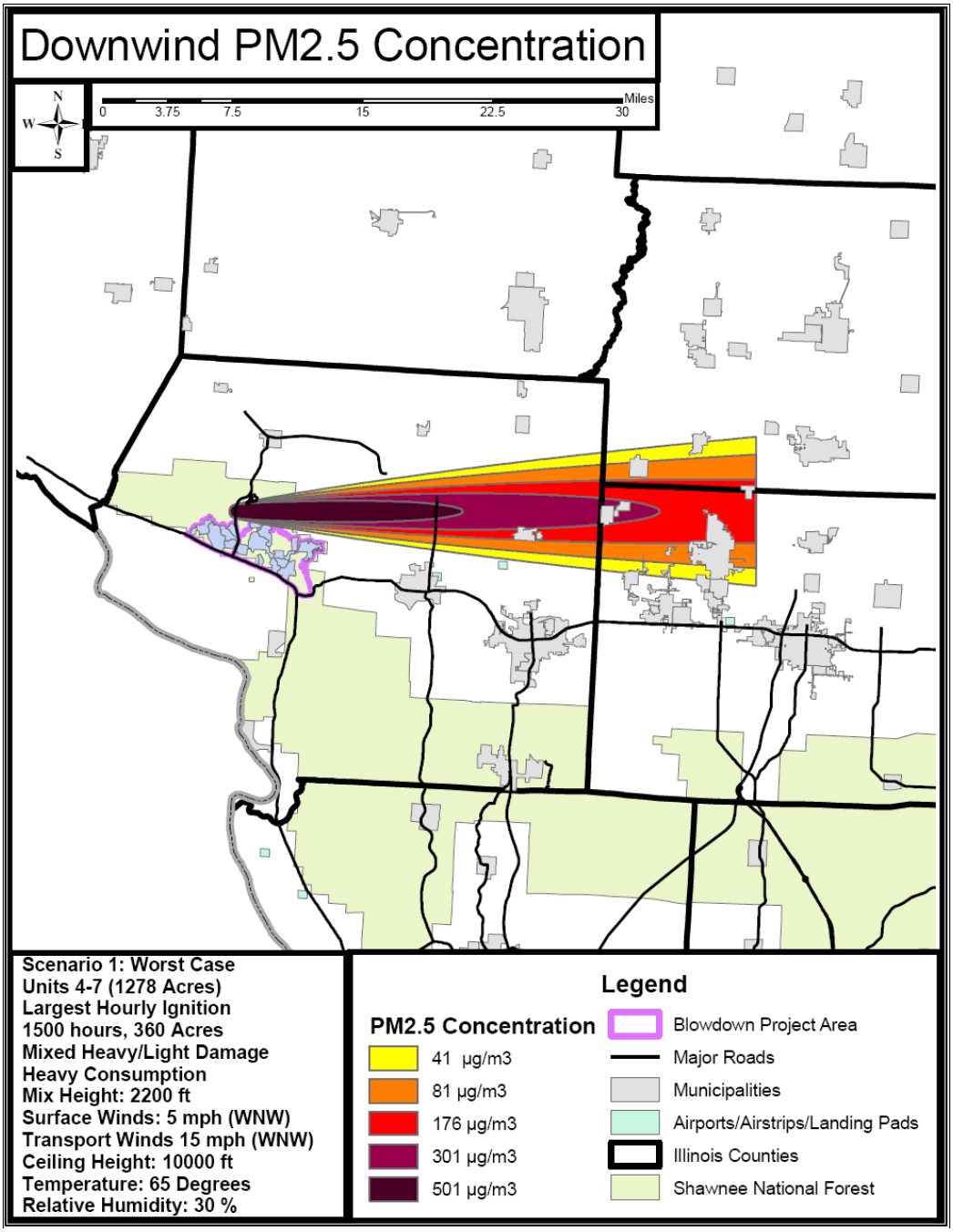


Figure 13. Modeled downwind $PM_{2.5}$ Concentrations from Scenario 1 (Worst Case).

Scenario 2: Largest Acreage, Combination of Units 4-7, Aerial Ignition, Normal Mixing Height.
The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This represents the maximum one-hour concentrations of emissions from the largest collective burn (i.e. a group of burn units) in the blowdown project. Units 4-7 are a combined 1420 acres, but the expected burn pattern would be a mosaic of 50-90% of the area burned. 90% of the area is 1278 acres. For this scenario I used an mixing height of 4000 ft, average for October for this area, and kept all other variables for consumption, emissions, and dispersion the same as in scenario 1. I used a combined ground and aerial ignition pattern to model the burn. If blacklining of the unit started in the 1000 hour, small acreage would be burned each hour until sufficient black is established. Then at the 1200 hour aerial ignition begins, burning a few hundred acres per hour until the unit is mostly lit, then finishing with ground ignition only by the 1600 hour. To estimate percentages of the various fuelbeds I assumed the ignition pattern as starting in the northeast portion of the unit on Dry Hill Rd, proceeding along the perimeter simultaneously west along Dry Hill Rd and south along the fields/firelines, eventually meeting with the other ignition group.

The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This time period has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 37.803 degrees latitude and -89.541 degrees longitude (-95027.446 meters east and 1538377.863 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 8909 grams/second, and carbon monoxide was 108459 grams/second. The heat release rate was 16459560 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 15 micrograms/cubic meter and 3 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.

The meteorological conditions used in this model run were:

1.) Mixing height was **4000** feet above ground level (AGL).
2.) Transport wind speed, and surface wind speed were 15 and 5 miles per hour, respectively.
3.) The sky had 20 percent cloud cover, and the clouds were located 10000 feet above the ground.
4.) Surface temperature was 65 degrees Fahrenheit, and the relative humidity was 30 percent.
5.) The calculated stability class from VSmoke was slightly unstable.

The VSmoke model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.

The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an area of approximately 1000 square miles under uniform weather conditions. Typically, the Dispersion Index value should be greater than 30 when igniting a large number of acres within an area. The calculated Dispersion Index value was 56, which predicts the atmosphere has a good capacity to disperse smoke.

Combining the Dispersion Index and relative humidity values provide an estimate (like is used in insurance actuary tables) of the likelihood of the smoke contributing to fog formation. The Low Visibility Occurrence Risk Index (LVORI) ranges from 1 (lowest risk) to 10 (greatest risk) and usually you want the value to be less than 4. The base line risk of having low visibility as a result of smoke contributing to fog formation is about 1 in 1000 accidents. The Low Visibility Occurrence Risk Index value for this VSmoke analysis was 1 and this is equal to the base line.

High concentrations of particulate matter, especially fine particles (PM2.5), and carbon monoxide can have a negative impact on people's health. The Environmental Protection Agency has developed a color coding system called the Air Quality Index (AQI) to help people understand what concentrations of air pollution may impact their health. When the AQI value is color code orange then people who are sensitive to air pollutants, or have other health problems, may experience health effects. This means they are likely to be affected at lower levels than the general public. Sensitive groups of people include the elderly, children, and people with either lung disease or heart disease. The general public is not likely to be affected when the AQI is code orange. Everyone may begin to experience health effects when AQI values are color coded as red. People who are sensitive to air pollutants may experience more serious health effects when concentrations reach code red levels. This analysis shows the air quality at downwind distances less than 24.74 miles from the edge of the fire may have a 1-hour particulate matter concentrations predicted to be code red or worse, while distances less than 62.14 miles are predicted to be code orange or worse. At distances less than 4.94 miles from the edge of the fire the one-hour carbon monoxide concentrations are predicted to be code red or worse, and distances less than 6.21 miles from the fire are predicted to be code orange or worse.

Distance from fire	PM2.5 (ug/m3)	CO (ppb)	Distance from fire	PM2.5 (ug/m3)	CO (ppb)
317 ft	19,368.34	200.61	2.47 mi	1,529.58	18.46
422 ft	17,033.94	176.78	3.11 mi	1,242.39	15.53
528 ft	14,836.88	154.34	3.92 mi	990.74	12.96
634 ft	12,813.67	133.68	4.94 mi	780.49	10.82
845 ft	10,987.12	115.03	6.21 mi	611.24	9.09
1056 ft	9,366.98	98.49	7.82 mi	478.47	7.73
0.25 mi	7,951.93	84.04	9.85 mi	376.85	6.69
0.31 mi	6,732.30	71.59	12.40 mi	301.64	5.93
0.39 mi	5,692.88	60.98	15.61 mi	246.63	5.37
0.49 mi	4,815.37	52.02	19.65 mi	204.56	4.94
0.62 mi	4,080.32	44.51	24.74 mi	170.63	4.59
0.78 mi	3,468.56	38.26	31.14 mi	142.78	4.30
0.98 mi	2,961.64	33.09	39.21 mi	119.91	4.07
1.24 mi	2,539.30	28.77	49.36 mi	101.16	3.88
1.56 mi	2,174.93	25.05	62.14 mi	85.81	3.72
1.96 mi	1,842.13	21.66			

Figure14. Downwind PM2.5 Concentrations from burning Units 4-7 combined in one day with 4000' mixing height.

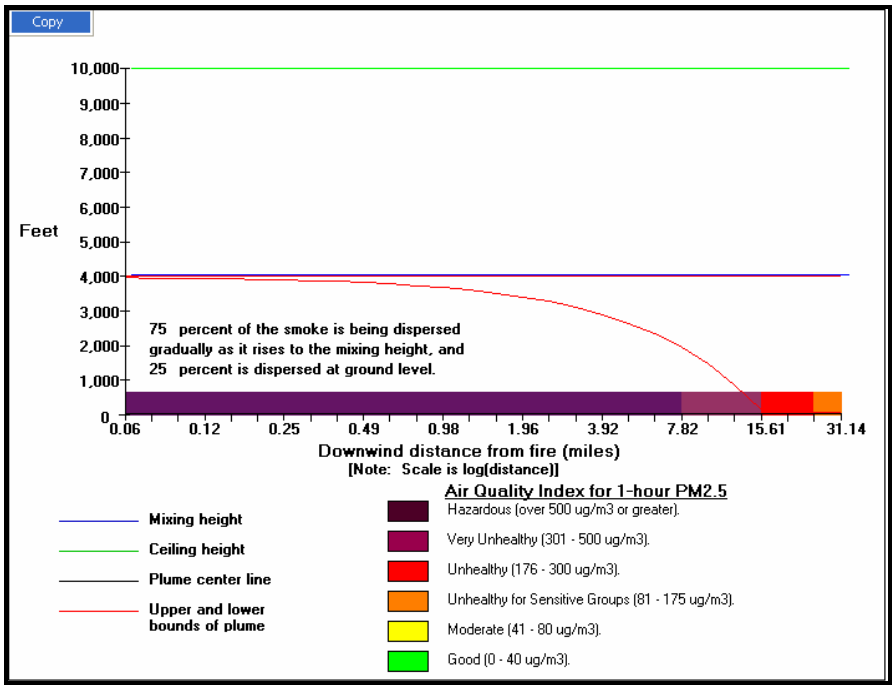


Figure 15. Atmospheric cross-section showing emissions from burning Units 4-7 combined in 1 day.

Smoke can also have an impact on how far and how clearly we can see on a highway or in viewing scenery. The fine particles in the smoke are known to be able to scatter and absorb light, which can reduce visibility conditions. The visibility estimates from VSmoke are valid only when the relative humidity is less than 70 percent. Also, the visibility estimates assume the smoke is passing in front of a person who is looking through the plume of smoke. The visibility thresholds used for this modeling analysis were to maintain a contrast ratio of greater than 0.05 and a visibility distance of 0.25 miles. Visibility conditions may exceed the threshold less than 1.56 miles from the edge of the fire.

Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)	Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)
317 ft	0.03	0.00	2.47 mi	0.38	0.13
422 ft	0.03	0.00	3.11 mi	0.48	0.19
528 ft	0.04	0.00	3.92 mi	0.61	0.27
634 ft	0.04	0.00	4.94 mi	0.79	0.35
845 ft	0.05	0.00	6.21 mi	1.03	0.44
1056 ft	0.06	0.00	7.82 mi	1.35	0.52
0.25 mi	0.07	0.00	9.85 mi	1.74	0.60
0.31 mi	0.08	0.00	12.40 mi	2.19	0.66
0.39 mi	0.10	0.00	15.61 mi	2.67	0.71
0.49 mi	0.12	0.00	19.65 mi	3.17	0.76
0.62 mi	0.14	0.00	24.74 mi	3.73	0.79
0.78 mi	0.16	0.01	31.14 mi	4.37	0.82
0.98 mi	0.19	0.02	39.21 mi	5.10	0.85
1.24 mi	0.22	0.03	49.36 mi	5.92	0.87
1.56 mi	0.26	0.06	62.14 mi	6.82	0.89
1.96 mi	0.31	0.09			

Figure 16. Visibility from burning Units 4-7 combined in one day with 4000 ft mixing height.

