Empirical Method for Determining
Fugitive Dust Emissions for Wind Erosion of Vacant Land:
"The MacDougall Method"
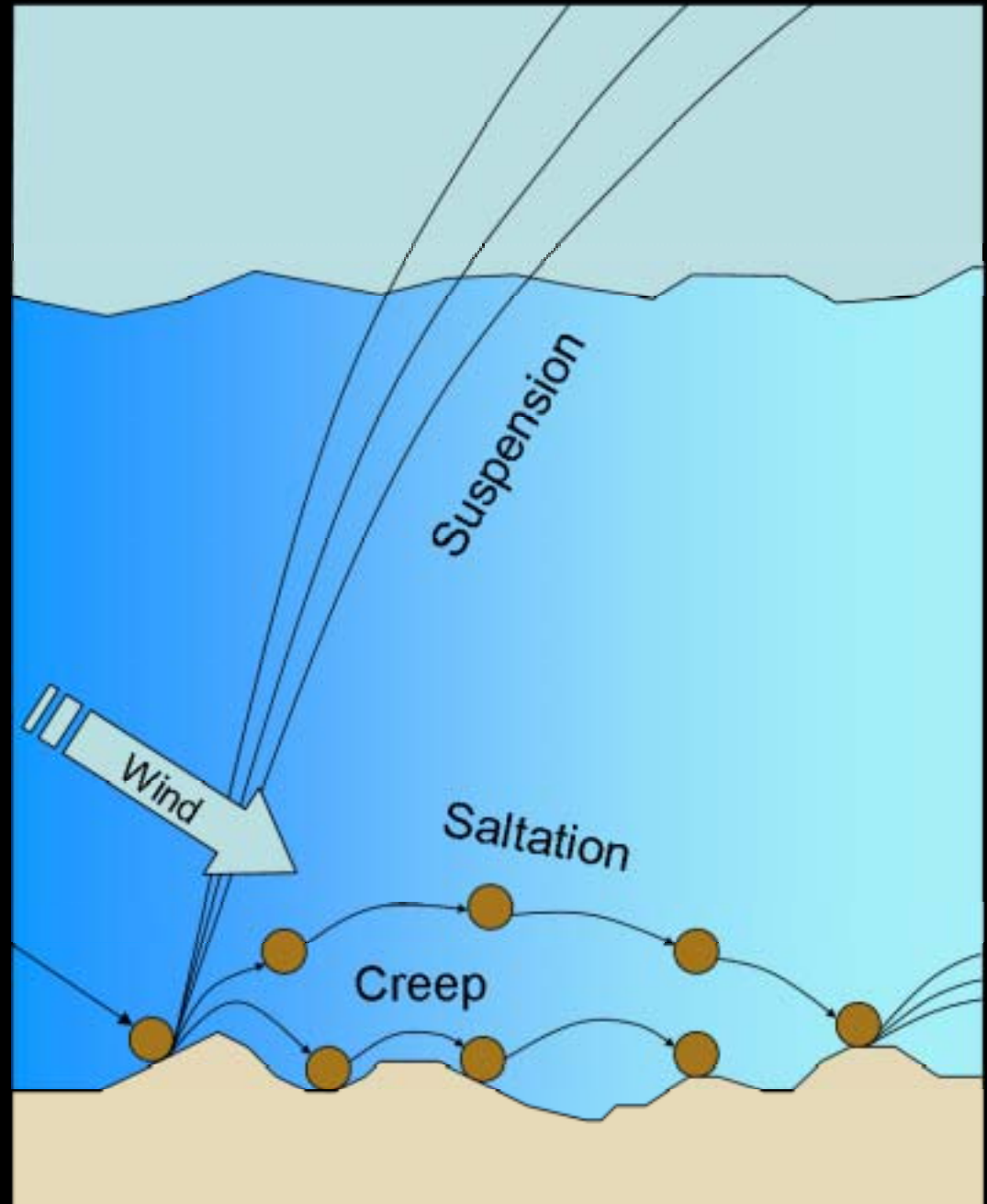
- ➢ Overview

- ➢ Process

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Overview

- Empirical Method

- Wind Tunnel Studies Required

- Develop Vacant Land Categories

Modes of Fugitive Dust Emissions:

- Creep
- Saltation
- Suspension

Step 1 & 2:
The Iterative Process

- Take big picture look at vacant land types.
- Review wind tunnel results for broad land-use categories to determine which factors have the greatest influence on the emission rates.
- Use the factors having the greatest influence to categorize vacant land.
- Review land categories in conjunction with tunnel study emission factors and assess the "fit" of the predicted relative impacts from the land-use categories.

