Effects of Prescribed Grass Fire on Wind Erosion Rates from Surface Soil at Rocky Flats, Colorado

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ABSTRACT

Removal of plants and plant litter by fire significantly increases the erosion potential of the underlying soil for some period of time. By using a portable wind tunnel to simulate high winds across test plots within a prescribed burn area, the effects of fire on soil erosion potential may be quantified as a function of wind speed and elapsed time following the fire.

A portable wind tunnel was used to generate high winds and collect soil particles eroded from a 50-acre study area that underwent a controlled burn in April 2000. Wind tunnel studies of the burned area and neighboring control areas were performed following the test burn, and again at intervals of 25 and 73 days following the fire. Soil erosion rates at incremented wind speeds were determined using optical particle counters and gravimetric analysis of dust samples. Shallow soil samples were collected from areas around the wind tunnel study plots for analysis in a soil dustiness test chamber.

The study was directed at answering the following questions:

- What increase in soil erosion potential may be expected as a result of grassland fire?
- What is the recovery rate of soil protective elements (vegetation and litter) for an area denuded by fire, as indicated by soil erosion potential?
- What algorithms may be employed to estimate increases in fugitive dust emissions resulting from post-fire increases in soil erosion potential?
- How may such algorithms be employed in common atmospheric dispersion models?

INTRODUCTION

The U.S. Department of Energy’s Rocky Flats Environmental Technology Site (Site) has several areas of actinide-contaminated soil as a result of spills and releases during the Site’s nuclear weapons production era. Most such areas are well vegetated, which has stabilized potential wind-driven resuspension of actinide-contaminated soil particles. The Site is currently undergoing cleanup and closure, and as plans are being made for post-closure use, the increase in actinide emissions that might result following removal of vegetation by fire has become an issue of great interest. The Site has experienced three small lightening-caused grass fires in the past 10 years, so fires represent reasonably foreseeable occurrences.

In Spring 2000, the Site conducted a test burn to evaluate a proposed program of prescribed burning for weed control and prairie restoration. The test burn, which covered approximately 50 acres in the Site's buffer zone (the large, undeveloped area surrounding the Site's industrial area), presented an opportunity to gather data on post-fire resuspension rates and subsequent recovery for use in estimating emissions and impacts from wildfires at the Site. A portable wind tunnel was used to generate high winds and collect soil particles eroded from soil surfaces following the test burn, and again at intervals of 25 and 73 days following the test burn. Wind tunnel tests were performed by Midwest Research Institute (MRI) on representative portions of the test-burn area and also on an adjacent, unburned grassy area within the Rocky Flats site.

Because removal of standing plants and plant litter by fire significantly increases the erosion potential of the underlying soil for some period of time, one goal of the study was to evaluate the length of time it takes for a burned surface to regain protection against wind erosion comparable to pre-burn conditions. The objectives of the study also included determining how dust resuspension increases from one wind speed plateau to the next and how resuspension rates decay in time at a given wind speed. The wind tunnel tests determined wind erosion emission rates that will be used in the future to model short-term and annual particulate matter and actinide emissions from potential fires at the Site. The methods and results of the study are described below.

TEST EQUIPMENT AND PROCEDURES

The prescribed burn was conducted on April 6, 2000 and wind tunnel testing was initiated the day after the burn. Wind tunnel tests were performed by MRI using a portable reference wind tunnel, described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites*.[1] Two TSI DustTRAK monitors were used to provide real-time concentrations of PM_{10} (particles less than or equal to 10 micrometers [μm] in aerodynamic diameter) in the tunnel effluent. Laboratory dustiness tests were run on bulk surface soil samples from burned areas to characterize the soil texture and to investigate the effects of soil moisture on erosion potential.

Wind Tunnel Trials

Field tests of the prescribed burn area at Rocky Flats were performed over one-week periods beginning April 7, May 2, and June 19, 2000. During each test, the wind tunnel was moved three times over the test area, to collect additional particulate on the back-up filter in the effluent sampling train and to improve the detection and precision of the PM_{10} erosion potential estimates.

The primary test device used in the evaluation was MRI's portable reference wind tunnel, shown in Figure 1. Although the portable wind tunnel does not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnel simulates the smaller scales of atmospheric turbulence. It is the smaller scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to the particle entrainment mechanisms. The wind tunnel method relies on a straightforward mass balance technique for calculation of particulate emission rates. Previous wind erosion studies using the MRI reference wind tunnel have led to the U.S. Environmental Protection Agency (EPA) recommended emission factors for industrial wind erosion presented in *Compilation of Air Pollutant Emission Factors (AP-42)*.[2]

For each run, the open-floored test section was placed directly over the surface to be tested. Air was drawn through the tunnel at controlled velocities, increasing at 2 meter per second [m/s] (5 mile per hour [mph]) increments, to a maximum velocity of about 40 mph at the tunnel centerline. This corresponded to a wind speed between 97 and 145 mph at a 10 meter (m) height; the equivalent 10-m speed varied with the roughness height of the surfaces tested in each trial.