The VSmoke-GIS model estimates where for the pre-selected fine particulate matter concentrations (41, 81, 176, 301, and 501 micrograms per cubic meter) to be predicted downwind of the fire. The results (map) are shown below. The VSmoke-GIS analysis had daytime dispersion characteristics to disperse the pollutants from the fire and this is the same as the VSmoke analysis. The downwind spacing interval was set at 0.025 kilometers, and the model ceased making downwind estimates at 30 miles from the edge of the fire. The stability class used for the VSmoke-GIS analysis was slightly unstable and this is the same as the calculated stability from VSmoke.

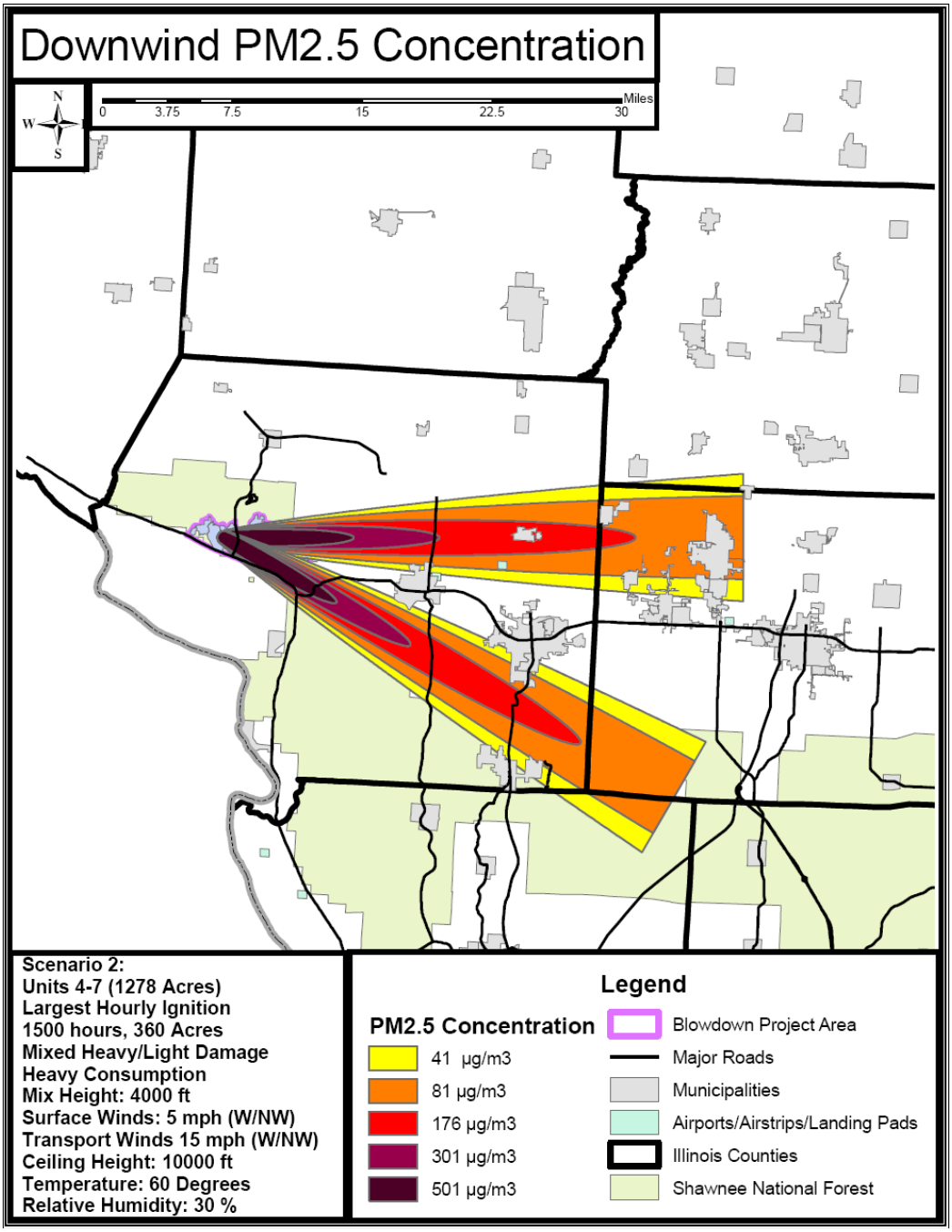


Figure 17. Modeled downwind $PM_{2.5}$ Concentrations from Scenario 2 (4000 ft mixing height).

Scenario 3: Same as Scenario 1 with Normal Mixing Height and Typical Consumption.
The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This represents the maximum one-hour concentrations of emissions from the largest collective burn (i.e. a group of burn units) in the blowdown project. Units 4-7 are a combined 1420 acres, but the expected burn pattern would be a mosaic of 50-90% of the area burned. 90% of the area is 1278 acres. For this scenario I used an mixing height of 4000 ft, average for October for this area, and but used realistic values for fuel consumption in the FEPS model. Dispersion variables are the same as in scenario 2. I used a combined ground and aerial ignition pattern to model the burn. If blacklining of the unit started in the 1000 hour, small acreage would be burned each hour until sufficient black is established. Then at the 1200 hour aerial ignition begins, burning a few hundred acres per hour until the unit is mostly lit, then finishing with ground ignition only by the 1600 hour. To estimate percentages of the various fuelbeds I modeled the ignition as starting in the northeast portion of the unit on Dry Hill Rd, proceeding along the perimeter simultaneously west along Dry Hill Rd and south along the fields/firelines, eventually meeting with the other ignition group.

The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This time period has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 37.803 degrees latitude and -89.541 degrees longitude (-95027.446 meters east and 1538377.863 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 4549 grams/second, and carbon monoxide was 55397 grams/second. The heat release rate was 8324739 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 15 micrograms/cubic meter and 3 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.

The meteorological conditions used in this model run were:

1.) Mixing height was **4000** feet above ground level (AGL).
2.) Transport wind speed, and surface wind speed were 15 and 5 miles per hour, respectively.
3.) The sky had 20 percent cloud cover, and the clouds were located 10000 feet above the ground.
4.) Surface temperature was 65 degrees Fahrenheit, and the relative humidity was 30 percent.
5.) The calculated stability class from VSmoke was slightly unstable.

The VSmoke model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.

The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an area of approximately 1000 square miles under uniform weather conditions. Typically, the Dispersion Index value should be greater than 30 when igniting a large number of acres within an area. The calculated Dispersion Index value was 56, which predicts the atmosphere has a good capacity to disperse smoke.

Combining the Dispersion Index and relative humidity values provide an estimate (like is used in insurance actuary tables) of the likelihood of the smoke contributing to fog formation. The Low Visibility Occurrence Risk Index (LVORI) ranges from 1 (lowest risk) to 10 (greatest risk) and usually you want the value to be less than 4. The base line risk of having low visibility as a result of smoke contributing to fog formation is about 1 in 1000 accidents. The Low Visibility Occurrence Risk Index value for this VSmoke analysis was 1 and this is equal to the base line.

High concentrations of particulate matter, especially fine particles (PM2.5), and carbon monoxide can have a negative impact on people's health. The Environmental Protection Agency has developed a color coding system called the Air Quality Index (AQI) to help people understand what concentrations of air pollution may impact their health. When the AQI value is color code orange then people who are sensitive to air pollutants, or have other health problems, may experience health effects. This means they are likely to be affected at lower levels than the general public. Sensitive groups of people include the elderly, children, and people with either lung disease or heart disease. The general public is not likely to be affected when the AQI is code orange. Everyone may begin to experience health effects when AQI values are color coded as red. People who are sensitive to air pollutants may experience more serious health effects when concentrations reach code red levels. This analysis shows the air quality at downwind distances less than 12.40 miles from the edge of the fire may have a 1-hour particulate matter concentrations predicted to be code red or worse, while distances less than 31.14 miles are predicted to be code orange or worse. At distances less than 2.47 miles from the edge of the fire the one-hour carbon monoxide concentrations are predicted to be code red or worse, and distances less than 3.11 miles from the fire are predicted to be code orange or worse.

Distance from fire	PM2.5 (ug/m3)	CO (ppb)	Distance from fire	PM2.5 (ug/m3)	CO (ppb)
317 ft	9,896.96	103.93	2.47 mi	788.35	10.90
422 ft	8,705.00	91.76	3.11 mi	641.72	9.40
528 ft	7,583.16	80.30	3.92 mi	513.22	8.09
634 ft	6,550.09	69.75	4.94 mi	405.87	6.99
845 ft	5,617.45	60.22	6.21 mi	319.44	6.11
1056 ft	4,790.19	51.77	7.82 mi	251.65	5.42
0.25 mi	4,067.65	44.39	9.85 mi	199.77	4.89
0.31 mi	3,444.90	38.03	12.40 mi	161.36	4.49
0.39 mi	2,914.17	32.61	15.61 mi	133.27	4.21
0.49 mi	2,466.10	28.04	19.65 mi	111.79	3.99
0.62 mi	2,090.78	24.20	24.74 mi	94.47	3.81
0.78 mi	1,778.41	21.01	31.14 mi	80.24	3.67
0.98 mi	1,519.58	18.37	39.21 mi	68.57	3.55
1.24 mi	1,303.93	16.16	49.36 mi	59.00	3.45
1.56 mi	1,117.87	14.26	62.14 mi	51.16	3.37
1.96 mi	947.95	12.53			

Figure 18. Downwind PM2.5 Concentrations Scenario 3: 4000' mixing height, typical consumption.

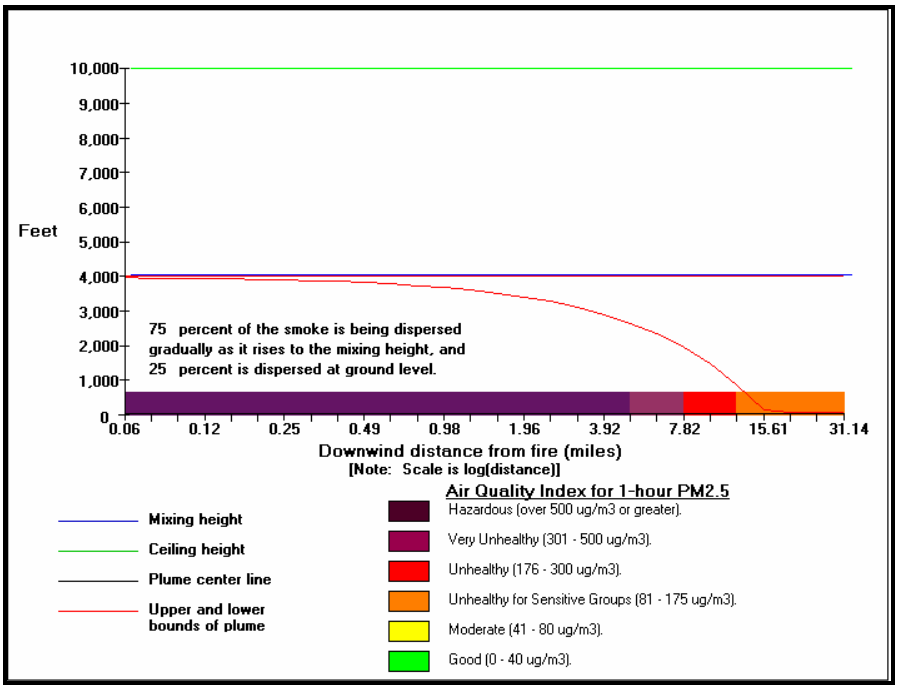


Figure 19. Atmospheric cross-section showing emissions from scenario 3.

Smoke can also have an impact on how far and how clearly we can see on a highway or in viewing scenery. The fine particles in the smoke are known to be able to scatter and absorb light, which can reduce visibility conditions. The visibility estimates from VSmoke are valid only when the relative humidity is less than 70 percent. Also, the visibility estimates assume the smoke is passing in front of a person who is looking through the plume of smoke. The visibility thresholds used for this modeling analysis were to maintain a contrast ratio of greater than 0.05 and a visibility distance of 0.25 miles. Visibility conditions may exceed the threshold less than 0.62 miles from the edge of the fire.

Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)	Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)
317 ft	0.06	0.00	2.47 mi	0.89	0.35
422 ft	0.06	0.00	3.11 mi	1.29	0.43
528 ft	0.07	0.00	3.92 mi	2.45	0.50
634 ft	0.09	0.00	4.94 mi	4.84	0.58
845 ft	0.10	0.00	6.21 mi	6.82	0.65
1056 ft	0.12	0.00	7.82 mi	8.42	0.71
0.25 mi	0.14	0.00	9.85 mi	9.67	0.76
0.31 mi	0.16	0.01	12.40 mi	10.47	0.80
0.39 mi	0.19	0.02	15.61 mi	10.82	0.83
0.49 mi	0.23	0.04	19.65 mi	10.91	0.86
0.62 mi	0.27	0.06	24.74 mi	10.95	0.88
0.78 mi	0.31	0.09	31.14 mi	11.07	0.89
0.98 mi	0.37	0.13	39.21 mi	11.39	0.91
1.24 mi	0.44	0.17	49.36 mi	11.93	0.92
1.56 mi	0.53	0.23	62.14 mi	12.64	0.93
1.96 mi	0.67	0.28			

Figure 20. Visibility from scenario 3: 4000 ft mixing height, typical fuel consumption.