Elements of the Iterative Process

- Categorization of land types is perhaps the most critical phase of the methodology, due to the categorization variability in wind tunnel studies and existing land-use data.
- Vacant land within the study area must be categorized based upon the potential of the parcels to emit fugitive dust during wind events.

Consideration to Make During the Iterative Process

- Does the land have vegetation cover? If so, what type and what frequency?
- Does the land have rocks or other sheltering elements?
- What is the surface roughness?
- What is the soil content?
- Is the soil crust intact or disturbed (Aeolian particulate emissions from the surface are strongly dependent on surface features.)?
- Are there periodic activities on the vacant land such as vehicles or plowing that will change the land from fairly stable to unstable?
- What are the soil characteristics?

Step 3:
Normalize Wind Tunnel Emission Factors

- Convert emission factor units to the same unit of measure for entire inventory.
- Determine if "spikes" from the initial portion of the wind tunnel test results are presented separately or averaged into an hourly factor.
- The spike is a natural element of the physical conditions of vacant land. This method accounts for the spike as follows:

  1. Spike should not be included in an hourly factor.
  2. Spike value should be included only at the beginning of each wind event.

"Spike" Signature
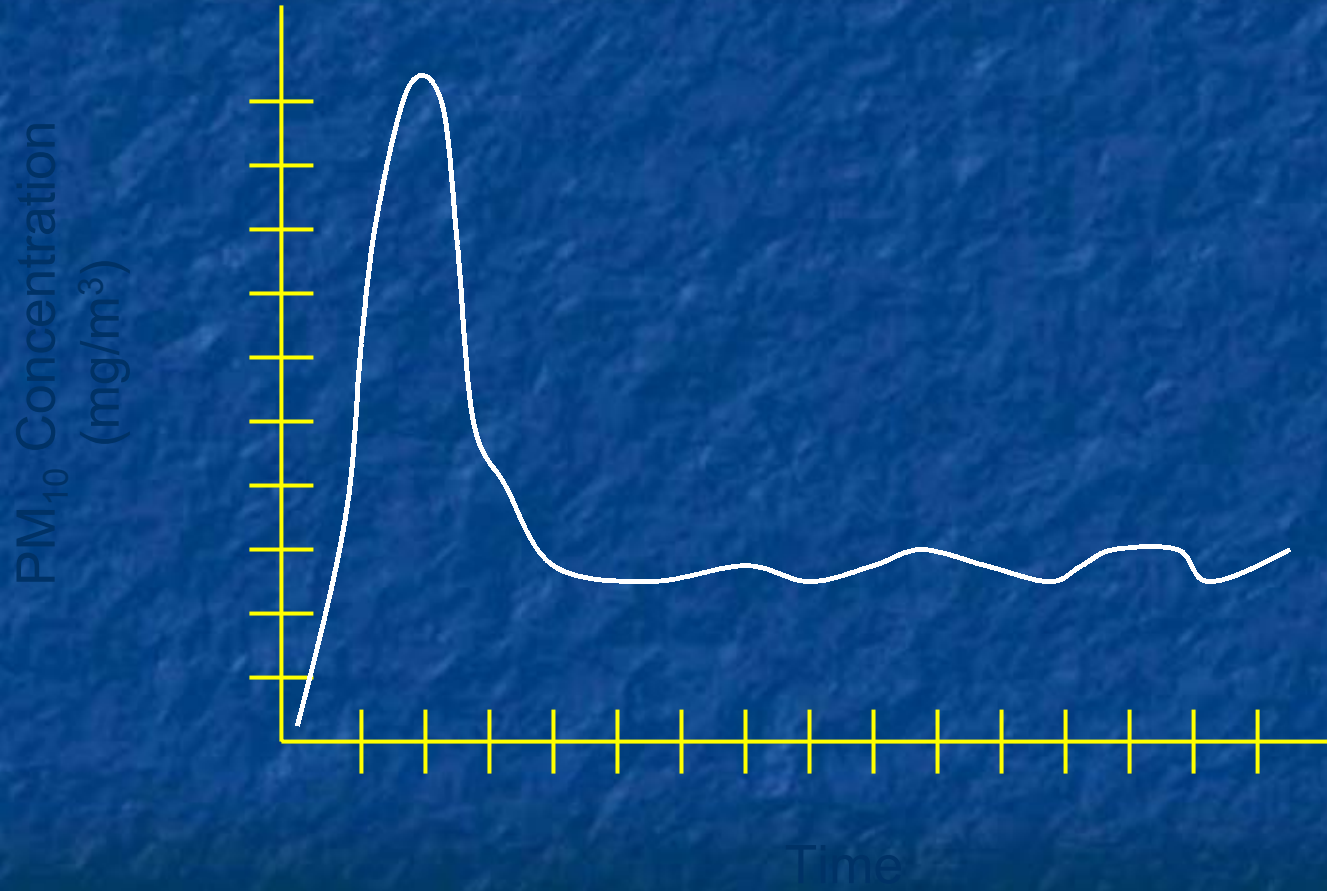
Step 4:
Develop Meteorological Data Set