Typically, each time the wind speed was increased, a PM_{10} concentration spike was observed. Furthermore, upon each successive increase, the peak value of the spike increased and the rate of decay decreased. The PM_{10} concentration values for each wind speed plateau were observable in the "real-time" concentration histories, recorded by the DustTRAK monitors (described below). For higher wind speed plateaus, the duration of sampling was increased to allow additional time for the spike to decay. An example of the concentration spikes that occurred during wind tunnel testing on the burned area can be seen in Figure 2.

A pitot tube was used to measure the centerline wind speed in the open-floored test section. The volumetric flow rate through the wind tunnel was determined from a published relationship between the maximum centerline velocity in a circular duct and the average velocity, as a function of Reynolds' number.[3] Because the ratio of the centerline wind speed in the sampling extension to the centerline wind speed in the working section was nearly independent of flow rate, the ratio could be used to determine isokinetic sampling conditions for any flow rate in the tunnel.

The surface roughness heights for the test runs were determined by fitting vertical profiles of wind speed in the test section of the wind tunnel to a logarithmic function. An average roughness height was calculated for each test series, for purposes of calculating friction velocities and 10-m equivalent wind speeds. The friction velocity, which is a measure of wind shear at the erodible surface, characterizes the capacity of the wind to cause surface particle movement.

The exit air stream from the test section was passed through a circular duct fitted with a sampling probe near the downstream end. The particulate sampling train, which was operated at 68 cubic meters per hour (m^3/hr) (40 actual cubic feet per minute [acfm]), consisted of the tapered sampling probe, cyclone pre-collector, quartz backup filter, and high-volume motor. The sampling probe was pointed into the air stream, and isokinetic sampling was achieved by fitting the sampling probe with a nozzle of appropriate size. Sampled total airborne particulate (TP) emissions were separated into two particle size fractions by the cyclone: particles larger than PM_{10} were collected inside the cyclone, and PM_{10} was collected on the backup filter below the cyclone.

A high-volume ambient air sampler was operated at 68 m^3/hr (40 acfm) near the inlet of the wind tunnel to provide for measurement and subtraction of the contribution of the ambient background particulate level. The filter was vertically oriented, parallel to the tunnel inlet face.

At the completion of each test series, the sampling train was disassembled and taken to the field instrument van, where the collected samples of dust emissions (cyclone catch and backup filter) were carefully placed in protective containers. Dust samples from the field tests were returned to an environmentally controlled laboratory for gravimetric analysis. Quartz filters were conditioned at constant temperature (23 degrees Celsius [^{o}C] ±1^{o}C) and relative humidity (45% ± 5%) for 24 hours prior to weighing (the same conditioning procedure used prior to tare weighing). The particulate catch from the cyclone pre-collector was weighed in a tared poly bag.

DustTRAK Monitoring

Continuous monitoring of particulate concentration in the sampling extension provides for a greater level of detail in tracking the dynamics of the wind erosion process. For this study, two portable DustTRAK Aerosol Monitors (TSI, Inc., St. Paul, Minnesota) were used to continuously sample the air between the cyclone and the backup filter to track the PM_{10} concentrations in the tunnel effluent.

The DustTRAK monitor is a portable, battery-operated instrument that gives real-time measurements and has a built-in data logger. The operating principle of the DustTRAK is based on 90°

light scattering. Light scattering (deflection) by local variations in refractive index is caused by the presence of particles whose size is comparable to the wavelength of the incident light. The theoretical detection efficiency peaks at about 0.2-0.3 μm and gradually decreases for larger particle sizes. A pump draws aerosol into the optics chamber where either solid or liquid particles are detected using a laser diode light source and a solid-state photodetector. The instrument can store measurements at programmable intervals for later trending and reporting.

The DustTRAK PM_{10} monitor was calibrated against the actual PM_{10} mass collected on the backup filter of the wind tunnel effluent sampling train during a given test run. This calibration required an integration of the real-time DustTRAK PM_{10} concentration profile (versus time) and calculation of the average DustTRAK PM_{10} concentration. The average DustTRAK PM_{10} concentration was then compared to the average PM_{10} concentration calculated from the PM_{10} mass collected on the backup filter below the cyclone.

Use of the DustTRAK monitor provided a more comprehensive analysis of surface erodibility than wind tunnel sampling alone, especially appropriate to study surfaces that do not have a well defined wind erosion threshold velocity. There are multiple contributors to wind generated particulate emissions on the burned vegetative surfaces at the Site: 1) bulk soil, 2) settled surface dust trapped by vegetation, and 3) the vegetation itself. The particle releases from these reservoirs are all driven by different mechanisms, each with a different wind speed dependence.

The approach taken in this study was to expose each test surface to a well-defined time history of increasing wind speeds, while simultaneously monitoring the PM_{10} concentration in the tunnel effluent. Each time the wind speed was increased, a concentration spike was observed. Time integration of these spikes generated erosion mass increments of PM_{10} that when added together yielded cumulative erosion potential as a function of wind speed.