The VSmoke-GIS model estimates the distance of various fine particulate matter concentrations (41, 81, 176, 301, and 501 micrograms per cubic meter) downwind of the fire. The results (map) for Scenario 3 are shown below. Note that this scenario represents the largest combination of units to be burned, under realistic atmospheric and consumption conditions. Code Orange PM2.5 conditions (Unhealthy for Sensitive Groups) are found less than 31 miles from the fire. Given the overprediction of the model, actual impacts would be expected to be much less. The VSmoke-GIS / Vsmoke analysis had daytime dispersion characteristics to disperse the pollutants from the fire. The downwind spacing interval was set at 0.025 kilometers, and the model ceased making downwind estimates at 30 miles from the edge of the fire. The stability class used for the VSmoke-GIS and VSmoke analysis was slightly unstable.

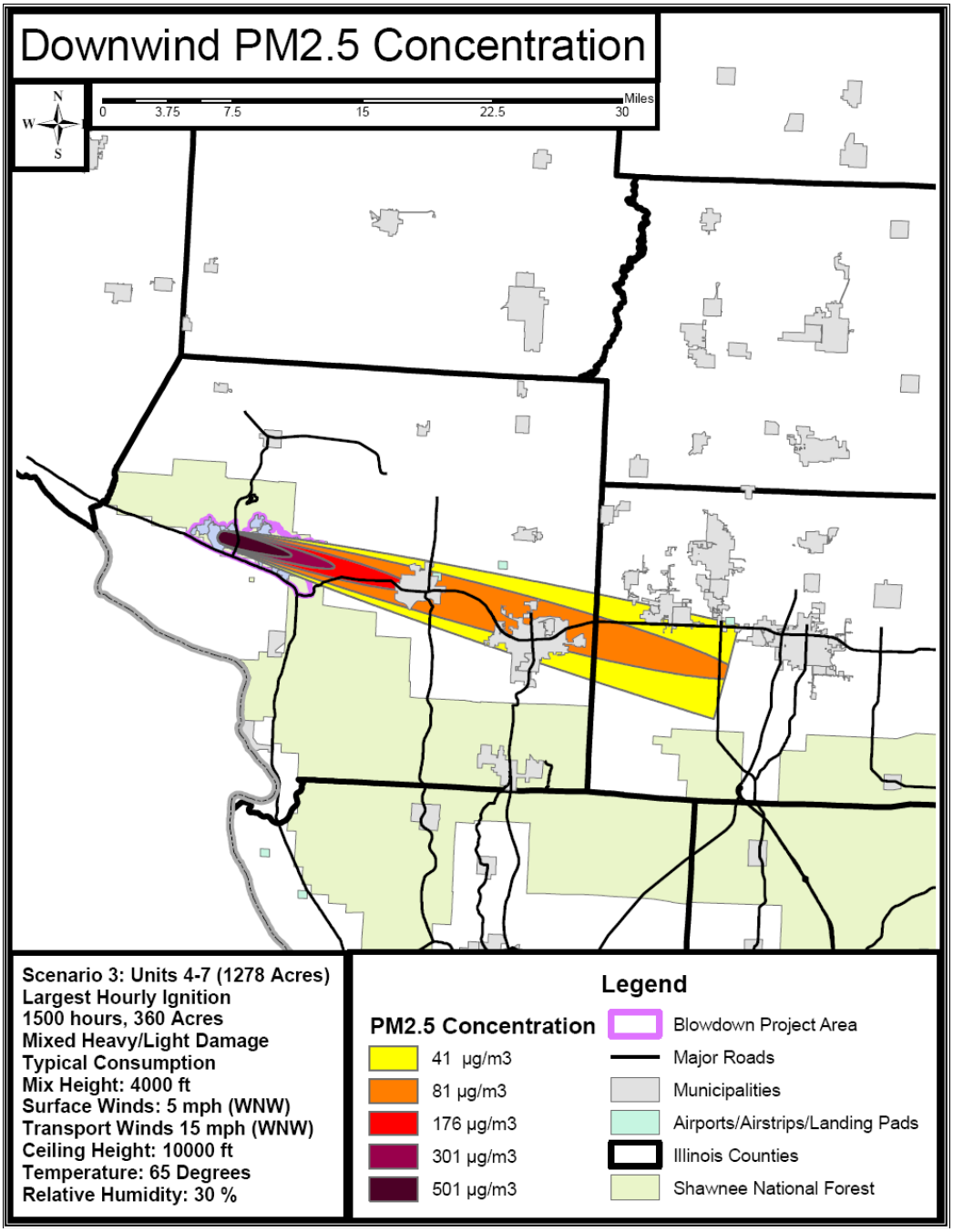


Figure 21. Modeled downwind $PM_{2.5}$ Concentrations from Scenario 3.

Scenario 4: Normal Mixing Height, Typical Consumption, and Realistic Smoldering.
The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This represents the maximum one-hour concentrations of emissions from the largest collective burn (i.e. a group of burn units) in the blowdown project. Units 4-7 are a combined 1420 acres, but the expected burn pattern would be a mosaic of 50-90% of the area burned. 90% of the area is 1278 acres. For this scenario I used an mixing height of 4000 ft, average for October for this area, and but used realistic values for fuel consumption in the FEPS model, and realistic values for short and long-term smoldering. Dispersion variables are the same as in scenario 2. I used a combined ground and aerial ignition pattern to model the burn. If blacklining of the unit started in the 1000 hour, small acreage would be burned each hour until sufficient black is established. Then at the 1200 hour aerial ignition begins, burning a few hundred acres per hour until the unit is mostly lit, then finishing with ground ignition only by the 1600 hour. To estimate percentages of the various fuelbeds I modeled the ignition as starting in the northeast portion of the unit on Dry Hill Rd, proceeding along the perimeter simultaneously west along Dry Hill Rd and south along the fields/firelines, eventually meeting with the other ignition group.

The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 360 acres to be burned on 10/25/2008 at the time period of 1500 hours. This time period has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 37.803 degrees latitude and -89.541 degrees longitude (-95027.446 meters east and 1538377.863 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 2552 grams/second, and carbon monoxide was 29805 grams/second. The heat release rate was 7016415 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 15 micrograms/cubic meter and 3 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.

The meteorological conditions used in this model run were:

1.) Mixing height was **4000** feet above ground level (AGL).
2.) Transport wind speed, and surface wind speed were 15 and 5 miles per hour, respectively.
3.) The sky had 20 percent cloud cover, and the clouds were located 10000 feet above the ground.
4.) Surface temperature was 65 degrees Fahrenheit, and the relative humidity was 30 percent.
5.) The calculated stability class from VSmoke was slightly unstable.

The VSmoke model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.

The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an area of approximately 1000 square miles under uniform weather conditions. Typically, the Dispersion Index value should be greater than 30 when igniting a large number of acres within an area. The calculated Dispersion Index value was 56, which predicts the atmosphere has a good capacity to disperse smoke.

Combining the Dispersion Index and relative humidity values provide an estimate (like is used in insurance actuary tables) of the likelihood of the smoke contributing to fog formation. The Low Visibility Occurrence Risk Index (LVORI) ranges from 1 (lowest risk) to 10 (greatest risk) and usually you want the value to be less than 4. The base line risk of having low visibility as a result of smoke contributing to fog formation is about 1

in 1000 accidents. The Low Visibility Occurrence Risk Index value for this VSmoke analysis was 1 and this is equal to the base line.

High concentrations of particulate matter, especially fine particles (PM2.5), and carbon monoxide can have a negative impact on people's health. The Environmental Protection Agency has developed a color coding system called the Air Quality Index (AQI) to help people understand what concentrations of air pollution may impact their health. When the AQI value is color code orange then people who are sensitive to air pollutants, or have other health problems, may experience health effects. This means they are likely to be affected at lower levels than the general public. Sensitive groups of people include the elderly, children, and people with either lung disease or heart disease. The general public is not likely to be affected when the AQI is code orange. Everyone may begin to experience health effects when AQI values are color coded as red. People who are sensitive to air pollutants may experience more serious health effects when concentrations reach code red levels. This analysis shows the air quality at downwind distances less than 7.82 miles from the edge of the fire may have a 1-hour particulate matter concentrations predicted to be code red or worse, while distances less than 19.65 miles are predicted to be code orange or worse. At distances less than 0.98 miles from the edge of the fire the one-hour carbon monoxide concentrations are predicted to be code red or worse, and distances less than 1.56 miles from the fire are predicted to be code orange or worse.

Distance from fire	PM2.5 (ug/m3)	CO (ppb)	Distance from fire	PM2.5 (ug/m3)	CO (ppb)
317 ft	5,558.80	57.30	2.47 mi	448.85	7.25
422 ft	4,890.11	50.75	3.11 mi	366.59	6.44
528 ft	4,260.75	44.59	3.92 mi	294.50	5.74
634 ft	3,681.20	38.91	4.94 mi	234.28	5.15
845 ft	3,157.99	33.79	6.21 mi	185.79	4.67
1056 ft	2,693.89	29.24	7.82 mi	147.76	4.30
0.25 mi	2,288.55	25.27	9.85 mi	118.65	4.02
0.31 mi	1,939.18	21.85	12.40 mi	97.11	3.80
0.39 mi	1,641.44	18.93	15.61 mi	81.35	3.65
0.49 mi	1,390.07	16.47	19.65 mi	69.30	3.53
0.62 mi	1,179.52	14.41	24.74 mi	59.58	3.44
0.78 mi	1,004.28	12.69	31.14 mi	51.60	3.36
0.98 mi	859.07	11.27	39.21 mi	45.05	3.29
1.24 mi	738.09	10.08	49.36 mi	39.68	3.24
1.56 mi	633.72	9.06	62.14 mi	35.28	3.20
1.96 mi	538.39	8.13			

Figure 22. Downwind PM2.5 Concentrations Scenario 4: 4000' mixing height, typical consumption and smoldering.

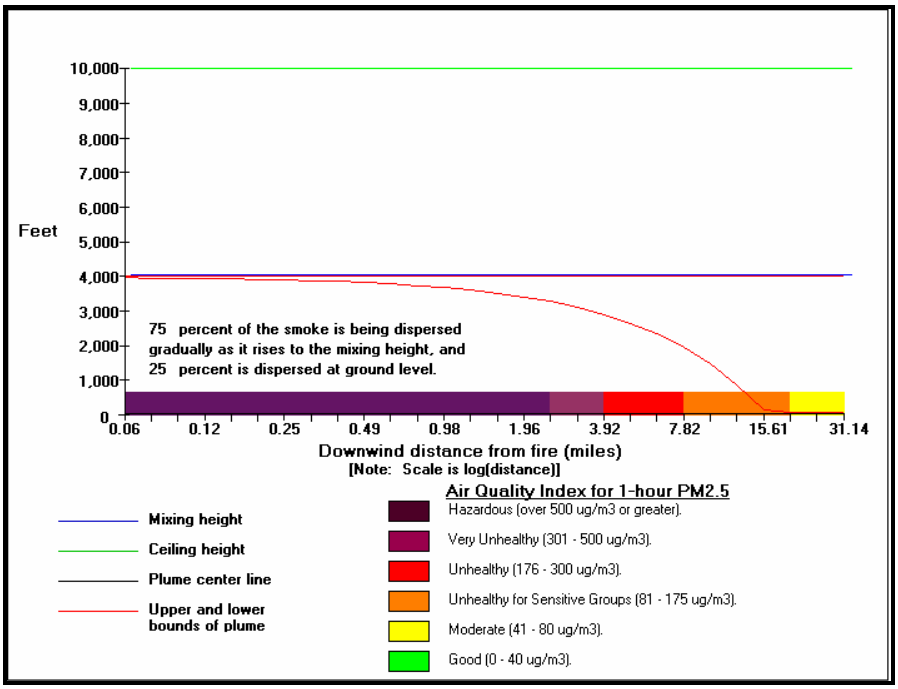


Figure 23. Atmospheric cross-section showing emissions from scenario 4.

Smoke can also have an impact on how far and how clearly we can see on a highway or in viewing scenery. The fine particles in the smoke are known to be able to scatter and absorb light, which can reduce visibility conditions. The visibility estimates from VSmoke are valid only when the relative humidity is less than 70 percent. Also, the visibility estimates assume the smoke is passing in front of a person who is looking through the plume of smoke. The visibility thresholds used for this modeling analysis were to maintain a contrast ratio of greater than 0.05 and a visibility distance of 0.25 miles. Visibility conditions may exceed the threshold less than 0.31 miles from the edge of the fire.

Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)	Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)
317 ft	0.10	0.00	2.47 mi	10.17	0.55
422 ft	0.11	0.00	3.11 mi	12.24	0.61
528 ft	0.13	0.00	3.92 mi	13.92	0.67
634 ft	0.15	0.01	4.94 mi	15.29	0.73
845 ft	0.18	0.01	6.21 mi	16.40	0.78
1056 ft	0.21	0.03	7.82 mi	17.30	0.82
0.25 mi	0.24	0.05	9.85 mi	17.99	0.85
0.31 mi	0.29	0.07	12.40 mi	18.44	0.87
0.39 mi	0.34	0.11	15.61 mi	18.64	0.89
0.49 mi	0.40	0.15	19.65 mi	18.69	0.91
0.62 mi	0.47	0.20	24.74 mi	18.70	0.92
0.78 mi	0.56	0.26	31.14 mi	18.70	0.93
0.98 mi	0.70	0.31	39.21 mi	18.70	0.94
1.24 mi	1.09	0.37	49.36 mi	18.72	0.94
1.56 mi	4.55	0.43	62.14 mi	18.83	0.95
1.96 mi	7.64	0.49			

Figure 24. Visibility from scenario 4: 4000 ft mixing height, typical fuel consumption and smoldering.

The VSmoke-GIS model estimates the distance of various fine particulate matter concentrations (41, 81, 176, 301, and 501 micrograms per cubic meter) downwind of the fire. The results (map) for Scenario 4 are shown below. Note that this scenario represents the largest combination of units to be burned, under realistic atmospheric, consumption, and smoldering conditions. Code Orange (Unhealthy for Sensitive Groups) $PM_{2.5}$ conditions are found less than 19.65 miles from the fire. Given the overprediction of the model, actual impacts would be expected to be much less. The VSmoke-GIS and VSmoke analysis had daytime dispersion characteristics to disperse the pollutants from the fire. The downwind spacing interval was set at 0.025 kilometers, and the model ceased making downwind estimates at 30 miles from the edge of the fire. The stability class used for the VSmoke-GIS and VSmoke analysis was slightly unstable.

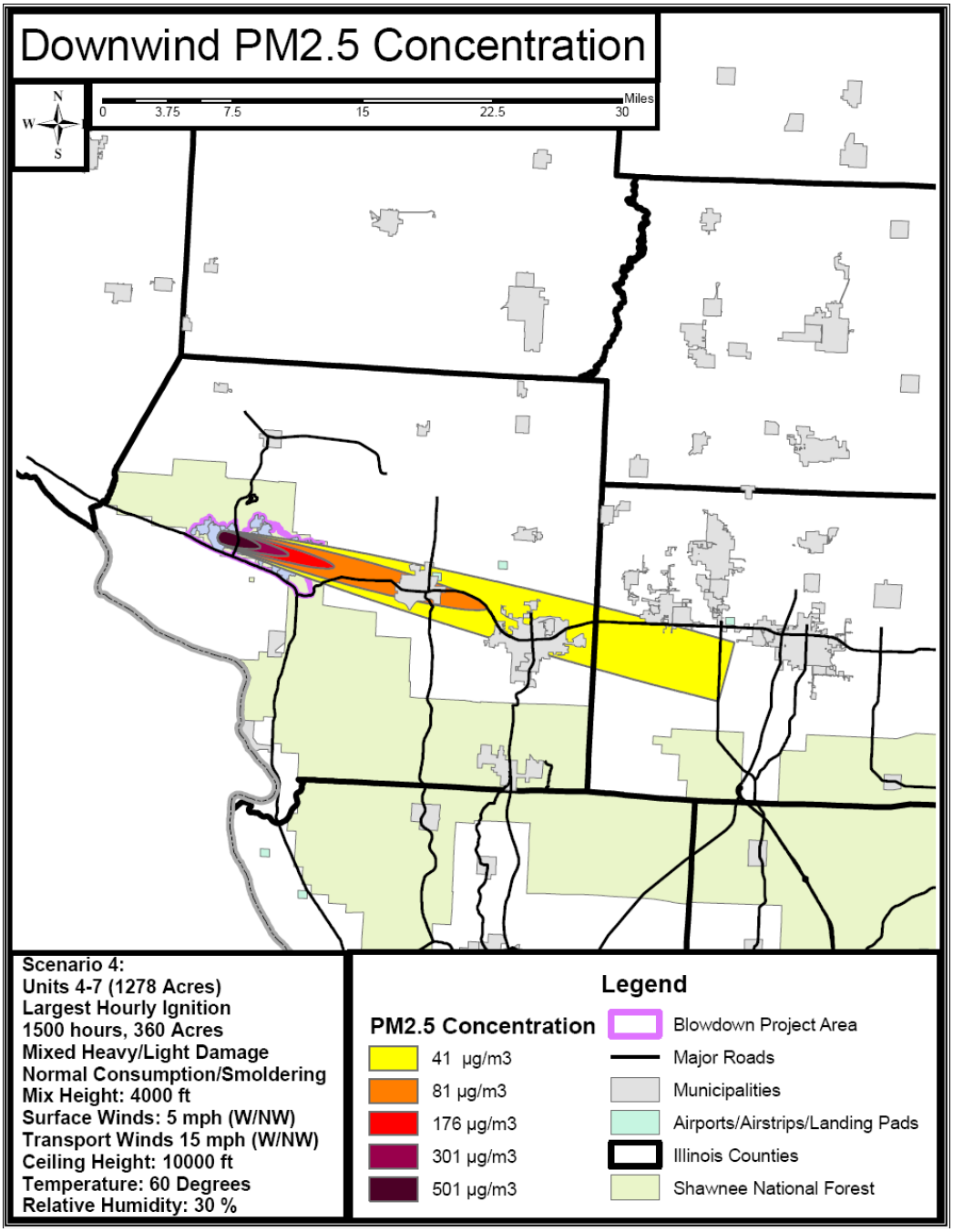


Figure 25. Modeled downwind $PM_{2.5}$ Concentrations from Scenario 4.

Scenario 5: Unit 7: Very Low Mixing Height, Typical Consumption, and Realistic Smoldering.
Unit 7 is 748 acres, but the expected burn pattern would be a 50-90% mosaic. 90% of the area is 691 acres. The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 169 acres to be burned on 10/25/2008 at the time period of 1500 hours. This represents the maximum one-hour concentrations of emissions from a simulated 6-hour burn in the largest burn unit in the blowdown project. 169 acres would be actively ignited, while another 502 would have been ignited earlier in the day and would be currently smoldering. For this scenario I used a mixing height of 1500 ft, very low for October for this area, but used realistic values for fuel consumption in the FEPS model, and realistic values for short and long-term smoldering. Other dispersion variables are the same as in scenario 2. I used a combined ground and aerial ignition pattern to model the burn. If blacklining of the unit started in the 1000 hour, small acreage would be burned each hour until sufficient black is established. Then at the 1300 hour aerial ignition begins, burning a few hundred acres per hour until the unit is mostly lit, then finishing with ground ignition only by the 1600 hour. To estimate percentages of the various fuelbeds I assumed the ignition pattern as starting in the northeast portion of the unit on Dry Hill Rd, proceeding along the perimeter simultaneously west along Dry Hill Rd and south along the fields/firelines, eventually meeting with the other ignition group.

The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 169 acres to be burned on 10/25/2008 at the time period of 1500 hours. This time period has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 37.804 degrees latitude and -89.548 degrees longitude (-95662.423 meters east and 1538559.302 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 1119 grams/second, and carbon monoxide was 13075 grams/second. The heat release rate was 3080892 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 15 micrograms/cubic meter and 3 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.

The meteorological conditions used in this model run were:

1.) Mixing height was **1500** feet above ground level (AGL).
2.) Transport wind speed, and surface wind speed were 15 and 5 miles per hour, respectively.
3.) The sky had 20 percent cloud cover, and the clouds were located 10000 feet above the ground.
4.) Surface temperature was 60 degrees Fahrenheit, and the relative humidity was 40 percent.
5.) The calculated stability class from VSmoke was slightly unstable.

The VSmoke model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.

The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an area of approximately 1000 square miles under uniform weather conditions. Typically, the Dispersion Index value should be greater than 30 when igniting a large number of acres within an area. The calculated Dispersion Index value was 28, which predicts the atmosphere has a fair capacity to disperse smoke.

Combining the Dispersion Index and relative humidity values provide an estimate (like is used in insurance actuary tables) of the likelihood of the smoke contributing to fog formation. The Low Visibility Occurrence Risk Index (LVORI) ranges from 1 (lowest risk) to 10 (greatest risk) and usually you want the value to be less

than 4. The base line risk of having low visibility as a result of smoke contributing to fog formation is about 1 in 1000 accidents. The Low Visibility Occurrence Risk Index value for this VSmoke analysis was 2 and this is close to the base line.

High concentrations of particulate matter, especially fine particles (PM2.5), and carbon monoxide can have a negative impact on people's health. The Environmental Protection Agency has developed a color coding system called the Air Quality Index (AQI) to help people understand what concentrations of air pollution may impact their health. When the AQI value is color code orange then people who are sensitive to air pollutants, or have other health problems, may experience health effects. This means they are likely to be affected at lower levels than the general public. Sensitive groups of people include the elderly, children, and people with either lung disease or heart disease. The general public is not likely to be affected when the AQI is code orange. Everyone may begin to experience health effects when AQI values are color coded as red. People who are sensitive to air pollutants may experience more serious health effects when concentrations reach code red levels. This analysis shows the air quality at downwind distances less than 7.82 miles from the edge of the fire may have a 1-hour particulate matter concentrations predicted to be code red or worse, while distances less than 19.65 miles are predicted to be code orange or worse. At distances less than 0.62 miles from the edge of the fire the one-hour carbon monoxide concentrations are predicted to be code red or worse, and distances less than 1.24 miles from the fire are predicted to be code orange or worse.

Distance from fire	PM2.5 (ug/m3)	CO (ppb)	Distance from fire	PM2.5 (ug/m3)	CO (ppb)
317 ft	3,769.60	39.46	2.47 mi	398.19	6.72
422 ft	3,341.66	35.30	3.11 mi	325.80	6.02
528 ft	2,938.89	31.39	3.92 mi	266.70	5.44
634 ft	2,568.00	27.79	4.94 mi	220.85	5.00
845 ft	2,233.15	24.54	6.21 mi	184.88	4.65
1056 ft	1,936.15	21.65	7.82 mi	155.31	4.36
0.25 mi	1,676.74	19.13	9.85 mi	130.56	4.12
0.31 mi	1,453.16	16.96	12.40 mi	109.94	3.92
0.39 mi	1,262.62	15.11	15.61 mi	92.89	3.76
0.49 mi	1,101.75	13.55	19.65 mi	78.86	3.62
0.62 mi	966.90	12.24	24.74 mi	67.35	3.51
0.78 mi	853.56	11.14	31.14 mi	57.92	3.42
0.98 mi	754.72	10.18	39.21 mi	50.20	3.34
1.24 mi	661.91	9.28	49.36 mi	43.90	3.28
1.56 mi	570.32	8.39	62.14 mi	38.74	3.23
1.96 mi	481.03	7.52			

Figure 26. Downwind PM2.5 Concentrations Scenario 5: 1500' mixing height, typical consumption and smoldering.

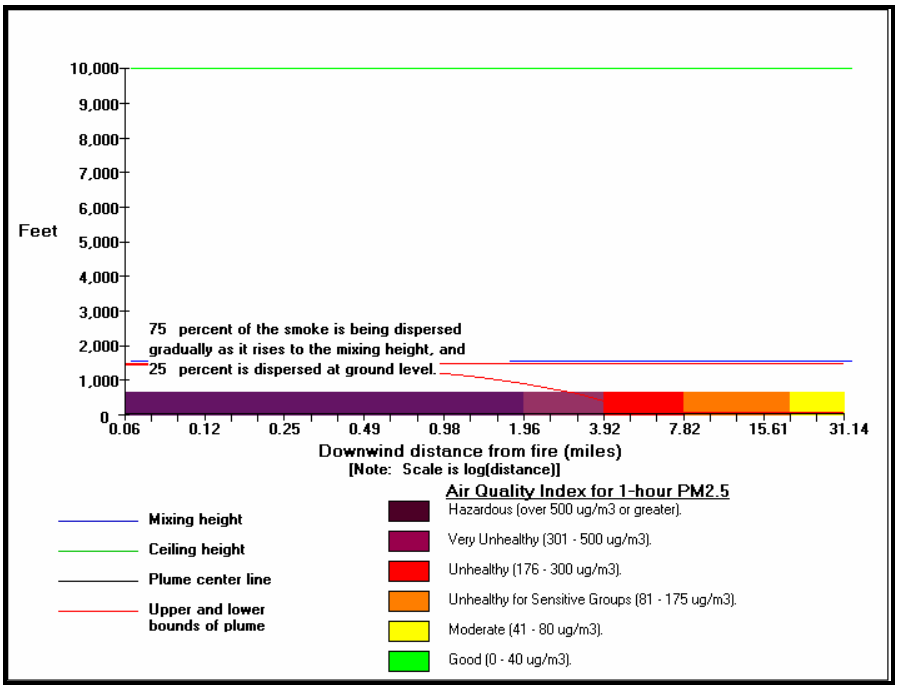


Figure 27. Atmospheric cross-section showing emissions from scenario 5.