For the area to be studied, hourly average wind speeds, rainfall, and if available peak wind gust data should be gathered. If a study area is particularly large, several different meteorological data sets may need to be gathered, and each land parcel matched with the meteorological data that impacts that parcel.

Step 5:
What Constitutes a Wind Event?

- Winds reach the threshold wind velocities;
- Separated by at least 24 hours before a new wind event;
- Do not include days with rain;
- If more than one inch of rain falls and there are colder temperatures and/or cloud cover, several days following a rain event should also not be considered;
- Evaluate soils in study area for ability to hold moisture;
- Consider the water table;

Step 5:
What Constitutes a Wind Event? (Continued)

- May vary depending on time period the emissions are being calculated for;
- Not all vacant land categories have an endless reservoir of the fugitive dust;
- Based on wind tunnel results, determine the length of time the vacant land category will emit for a given wind event; and
- Vacant land categories with a relatively high silt component or with frequent disturbance will probably continue to emit throughout a wind event.

Regional Rain

- Dry areas with relatively low humidity, only days where rain actually falls should emissions be set to zero; and

- Humid areas with generally saturated soils, the following two to three days should also not be included in the emissions.

Step 6:
Develop Emission Inventory Specific Emission Factors

Using the reservoir determination, threshold wind speeds, wind event determination and rainfall factors, determine hours when wind conditions produced emissions from each vacant land category for the time period of the emission inventory. Remember there may be:

- Some vacant land categories with no emissions during some time periods,
- Some vacant land categories with only a one hour reservoir during some time periods, or
- Some vacant land categories that emit throughout an entire wind event during some time periods.

Step 6:
Develop Emission Inventory Specific Emission Factors (Continued)

- Total the hours for each wind speed category;
- Multiply each of the category hours by the applicable wind tunnel emission factor;
- Calculate a total emission factor for the time period of the inventory.

Emissions Formula

$$E = A(EF_1 + EF_2)$$

E	-	Emissions
A	-	Vacant Land Category Acreage
EF_1	-	Annual Emission Factor
EF_2	-	Spike Emission Factor

Vacant Land Category With Sustained Emissions Emission Factor Formula

$$EF_1 = (\sum (H_S \times P_S))$$

EF_1 -   Emission Factor

H_S -   Hours When Wind Conditions
                 Result in Emissions

P_S -   Pounds/Hour/Acre by Vacant Land Category

Vacant Land Category Without Sustained Emissions Emission Factor Formula

$$EF_1 = (\sum (W_S \times P_S))$$

EF_1 -   Emission Factor

W_S -   Wind Events When Wind Conditions
                  Result in Emissions

P_S -   Pounds/Hour/Acre by Vacant Land Category

"Spike" Emission Factor Formula

$$EF_2 = (\sum (E_S \times S_S))$$

EF_2 -   Spike Emission Factor

E_S -   Events Producing Spike Emissions

S_S -   Spike Mass by Vacant Land Category

Step 7:
Apply Emission Inventory Specific Emission Factors to Vacant Land Categories

Once emission inventory emission factors have been developed, the number of acres in each category should be multiplied by the factor and the emissions totaled. It may be useful to develop and apply certain factors over shorter time periods and then total the emissions over a longer time period.