Dustiness Testing

In April and May 2000, six subareas in the controlled burn area were sampled for surface soil. The soil samples were collected to a depth of approximately 1 to 1.5 centimeters (cm) using a whiskbroom and dustpan. The areas were judged to be representative of the wind tunnel test areas.

Dustiness testing was performed on samples of surface soil to characterize the potential for release of airborne PM_{10} when the soil is disturbed. Dustiness tests were also run under varying soil moisture levels to provide information on the mitigating effect of soil moisture in reducing PM_{10} emissions. The moisture levels selected for dustiness testing were 0%, 2%, 4%, 6%, and 8%.

The MRI Dustiness Test Chamber is a laboratory device used to determine the tendency of finely divided bulk materials (e.g., soils, powders) to release fine particles. Within the chamber, the particles generated from controlled pouring of material are captured on an overhead filter with a sampling rate of 5 liters per minute. The net weight of particulate matter caught on the filter (final filter weight minus tare weight) is divided by the mass of material poured to calculate the mass emission rate in units of milligrams of dust per kilogram of material poured. This quantity is defined as the dustiness index of the test material.

TEST ANALYSIS

Because wind erosion is an avalanching process, it is reasonable to assume that the loss rate from a surface is proportional to the amount of erodible material remaining:

$$\frac{dM}{dt} = -kM \tag{1}$$

where

M = quantity of erodible material on the surface at any time, grams per square meter (g/m^2)
k = proportionality constant, inverse seconds (s^{-1})
t = cumulative erosion time, seconds (s)

Integration of Equation 1 yields:

$$M = M_o\, e^{-kt} \tag{2}$$

where

M_o = erosion potential, i.e, quantity of erodible material present on the surface before the onset of erosion, g/m^2

The loss of erodible material (g/m^2) from the exposed surface area during a test is calculated:

$$L = \frac{CQt}{A} \tag{3}$$

where

C = average particulate concentration in tunnel exit stream (after subtraction of background concentration), g/m^3
Q = tunnel flow rate, cubic meters per second (m^3/s)
A = exposed test surface area (0.918 square meters [m^2] for the reference wind tunnel)

Alternatively, the erosion potential can be directly calculated from the cyclone and filter net mass (after correction for background).

For a specific surface, the wind erosion potential is dependent on the wind speed and on the frequency of disturbance of the erodible surface. Each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action that results in the exposure of fresh surface material. For this study, a disturbance occurred when the soil surface was exposed by the prescribed burn.

Whenever a surface is tested at sequentially increasing wind speeds, the measured losses from the lower speeds are added to the losses at the next higher speed and so on. This reflects the hypothesis that, if the lower speeds had not been tested beforehand, correspondingly greater losses would have occurred at the higher speeds.

In summary, the calculated test results for each test surface included:

- Roughness height: from extrapolated subthreshold velocity profile;

- Friction velocity: from measured centerline wind speed and roughness height;
- Equivalent wind speed at reference 10-m height: from measured centerline wind speed and roughness height; and
- Erosion potential (for “limited reservoir” surfaces) for a maximum wind speed: equivalent to the cumulative particle mass loss.

In addition to the wind tunnel results, 6-second concentrations were graphed and integrated over wind tunnel run time to calculate the hypothetical mass that would have been collected by each DustTRAK monitor. As discussed previously, the integrated mass (erosion potential) for each wind speed plateau included integrated masses from each previous plateau. Finally, the average PM_{10} mass for the entire DustTRAK sampling period was compared to the actual PM_{10} mass collected on the PM_{10} backup filter.

TEST RESULTS

The results of the wind tunnel tests and erosion potential calculations are presented in Table 1. As expected, the average PM_{10} concentration in the wind tunnel effluent for the April test series was much higher for the burned areas than for the adjacent unburned areas. At the beginning of the first test series, one day after the burn, the average PM_{10} erosion potential was approximately nine times higher than found for unburned grassland adjacent to the burn area.

The PM_{10} erosion potentials, normalized to a 10-m wind speed of 95 mph, are shown graphically in Figure 3. Normalization was performed because the growth of vegetation between the prescribed burn and the later tests, on both burned and unburned plots, resulted in different surface roughness heights and consequent 10-m wind speed equivalents for the maximum wind tunnel centerline speeds. This effect is also shown in the progression of roughness heights and friction velocities between the earlier and later tests that can be seen from Table 1.

From Figure 3, the PM_{10} erosion potential of the burned area appears to decay in time with the regrowth of vegetation. Observations made at the time of each test series also indicated that the ground was somewhat moist in May but was fairly dry for both the April and June test series on the burned area. The dustiness tests that were performed with soil from the burned area showed that moisture is very effective in limiting PM_{10} erosion potential. As moisture was increased from 2% to 8%, for example, in the laboratory testing, the dustiness (potential for release of airborne PM_{10}) was seen to decrease by over an order of magnitude.

The PM_{10} erosion potential for the unburned grassland remained consistently low, in the range of 0.05 g/m^2 or less, as seen from April and June tests shown in Table 1. The PM_{10} erosion potential for the unburned areas also decreased between April and June as the vegetation grew.