Smoke can also have an impact on how far and how clearly we can see on a highway or in viewing scenery. The fine particles in the smoke are known to be able to scatter and absorb light, which can reduce visibility conditions. The visibility estimates from VSmoke are valid only when the relative humidity is less than 70 percent. Also, the visibility estimates assume the smoke is passing in front of a person who is looking through the plume of smoke. The visibility thresholds used for this modeling analysis were to maintain a contrast ratio of greater than 0.05 and a visibility distance of 0.25 miles. Visibility conditions may exceed the threshold less than 1025 feet from the edge of the fire.

Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)	Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)
317 ft	0.15	0.01	2.47 mi	15.09	0.59
422 ft	0.17	0.01	3.11 mi	15.97	0.65
528 ft	0.19	0.02	3.92 mi	16.59	0.70
634 ft	0.22	0.03	4.94 mi	16.90	0.74
845 ft	0.25	0.05	6.21 mi	17.00	0.78
1056 ft	0.29	0.07	7.82 mi	17.01	0.81
0.25 mi	0.33	0.10	9.85 mi	17.01	0.83
0.31 mi	0.38	0.14	12.40 mi	17.01	0.86
0.39 mi	0.45	0.18	15.61 mi	17.01	0.88
0.49 mi	0.61	0.23	19.65 mi	17.01	0.89
0.62 mi	3.55	0.27	24.74 mi	17.01	0.91
0.78 mi	6.51	0.32	31.14 mi	17.01	0.92
0.98 mi	8.95	0.37	39.21 mi	17.02	0.93
1.24 mi	10.97	0.42	49.36 mi	17.09	0.94
1.56 mi	12.63	0.48	62.14 mi	17.29	0.94
1.96 mi	13.98	0.53			

Figure 28. Visibility from scenario 5: 1500 ft mixing height, typical fuel consumption and smoldering.

The VSmoke-GIS model estimates the distance of various fine particulate matter concentrations (41, 81, 176, 301, and 501 micrograms per cubic meter) downwind of the fire. The results (map) for Scenario 5 are shown below. Note that this scenario represents the largest single unit to be burned, under very low mixing heights, but realistic consumption and smoldering conditions. Code Orange (Unhealthy for Sensitive Groups) PM2.5 conditions are found less than 19.65 miles from the fire. Given the overprediction of the model, actual impacts would be expected to be much less. The VSmoke-GIS and VSmoke analysis had daytime dispersion characteristics to disperse the pollutants from the fire. The downwind spacing interval was set at 0.025 kilometers, and the model ceased making downwind estimates at 30 miles from the edge of the fire. The stability class used for the VSmoke-GIS and VSmoke analysis was slightly unstable.

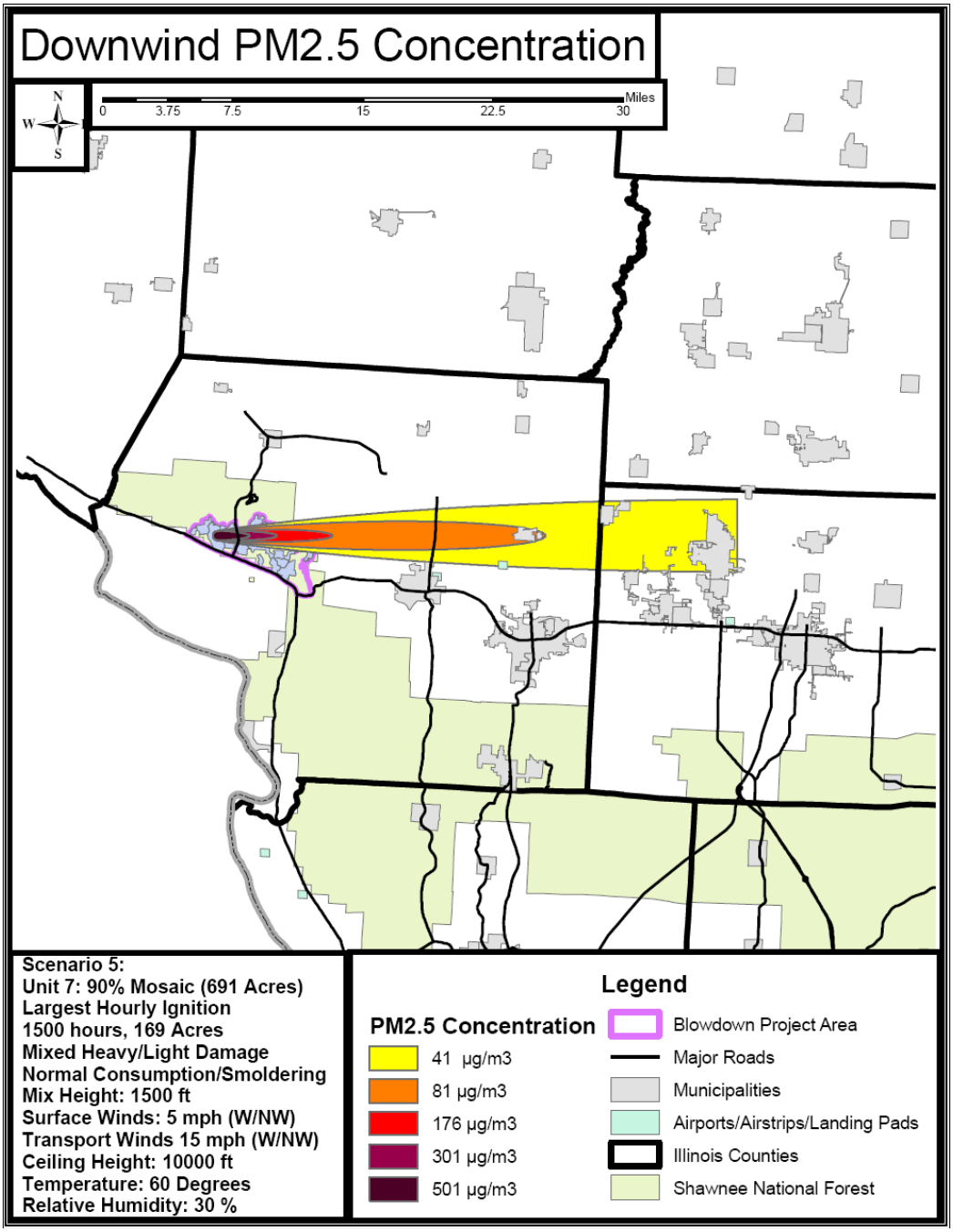


Figure 29. Modeled downwind $PM_{2.5}$ Concentrations from Scenario 5.

Scenario 6: Unit 7: Normal Mixing Height, Typical Consumption, and Realistic Smoldering.
Unit 7 is 748 acres, but the expected burn pattern would be a 50-90% mosaic. 90% of the area is 691 acres. The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 169 acres to be burned on 10/25/2008 at the time period of 1500 hours. This represents the maximum one-hour concentrations of emissions from a simulated 6-hour burn in the largest burn unit in the blowdown project. 169 acres would be actively ignited, while another 502 would have been ignited earlier in the day and would be currently smoldering. For this scenario I used an mixing height of 4000 ft, average for October for this area, and but used realistic values for fuel consumption in the FEPS model, and realistic values for short and long-term smoldering. Dispersion variables are the same as in scenario 2. I used a combined ground and aerial ignition pattern to model the burn. If blacklining of the unit started in the 1000 hour, small acreage would be burned each hour until sufficient black is established. Then at the 1300 hour aerial ignition begins, burning a few hundred acres per hour until the unit is mostly lit, then finishing with ground ignition only by the 1600 hour. To estimate percentages of the various fuelbeds I modeled the ignition as starting in the northeast portion of the unit on Dry Hill Rd, proceeding along the perimeter simultaneously west along Dry Hill Rd and south along the fields/firelines, eventually meeting with the other ignition group.

The smoke dispersion modeling analysis (using VSmoke and/or VSmoke-GIS) for this project was performed for 169 acres to be burned on 10/25/2008 at the time period of 1500 hours. This time period has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 37.804 degrees latitude and -89.55 degrees longitude (-95802.392 meters east and 1538588.41 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 1119 grams/second, and carbon monoxide was 13075 grams/second. The heat release rate was 3080892 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 15 micrograms/cubic meter and 3 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.

The meteorological conditions used in this model run were:

1.) Mixing height was **4000** feet above ground level (AGL).
2.) Transport wind speed, and surface wind speed were 15 and 5 miles per hour, respectively.
3.) The sky had 20 percent cloud cover, and the clouds were located 10000 feet above the ground.
4.) Surface temperature was 65 degrees Fahrenheit, and the relative humidity was 30 percent.
5.) The calculated stability class from VSmoke was slightly unstable.

The VSmoke model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.

The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an area of approximately 1000 square miles under uniform weather conditions. Typically, the Dispersion Index value should be greater than 30 when igniting a large number of acres within an area. The calculated Dispersion Index value was 56, which predicts the atmosphere has a good capacity to disperse smoke.

Combining the Dispersion Index and relative humidity values provide an estimate (like is used in insurance actuary tables) of the likelihood of the smoke contributing to fog formation. The Low Visibility Occurrence Risk Index (LVORI) ranges from 1 (lowest risk) to 10 (greatest risk) and usually you want the value to be less

than 4. The base line risk of having low visibility as a result of smoke contributing to fog formation is about 1 in 1000 accidents. The Low Visibility Occurrence Risk Index value for this VSmoke analysis was 1 and this is equal to the base line.

High concentrations of particulate matter, especially fine particles (PM2.5), and carbon monoxide can have a negative impact on people's health. The Environmental Protection Agency has developed a color coding system called the Air Quality Index (AQI) to help people understand what concentrations of air pollution may impact their health. When the AQI value is color code orange then people who are sensitive to air pollutants, or have other health problems, may experience health effects. This means they are likely to be affected at lower levels than the general public. Sensitive groups of people include the elderly, children, and people with either lung disease or heart disease. The general public is not likely to be affected when the AQI is code orange. Everyone may begin to experience health effects when AQI values are color coded as red. People who are sensitive to air pollutants may experience more serious health effects when concentrations reach code red levels. This analysis shows the air quality at downwind distances less than 3.92 miles from the edge of the fire may have a 1-hour particulate matter concentrations predicted to be code red or worse, while distances less than 7.82 miles are predicted to be code orange or worse. At distances less than 0.49 miles from the edge of the fire the one-hour carbon monoxide concentrations are predicted to be code red or worse, and distances less than 0.78 miles from the fire are predicted to be code orange or worse.

Distance from fire	PM2.5 (ug/m3)	CO (ppb)	Distance from fire	PM2.5 (ug/m3)	CO (ppb)
317 ft	3,562.85	37.77	2.47 mi	244.03	5.24
422 ft	3,134.91	33.58	3.11 mi	191.48	4.73
528 ft	2,732.14	29.63	3.92 mi	149.83	4.32
634 ft	2,361.25	25.99	4.94 mi	117.71	4.01
845 ft	2,026.41	22.71	6.21 mi	93.35	3.77
1056 ft	1,729.40	19.80	7.82 mi	75.02	3.59
0.25 mi	1,470.00	17.26	9.85 mi	61.40	3.45
0.31 mi	1,246.41	15.07	12.40 mi	51.51	3.36
0.39 mi	1,055.87	13.20	15.61 mi	44.36	3.29
0.49 mi	895.00	11.62	19.65 mi	38.96	3.23
0.62 mi	760.18	10.30	24.74 mi	34.63	3.19
0.78 mi	647.13	9.19	31.14 mi	31.09	3.16
0.98 mi	549.99	8.24	39.21 mi	28.20	3.13
1.24 mi	462.43	7.38	49.36 mi	25.84	3.11
1.56 mi	381.36	6.59	62.14 mi	23.90	3.09
1.96 mi	307.77	5.87			

Figure 30. Downwind PM2.5 Concentrations Scenario 6: 4000' mixing height, typical consumption and smoldering.

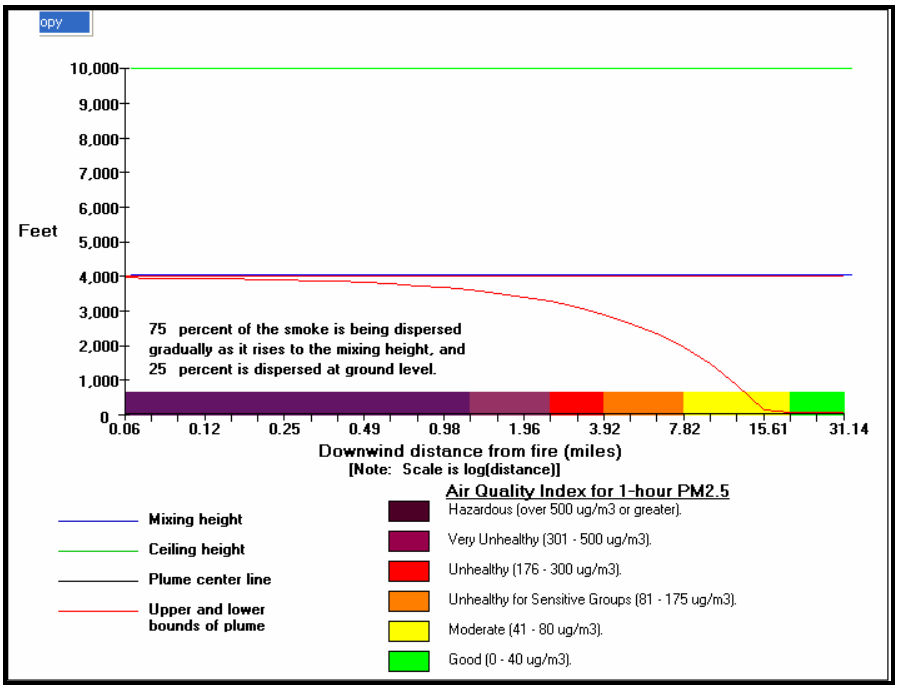


Figure 31. Atmospheric cross-section showing emissions from scenario 6.