Step 7:
Apply Emission Inventory Specific Emission Factors to Vacant Land Categories
(Continued)

For larger areas, where vacant land categories will change over the duration of an inventory or different meteorological data sets will apply, it is advisable to subdivide the inventory by time period or area, and then total the inventory at the end.

Example

Data				
Wind Speed Category (mph)	Number of Hours	Number of Wind Events	Hourly Emission Factor (lb/hr/acre)	Spike Emission Factors (lbs/acre)
25-29	31	4	2	0.10
30-34	9	3	3	0.15
35-39	6	2	4	0.20

Example (Continued)
Continuous Reservoir No Spike Example

$EF_1 = (\sum (H_S \times P_S))$ EF_1 - Annual Emission Factor

H_S - Hours When Wind Conditions Result in Emissions

P_S - Pounds/Hour/Acre by Vacant Land Category

$EF_1 = (31 \text{ hrs} \times 2 \text{ lbs/hr/acre}) + (9 \text{ hrs} \times 3 \text{ lbs/hr/acre}) + (6 \text{ hrs} \times 4 \text{ lbs/hr/acre})$

$EF_1 = 113$ lbs/acre

$E = A(EF_1 + EF_2)$ E - Annual Emissions

$E = 5 \text{ acres } (113 \text{ lbs/acre} + 0 \text{ lbs/acre})$ A - Vacant Land Category Acreage

$E = 565$ lbs EF_1 - Annual Emission Factor

EF_2 - Spike Emission Factor

NOTE: When there is no spike emissions factor, set the EF_2 to "0".

Example (Continued)
Non-Continuous Reservoir No Spike

$EF_1 = (\sum (W_S \times P_S))$ EF_1 - Annual Emission Factor

W_S - Wind Events When Wind Conditions Result in Emissions

P_S - Pounds/Hour/Acre by Vacant Land Category

EF_1 = (4 events x 2 lbs/hr/acre) + (3 events x 3 lbs/hr/acre)

+ (2 events x 4 lbs/hr/acre)

EF_1 = 25 lbs/acre

$E = A(EF_1 + EF_2)$ E   - Annual Emissions

E = 12 acres (25 lbs/acre + 0 lbs/acre)   A   - Vacant Land Category Acreage

E = 300 lbs EF_1 - Annual Emission Factor

EF_2 - Spike Emission Factor

NOTE: When there is no spike emissions factor, set the EF_2 to "0".

Example (Continued)
Continuous Reservoir With Spike

$EF_1 = (\sum (H_S \times P_S))$ EF_1 - Annual Emission Factor

H_S - Hours When Wind Conditions Result in Emissions

P_S - Pounds/Hour/Acre by Vacant Land Category

$EF_1 = (31 \text{ hrs} \times 2 \text{ lbs/hr/acre}) + (9 \text{ hrs} \times 3 \text{ lbs/hr/acre}) + (6 \text{ hrs} \times 4 \text{ lbs/hr/acre})$

$EF_1 = 113 \text{ lbs/acre}$

$EF_2 = (\sum (E_S \times S_S))$ EF_2 - Spike Emission Factor

E_S - Events Producing Spike Emissions

S_S - Spike Mass by Vacant Land Category

$EF_2 = (4 \text{ events} \times 0.10 \text{ lbs/acre}) + (3 \text{ events} \times 0.15 \text{ lbs acre})$
$\quad + (2 \text{ events} \times 0.20 \text{ lbs/acre})$

$EF_2 = 1.25 \text{ lbs/acre}$

$E = A(EF_1 + EF_2)$ E   - Annual Emissions

$E = 18 \text{ acres} (113 \text{ lbs/acre} + 1.25 \text{ lbs/acre})$ A   - Vacant Land Category Acreage

$E = 2056.60 \text{ lbs}$ EF_1 - Annual Emission Factor

EF_2 - Spike Emission Factor

Additional Information

- A list of published wind tunnel studies with principle participants is provided at the end of the paper.
- Clark County, NV PM$_{10}$ SIP Appendices B & C (to request a copy please provide a business card with an email address)