Table 1 also shows erosion potential for total particulates. The results show a somewhat different pattern than found for PM_{10} and indicate that erosion potential increased with time, on both the burned and unburned areas. These results are somewhat misleading, because the results cannot be normalized in the same manner as the PM_{10} since DustTRAK data are not available for the larger particles, nor would they be reliable. However, the indicated trend may also result from changes in vegetation with time. As the vegetation grew, it would have presented a larger surface area to catch and hold deposited dust. Other researchers have found that larger particles may be more easily dislodged from vegetation surfaces than smaller particles, such as PM_{10}, which may be better protected by boundary layer effects on the leaves themselves.[4,5] As a result, the growing vegetation may constitute an effective reservoir of erodible particles, particularly in the larger size fractions that contribute to total airborne particulate.

The logging mode of the DustTRAK provided 6-second average concentration values for each of the test runs. After subtracting out a minimum value assumed to be background, these values were used to find an average concentration value from the beginning of the test run to the end of the run time for each 10-m wind speed. The average concentration along with the tunnel volumetric flow rate, the length of time from the beginning of the test until the end of the specified wind speed plateau, and the exposed test surface area were used to determine the (cumulative) erosion potential for that wind speed.

It should be noted that the actual average PM_{10} concentration in the tunnel effluent was several times higher than the average PM_{10} concentration indicated by the DustTRAK. This reflects the fact that while the coarse mode of the PM_{10} (particles larger than 2.5 μm) constitutes much of the PM_{10} sample mass, it does not scatter light very effectively. Calibration of DustTRAK results to backup filter mass corrected for this bias.

Figure 4 shows average erosion potential values versus wind speed (mph) at a 10-m height. The same pitot tube pressure differentials for the predetermined tunnel centerline wind speeds were used for the three test periods, yet the roughness height of the surface changed over the three-month period, corresponding to increases in 10-m wind speeds, in relation to centerline values.

It is clear from Figure 4 that the erosion potential distributions (versus 10-m wind speed) decay with time after the prescribed burn. The May curve lies below the June curve because of the damp soil conditions encountered during the May testing.

DISPERSION MODELING APPROACH

Wind tunnel test results are being used to model the movement of airborne particulate matter and actinides in the Site environment. A Site-specific wind erosion equation was developed from previous wind tunnel studies performed at the Site by MRI in 1993.[6] In that approach, particulate emissions from undisturbed, vegetated surfaces at the Site were calculated as a function of the 1-hour average wind speed measured at a 10 m height, and the presence or absence of snow cover. Actinide emissions were calculated based on concentrations in the underlying soil.

Emissions were then modeled using a Site-specific implementation of EPA's Industrial Source Complex Short Term model (ISCST3) (the model uses a 1-hour time step). Comparison of model predictions to measured ambient air plutonium and americium concentrations at various locations around the Site indicated that the approach overpredicts actinide concentrations by up to an order of magnitude close to source areas and by a factor of 3 to 6 at the downwind fenceline (located 2,500 to 3,000 m east of source areas)[7]. Much of this overprediction is presumed to be caused by the inability of the present model to account for limitations in the available reservoir of erodible particles. Rather than depleting the supply of particles that can be eroded in an hour at a given wind speed, the model assumes that each subsequent hour at a similar wind speed could erode a similar mass of material.

Refinements are being made to the modeling approach to take this limitation into account. The modeling approach is also being revised to account for removal of vegetation by a fire and to incorporate the subsequent, temporary increases in erosion potentials that were the subject of the study reported here. The refined approach is outlined below for a 1-year modeling scenario, using historical meteorological data measured at the Site.

- Track 15-Minute Wind Speed and Precipitation

  The 15-minute mean wind speeds are representative of maximum sustained winds (wind data from the Site are recorded as 15-minute averages). The 15-minute wind speed and precipitation data will be used to calculate wind erosion rates.

- Develop 15-Minute Emission Rates as a Function of Wind Speed Using Wind Tunnel Data From Undisturbed Areas

  Dispersion models for open dust sources require emission rates in units of mass per unit area per unit time (i.e., $g/m^2/s$). In contrast, particulate emissions from wind erosion are expressed in terms of mass per unit area (g/m^2) for the maximum sustained wind speed (minimum of 2 minutes) between surface disturbances. To account for these differences, the refined approach will assume that the erosion potential for a given wind speed will be exhausted within a 15-minute time step and the total particulate and actinide emissions will be averaged over the time step. It will be assumed that additional erosion for subsequent wind speeds at or below the initial wind speed will be insignificant until the erosion potential is replenished by surface disturbance; subsequent higher wind speeds will be allowed to erode an additional increment of material based on wind tunnel erosion potential data for undisturbed, vegetated surfaces.

- Eliminate Periods During and Immediately After Precipitation Events and When Snow Cover is Present

  High winds that occur in the same 4-hour period as light precipitation or within 24 hours of significant precipitation are unlikely to cause significant wind erosion. Emission rates for these periods will be reduced to zero for calculation purposes. Similarly, periods with snow cover (based on measured albedo data) will also be reduced to zero.