Smoke can also have an impact on how far and how clearly we can see on a highway or in viewing scenery. The fine particles in the smoke are known to be able to scatter and absorb light, which can reduce visibility conditions. The visibility estimates from VSmoke are valid only when the relative humidity is less than 70 percent. Also, the visibility estimates assume the smoke is passing in front of a person who is looking through the plume of smoke. The visibility thresholds used for this modeling analysis were to maintain a contrast ratio of greater than 0.05 and a visibility distance of 0.25 miles. Visibility conditions may exceed the threshold less than 845 feet from the edge of the fire.

Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)	Distance from fire	Crossplume Visibility (miles)	Contrast Ratio (miles)
317 ft	0.16	0.01	2.47 mi	20.54	0.72
422 ft	0.18	0.01	3.11 mi	21.45	0.77
528 ft	0.20	0.03	3.92 mi	22.18	0.82
634 ft	0.24	0.04	4.94 mi	22.78	0.85
845 ft	0.27	0.07	6.21 mi	23.27	0.88
1056 ft	0.32	0.10	7.82 mi	23.67	0.90
0.25 mi	0.38	0.14	9.85 mi	23.97	0.92
0.31 mi	0.45	0.19	12.40 mi	24.17	0.93
0.39 mi	1.21	0.24	15.61 mi	24.26	0.94
0.49 mi	5.45	0.30	19.65 mi	24.28	0.94
0.62 mi	9.00	0.36	24.74 mi	24.28	0.95
0.78 mi	11.95	0.42	31.14 mi	24.28	0.95
0.98 mi	14.40	0.48	39.21 mi	24.28	0.96
1.24 mi	16.42	0.55	49.36 mi	24.28	0.96
1.56 mi	18.07	0.61	62.14 mi	24.29	0.96
1.96 mi	19.43	0.67			

Figure 32. Visibility from scenario 6: 4000 ft mixing height, typical fuel consumption and smoldering.

The VSmoke-GIS model estimates the distance of various fine particulate matter concentrations (41, 81, 176, 301, and 501 micrograms per cubic meter) downwind of the fire. The results (map) for Scenario 6 are shown below. Note that this scenario represents the largest single unit to be burned, under realistic atmospheric, consumption, and smoldering conditions. Code Orange (Unhealthy for Sensitive Groups) PM2.5 conditions are found less than 7.8 miles from the fire. Given the overprediction of the model, actual impacts would be expected to be much less. The VSmoke-GIS and VSmoke analysis had daytime dispersion characteristics to disperse the pollutants from the fire. The downwind spacing interval was set at 0.025 kilometers, and the model ceased making downwind estimates at 30 miles from the edge of the fire. The stability class used for the VSmoke-GIS and VSmoke analysis was slightly unstable.

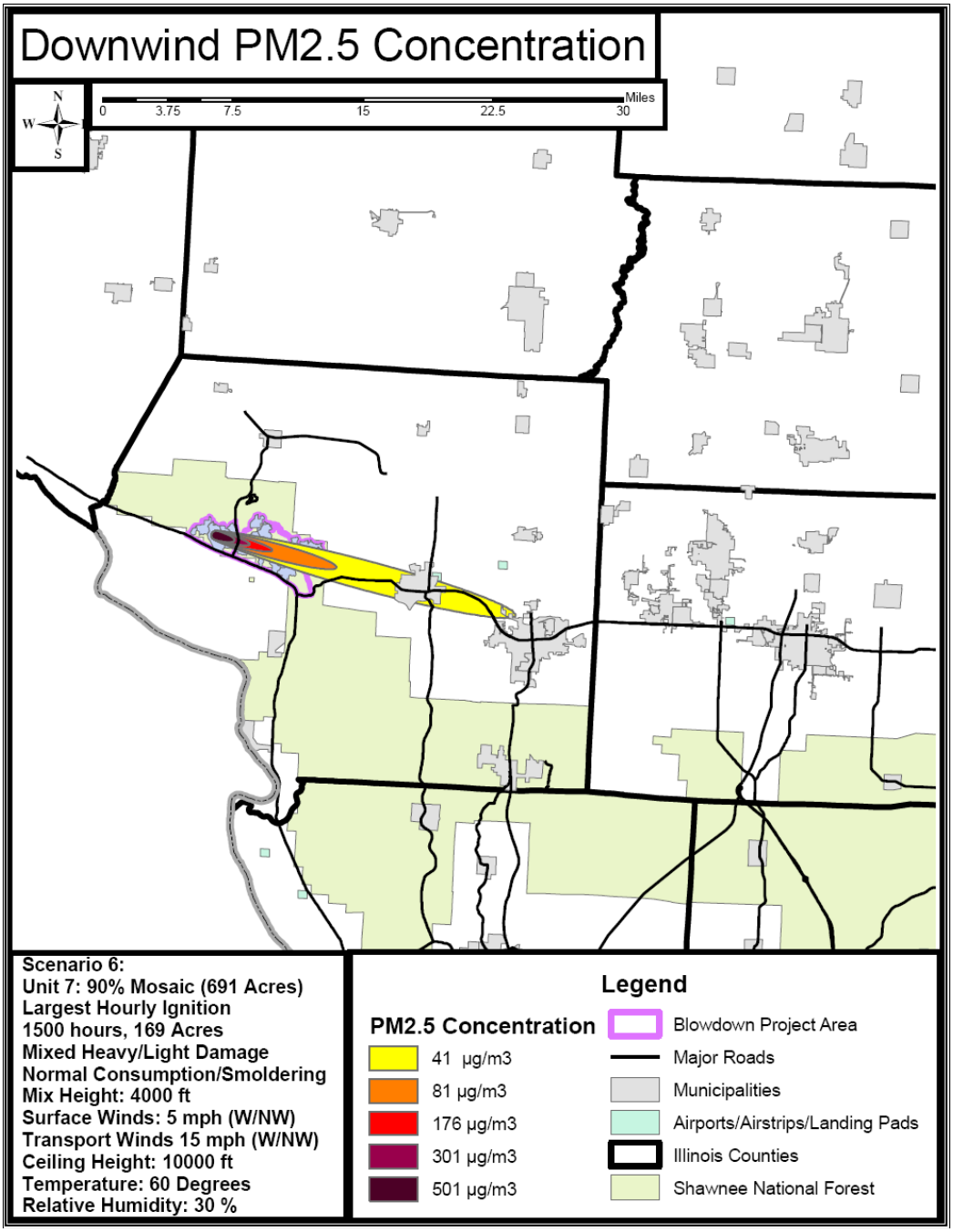
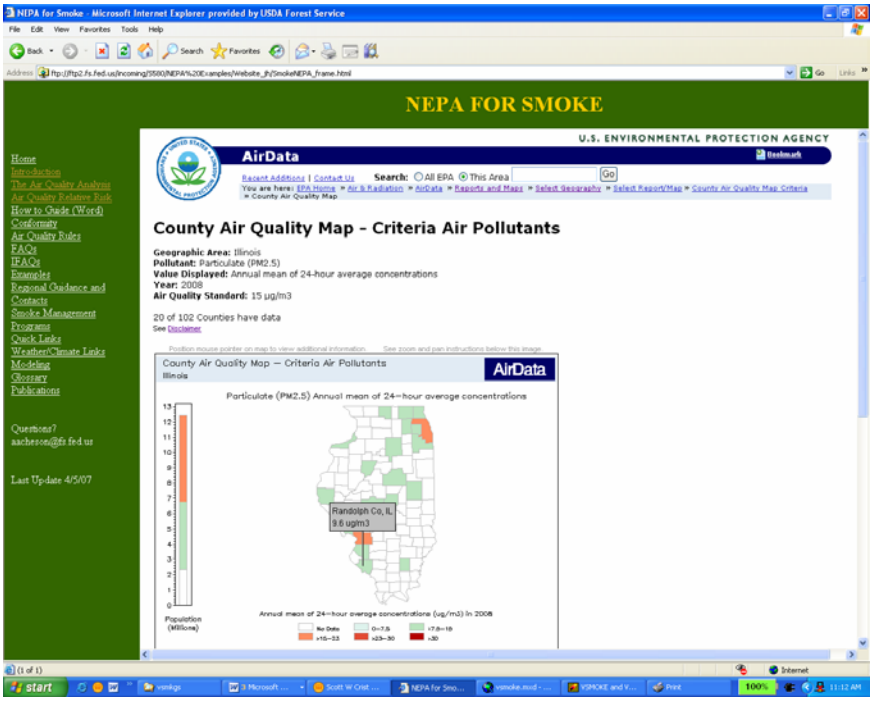


Figure 33. Modeled downwind $PM_{2.5}$ Concentrations from Scenario 6.

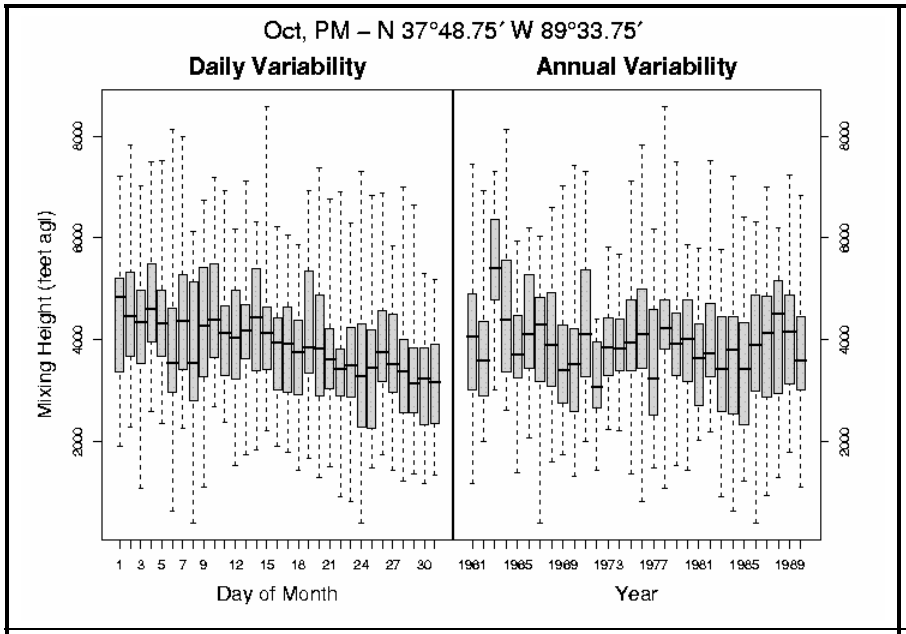
Rationale Used for Smoke Emissions Modeling

Applicability of the VSmoke-GIS / VSmoke Model: The VSmoke-GIS computer model is a moderately complex Gaussian plume dispersion model that allows for user-input meteorological and fuels conditions and ignition patterns. It assumes smoke is dispersed under uniform atmospheric conditions. For this reason, it is useful for comparing smoke trajectories created under various burning/weather conditions as "snapshots in time." This also means it overestimates smoke impact since it does not allow for the greater dispersal found under realistically varying wind and lift conditions. It provides a graphical output of expected smoke transport and density, which simplifies communicating the geographic impact. It uses the Fire Emissions Production Simulator (FEPS) to calculate emission amounts and rates. FEPS has many default fuel types available, including many pertaining to the central hardwoods region. Where actual values for fuel information existed, these were used. Page 167 of the *Smoke Management Guidelines for Prescribed and Wildland Fire Management, 2001 Edition* states that "plume models are most commonly applied in areas of flat to gently rolling terrain but can be used whenever the plume is expected to rise above the influence of underlying terrain." Maximum vertical relief in the project area does not exceed *400* feet, yet as shown above the average burn season mixing height for the area is about *4000* feet above ground level, clearly above the influence of underlying terrain. The *minimum* mixing height modeled was 1500 feet. Though the area has more pronounced hills than some other parts of Illinois, from a national perspective the project area *is* flat to rolling. Tracking individual particles or "puffs" of smoke through complex or mountainous terrain requires detailed weather information at small spatial / temporal scales and often advanced computing ability, and is generally only used by researchers with such information and capability available. For these reasons, VSmoke-GIS is appropriate for and is commonly used throughout the southern and eastern states.