- Project Hourly Particle Deposition and Erosion Potential Replenishment

  A small replenishment of erosion potential will occur on an ongoing basis because of particle deposition, freeze/thaw events, etc. Hourly estimates of particle and actinide deposition will be made based on measured meteorological data and historical $PM_{10,}$ total suspended particulate, and ambient actinide concentration data for the Rocky Flats area. A small additional increment will be added for ongoing, small-scale soil disturbances such as freeze/thaw cycles, rainsplash, and animal activity.

- Calculate Hourly Emission Rates, Taking into Account Erosion Losses from Previous Wind Events

  The erosion potential will be reduced with each high wind event. If the erosion potential at 35 mph (10-m height) is $\boldsymbol{x}$ g/m^2, then that erosion potential will no longer be available for future winds of 35 mph or less until the erosion potential is restored by deposition or other means. Only winds above ~35 mph will produce future soil erosion. In addition, if a 50-mph wind event follows a 25-mph wind event, the curve will produce $\boldsymbol{y}$ g/m^2 erosion potential, but the previous wind erosion potential must be subtracted to give only $(\boldsymbol{y} - \boldsymbol{x})$ g/m^2 for the 50-mph wind event.

  Hourly emission rates will be calculated for each source area by treating this situation using a mass balance, "bookkeeping" approach. Beginning with an assumed initial erosion potential at the beginning of the modeling period, increases and decreases in erosion potential will be calculated for each 15-minute period based on losses due to emissions and inputs due to deposition, etc. Emissions will be constrained for each 15-minute time step so that they do not exceed the net remaining erosion potential for the applicable wind speed. The calculated 15-minute emissions will be used to develop hour-by-hour emission rates for input to ISCST3.

To model resuspension following a fire, multipliers will be developed and applied to the above-estimated emissions. The multipliers will vary based on the elapsed time following the fire and based on soil moisture conditions, as follows.

- Generate Erosion Potential Decay Curves for Each Tested Wind Speed, Soil Condition, and Time Period Following a Grass Fire

  Erosion potentials for three different elapsed times following the test burn are given in g/m^2 for each tested wind speed in Figure 4. May is assumed to represent "damp soil" erosion potential, while the April and June tests are assumed to represent dry conditions. Erosion potentials at intermediate wind speeds can be interpolated from the curves.

- Use Damp/Dry Soil Curves as Appropriate for each 15-Minute Period

  High winds that occur within 24 to 48 hours of significant precipitation should be associated with a damp soil curve for calculation of erosion potential and emissions.

- Model 1-yr Periods (Assume Full Revegetation and Restoration of Original, Reduced Erosion Potential Within 1 Year)

  Decay curves will be assumed to decline to a level represented by the unburned area tests after one year. Restoration of the full vegetation protection against wind erosion will not be complete until a new layer of thatch is laid down and covers the soil between grass clumps.

CONCLUSIONS

The results of the wind erosion tests on the Rocky Flats prescribed burn area showed that low PM_{10} emissions occurred below 40 mph (equivalent wind speed at a height of 10 m above ground). Above 40 mph, PM_{10} emissions increased with increasing wind speed. After burning, the land was observed to retain many of the characteristics that limit wind erosion—including soil crusts, rocks/pebbles that protected the surface soil, and grass clumps. Grass clumps, even when burnt, are very protective of soil erosion, but usually were not spaced closely enough on Rocky Flats land for good protection of all of the exposed area.

PM_{10} emissions were observed to increase as wind speed increased, and erosion potentials were calculated for various wind speed plateaus during each of the three months of testing.   Erosion potentials from the prescribed burn area were always somewhat greater than for unburned areas, even for the June tests—approximately 2½ months after the burn. This was clearly due to the wind protection afforded by dead grass thatch that had formerly covered the unburned areas, but was not present after the prescribed burn.

Even though the burned areas had revegetated to a large extent by the June test period, bare soil that constituted an emission source was still visible between the revegetating plants. Moreover, the vegetative restoration of the prescribed burn areas included mostly tall, thin plants that did not completely protect the soil from wind erosion through late June, when the latest wind tunnel tests were conducted. During May tests, soil moisture was observed to be effective in reducing soil erosion rates from high winds at moderate temperatures. However, when rainfall wets the soil surface and temperatures are warm, the surface dries quickly in the relatively low humidity environment of Rocky Flats, so this mitigating effect is transient.

A new approach to ambient impact modeling of a grass fire is being developed for wind erosion sources to reflect a limited reservoir erosion potential (emission rate) in units of g/m^2. This approach tracks historical 15-minute mean wind speeds. The times and extent of wind erosion are dominated by the occurrence of the highest wind speeds. Wind tunnel data provide the relationship between particulate emission rates and maximum sustained winds. The modeling approach takes into account losses of erosion potential from previous high wind events, the mitigating effects of vegetation, and the role of background dust deposition.

The new approach will account for the absence of emissions during precipitation events and when snow cover is present. Increases and decreases in erosion potential will be calculated for each 15-minute period based on losses due to resuspension and input due to deposition and other natural processes (e.g., freeze/thaw). A mass balance accounting will be performed so that emissions will not exceed the net remaining erosion potential for a given source area for the applicable wind speed. Calculated 15-minute emissions will be used to develop hour-by-hour emission rates for input to ISCST3. To model resuspension following a fire, multipliers based on the elapsed time following the fire and on soil moisture conditions will be applied to the above-estimated emissions.

REFERENCES

1) U.S. Environmental Protection Agency. *National Technical Guidance Series Air Pathway Analysis Procedure for Superfund Applications*. Vol. II: *Estimates of Baseline Air Emissions at Superfund Sites*. Research Triangle Park, NC, 1989; EPA-450/1-89-002a.
2) U.S. Environmental Protection Agency. *Compilation of Air Pollutant Emissions Factors*, AP-42. Fifth Edition, Supplements A-F, Volume I: *Stationary Point and Area Sources.* Research Triangle Park, NC, 2000.
3) Owen, E.; Pankhurst, R.C. *The Measurement of Air Flow*; Pergamon Press; London, 1969.
4) Garland, J.A. *Resuspension of Particulate Matter From Grass Experimental Programme 1979-1980*. UKAEA Atomic Energy Research Establishment, Environmental and Medical Sciences Division, Harwell, England, 1982; AERE-R-10106.
5) Langer, G. *Resuspension of Soil Particles from Rocky Flats Containing Plutonium Particles*. EG&G Rocky Flats, Inc., Golden, CO, 1991.
6) Midwest Research Institute. *OU3 Wind Tunnel Study*, Vol. I: *Test Report*. Prepared for EG&G Rocky Flats, Inc., Golden, CO, 1994.
7) Radian International. *Air Transport and Deposition of Actinides at the Rocky Flats Environmental Technology Site, FY00 Report*. Prepared for Kaiser-Hill Company, L.L.C., Golden, CO, 2000.

Figure 1. MRI portable wind tunnel.

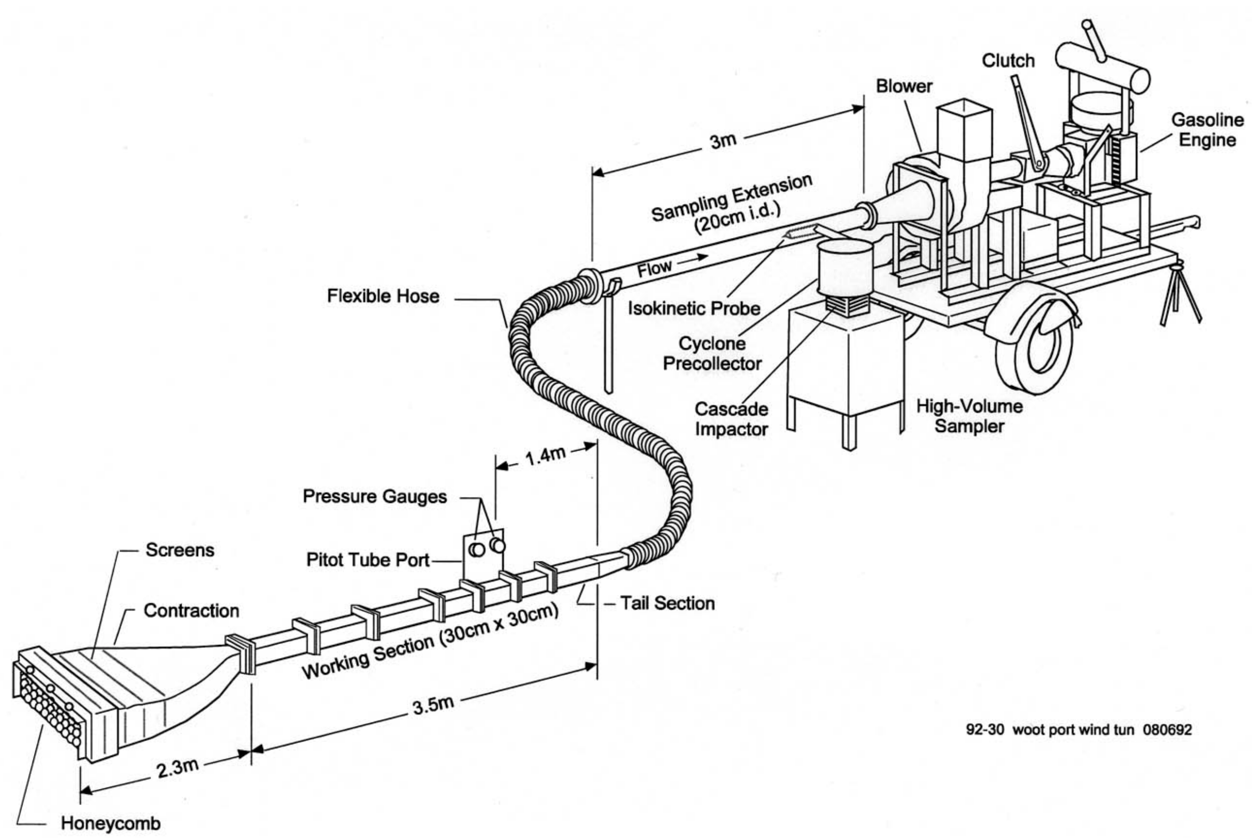

Figure 2. DustTRAK graph for run CB-8B.