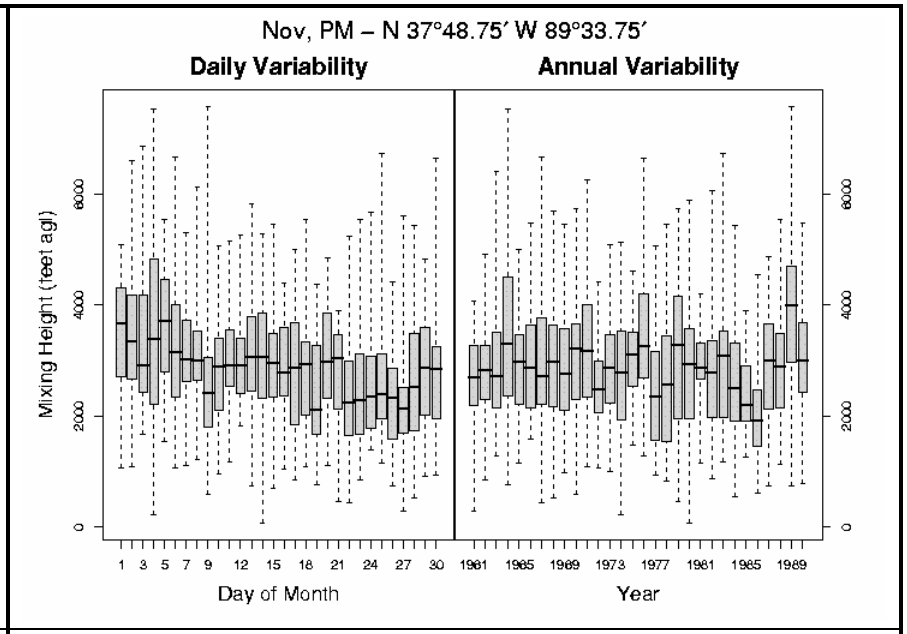
Background Particulate Matter Rationale: The statewide average is 15 ug/m^3, but Randolph County just northwest of the project area has 9.6 ug/m^3 (USEPA 2008). I used 15 as a conservative estimate.



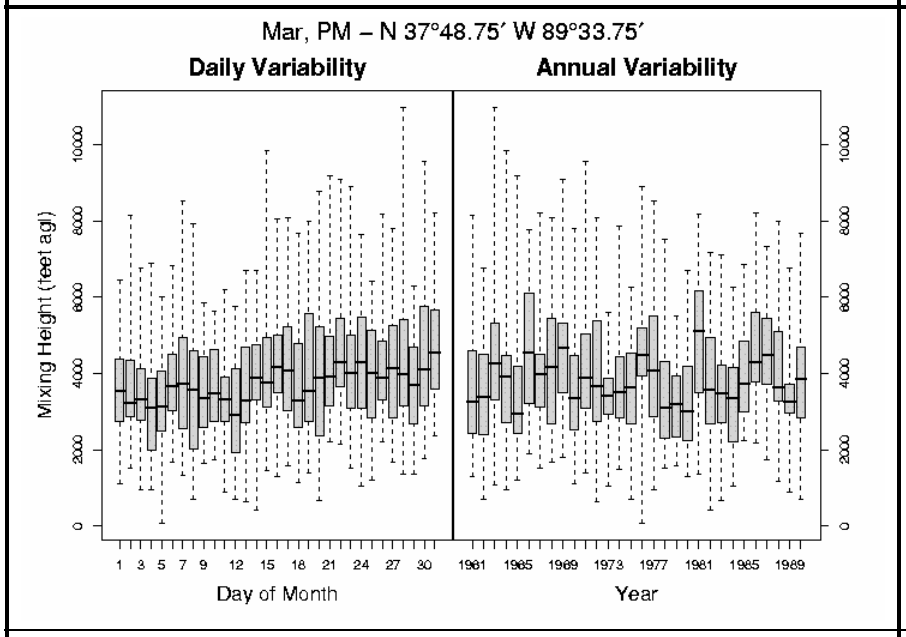
Mixing Height Rationale: Mixing heights were determined by looking at average mixing height data extrapolated for the project area (VCIS 2008). Minimums were from past Shawnee experience. Mixing Height graphs for the four main months of fire/prescribed burn season are shown below.



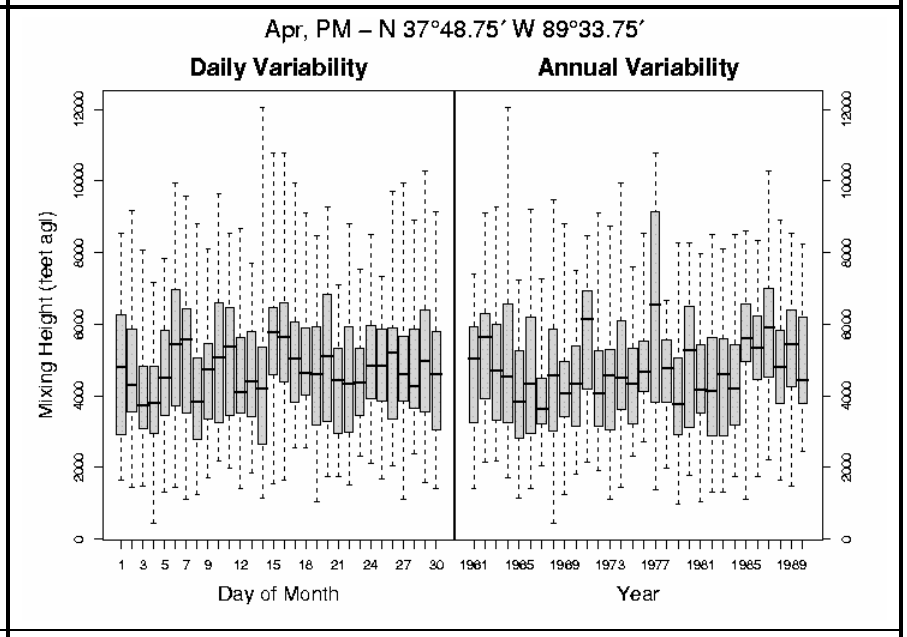
Average Mixing Heights Modeled for the Project Area for October.



Average Mixing Heights Modeled for the Project Area for November.

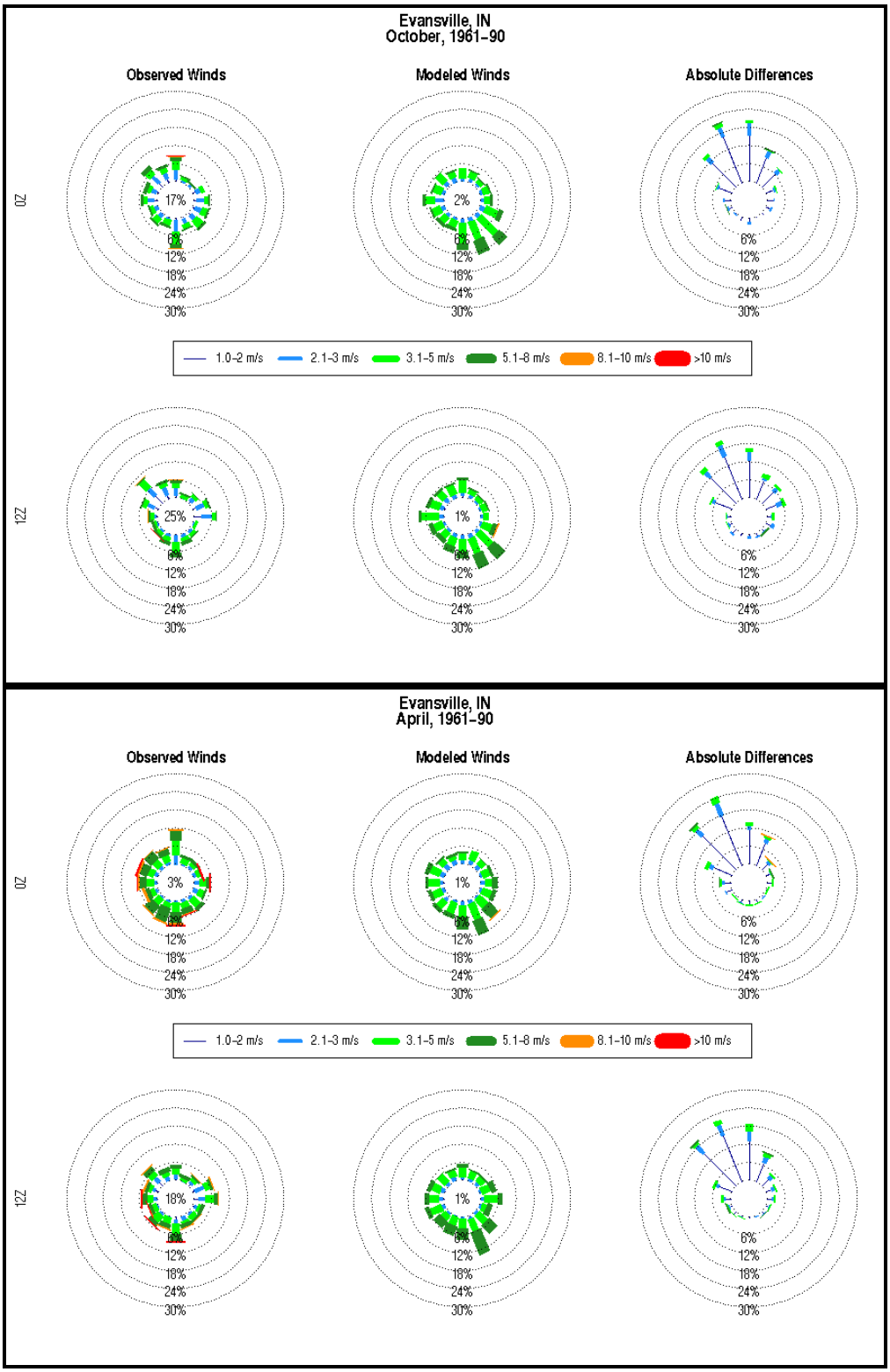


Average Mixing Heights Modeled for the Project Area for March.

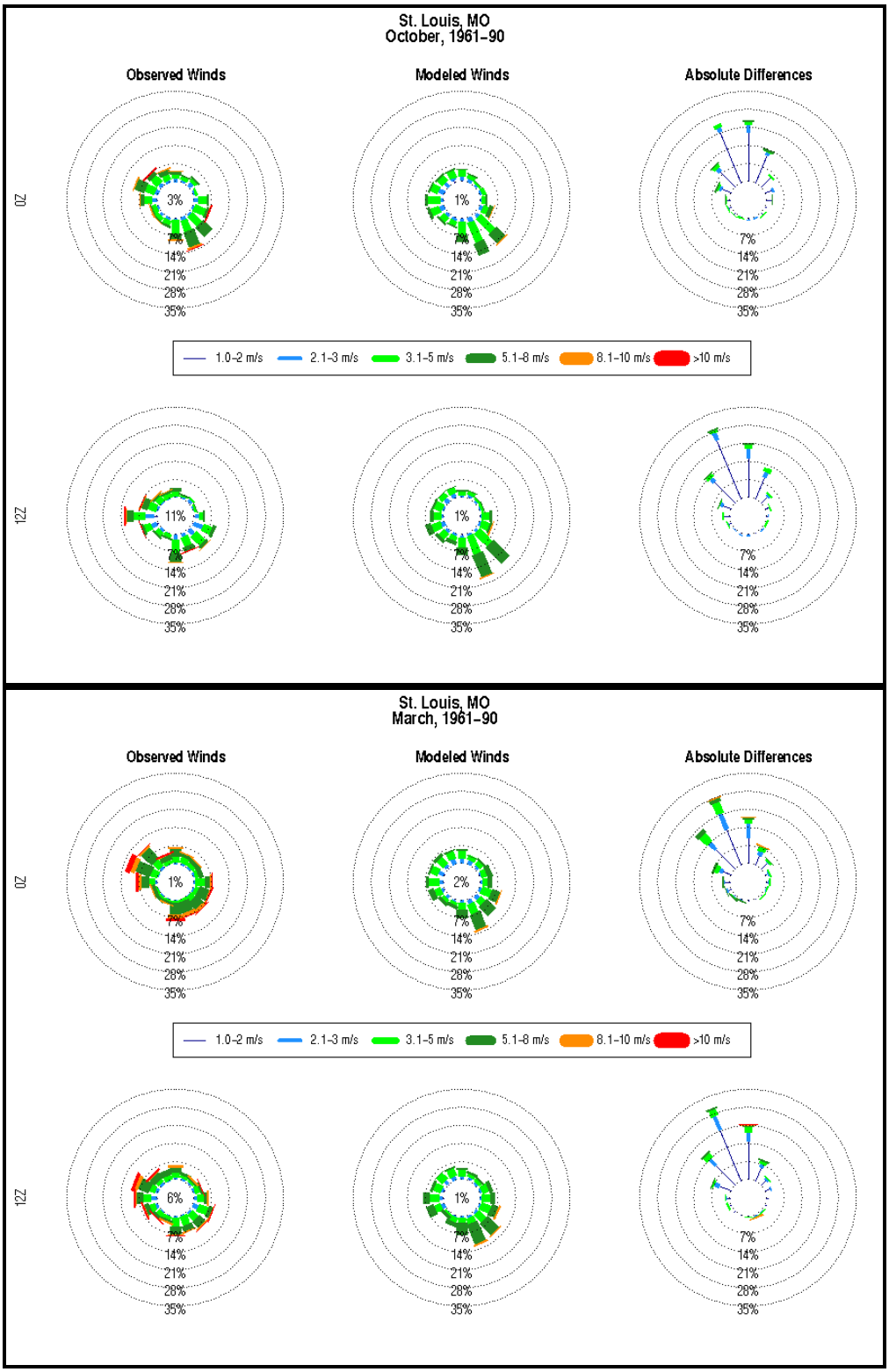


Average Mixing Heights Modeled for the Project Area for April.