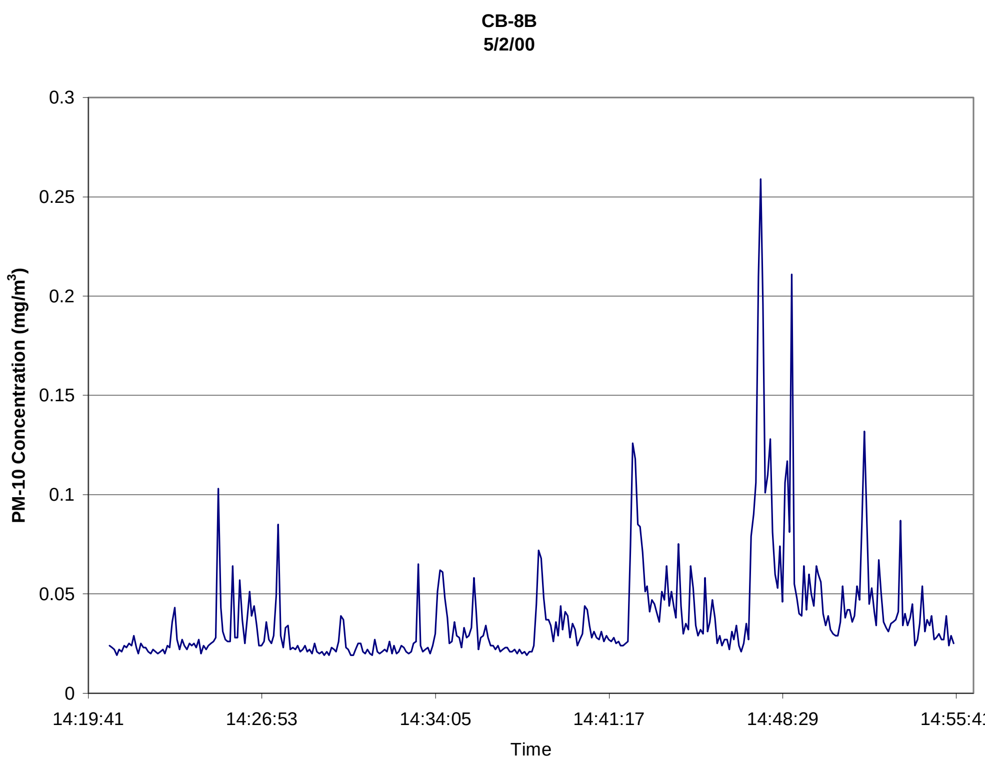

Figure 3. Erosion potential history for each test series.

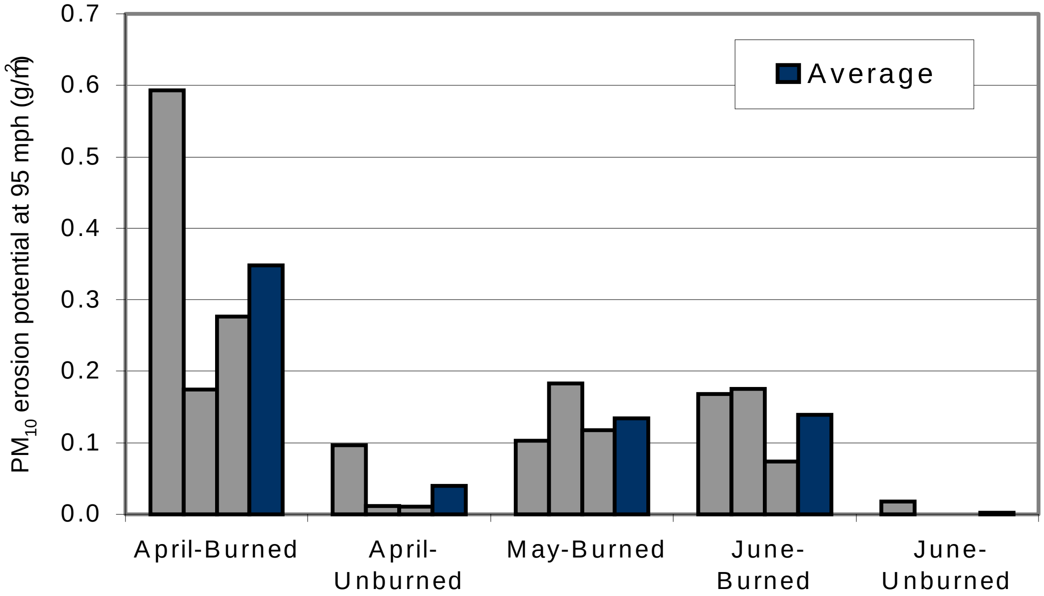

Figure 4. Erosion potential at 10-m wind speeds as determined from DustTRAK data.

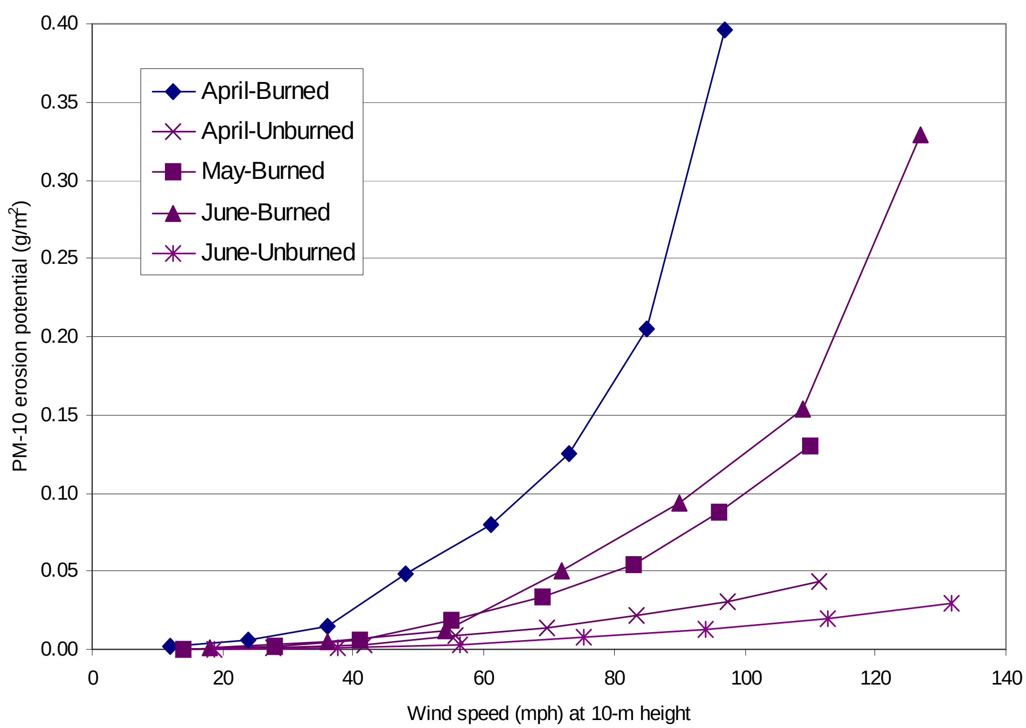

Table 1. Wind tunnel erosion potentials.

Date of test series	Surface condition	Average roughness height (cm)	Maximum wind speed (mph) at tunnel CL[a]	Equivalent maximum wind speed (mph) at 10-m height[b]	Corresponding friction velocity[b] (cm/s)	Erosion potential[c] (g/m^2)		
						TP	PM_{10}	PM_{10} normalized to 95 mph at 10-m height
4/7/00	Burned	0.85	40.3	97.6	244.7	1.33	0.65	0.59
4/8/00	Burned	0.66	40.3	97.6	244.7	0.61	0.19	0.17
4/8/00	Burned	0.89	40.3	97.6	244.7	0.62	0.30	0.28
4/9/00	Unburned	1.65	39.7	110.1	301.0	0.31	0.14	0.10
4/10/00	Unburned	1.76	40.3	111.9	305.8	0.13	0.02	0.01
4/11/00	Unburned	0.92	40.3	111.9	305.8	0.18	0.02	0.01
5/2/00	Burned	1.10	37.0	100.5	271.4	1.07	0.12	0.10
5/2/00	Burned	1.31	40.3	109.6	295.8	2.50	0.26	0.18
5/3/00	Burned	1.57	37.2	101.2	273.3	0.76	0.14	0.12
6/21/00	Burned	3.00	38.6	138.3	425.9	11.09	0.67	0.17
6/21/00	Burned	3.12	29.2	104.7	322.4	1.67	0.23	0.18
6/22/00	Burned	2.91	35.8	128.4	395.3	3.65	0.23	0.07
6/22/00	Unburned	3.17	39.3	145.2	452.5	0.16	0.05	0.02
6/23/00	Unburned	3.16	34.8	128.6	400.6	0.45	<0.02	<0.02
6/23/00	Unburned	3.32	37.5	138.8	432.4	0.83	<0.02	<0.02

Notes:

cm = centimeter
mph = miles per hour
CL = centerline
m = meters
cm/s = centimeters per second
g/m^2 = grams per square meter
TP = total particulate

[a] Average maximum wind speed at tunnel centerline for all three tests.

[b] Average roughness height over three runs used to calculate equivalent 10-m wind speed and friction velocity.

[c] Calculated using net mass.

KEYWORDS

Wind tunnel
PM_{10}
Fire
Controlled burn, prescribed burn
Fugitive dust