Appendix B – Ventilation Climate Index System Regional Wind Roses

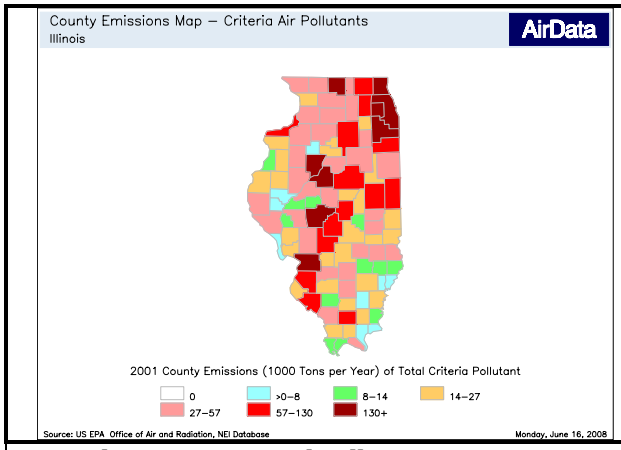


Wind Roses from Evansville, IN for October and April. Data averaged from 1961-1990.

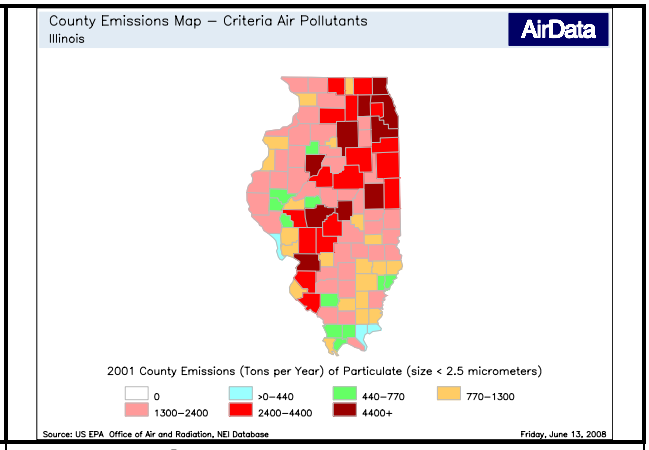


Wind Roses from St. Louis, MO for October and April. Data averaged from 1961-1990.

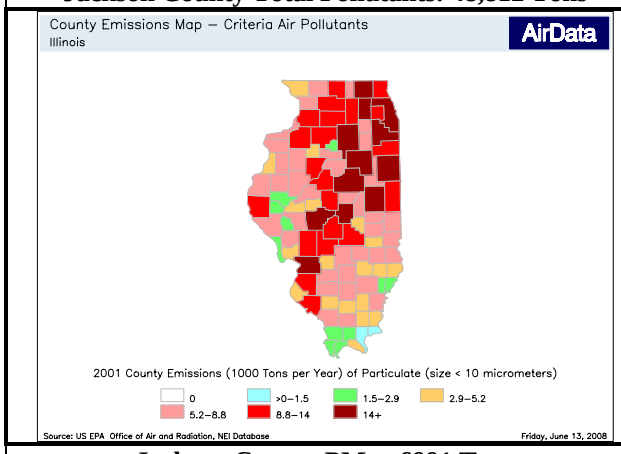
Appendix C – Emissions for Criteria Pollutants by Illinois County



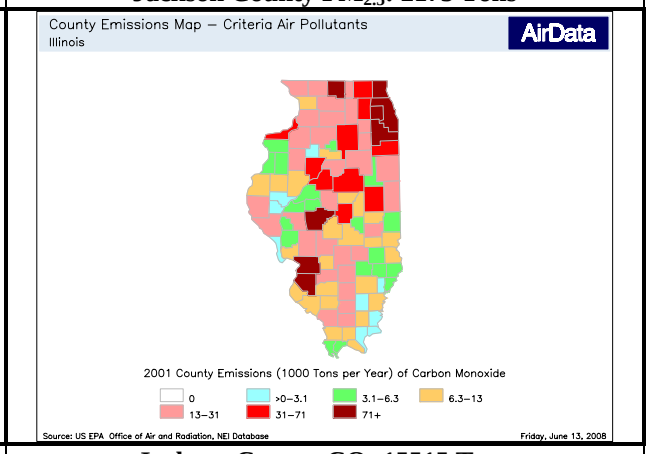
Jackson County Total Pollutants: 48,812 Tons



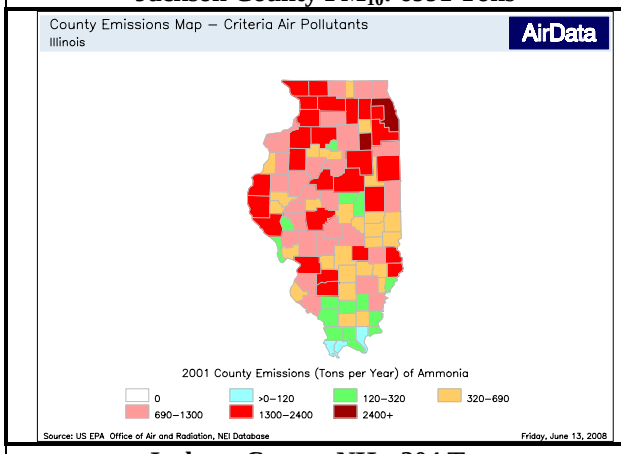
Jackson County $PM_{2.5}$: 2175 Tons



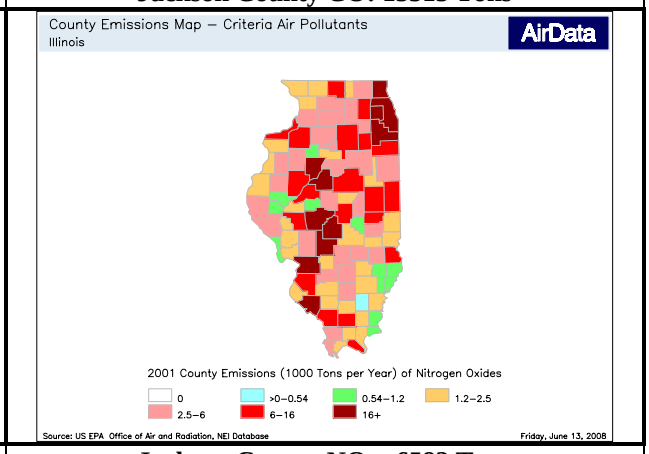
Jackson County PM_{10}: 6991 Tons



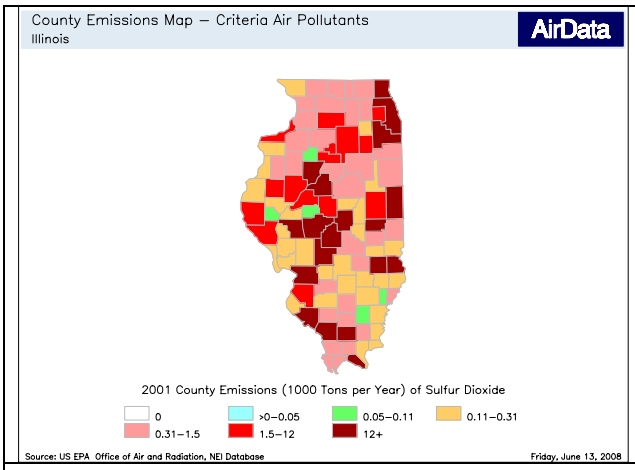
Jackson County CO: 15515 Tons



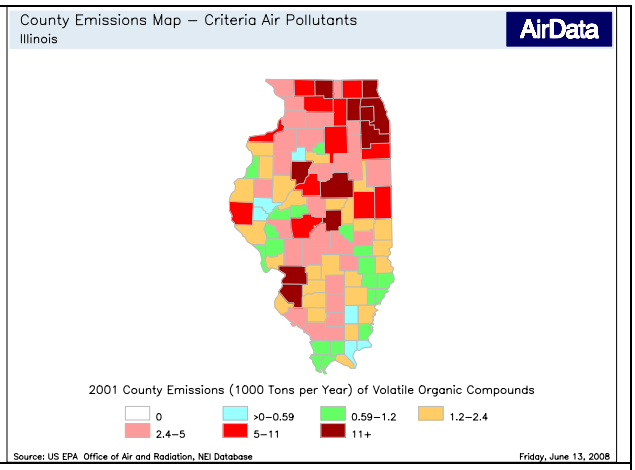
Jackson County NH_3: 304 Tons



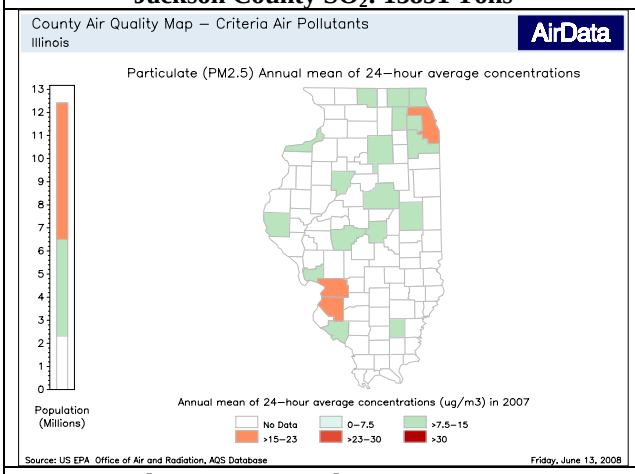
Jackson County NOx: 6582 Tons



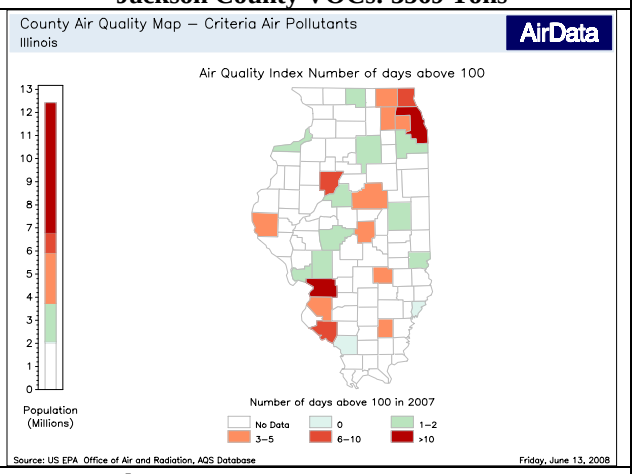
Jackson County SO_2: 15851 Tons



Jackson County VOCs: 3569 Tons



Jackson County 24-hr $PM_{2.5}$: No Data



Jackson County AQI Days Over 100: 0

Appendix D – References Cited

Illinois Environmental Protection Agency (IEPA). 2007. Illinois Annual Air Quality Report – 2006. Found on line at: http://www.epa.state.il.us/air/air-quality-report/2005/air-quality-report-2006.pdf.

Illinois Environmental Protection Agency (IEPA). 2006. Illinois Annual Air Quality Report – 2005. Found on line at: http://www.epa.state.il.us/air/air-quality-report/2005/air-quality-report-2005.pdf.

Keane, B., Reinhardt, E., Brown, J., Gangi, L., 2004. FOFEM Version 5.21. First Order Fire Effects Model. Rocky Mountain Research Station, Missoula Fire Laboratory, Missoula, MT.

Naeher, Luke H, Achtemeier, Gary L., Glitzenstein, Jeff S., Streng, Donna R., and Macintosh, David. 2006. Real-time and time-integrated PM2.5 and CO from prescribed burns in chipped and non-chipped plots: firefighter and community exposure and health implications. *Journal of Exposure Science and Environmental Epidemiology*. 1–11.

National Wildfire Coordinating Group (NWCG) 2001. Smoke Management Guidelines for Prescribed and Wildland Fire Management, 2001 Edition. Hardy, Ottmar, Peterson, Core, and Seamon, eds.

USDA Forest Service 2006. Shawnee National Forest Land and Resource Management Plan.

USDA Forest Service 2004. VSMOKE-GIS Version 2.1.0

US Environmental Protection Agency (USEPA) AirData website. Accessed May 2008. Available online at: http://www.epa.gov/air/data/index.html

Ventilation Climate Information System website. Accessed May 2008. Available online at: http://www.airfire.org/vcis