SECTION 7.12

WINDBLOWN DUST - AGRICULTURAL LANDS

(Revised July 1997)

EMISSION INVENTORY SOURCE CATEGORY
Miscellaneous Processes / Fugitive Windblown Dust

EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION
650-650-5400-0000 (83337) Windblown Dust - Agricultural Lands

650-651-5400-0000 (84863) Windblown Dust - Pasture Lands

METHODS AND SOURCES

A. Introduction

Wind blowing across exposed agricultural land results in particulate matter (PM) emissions. The methodology used by the California Air Resources Board (ARB) to estimate these emissions has changed significantly since the 1987 inventory produced from the original 1989 ARB methodology.[1]

Because of the complexity, and detailed nature of the calculations for this latest version, the calculation methodology is only summarized here. Additional background, and details on the methodology are included in the supplemental documentation[2] to this methodology, which is available on request from the ARB.

The acreages of agricultural crops used in this latest version of the methodology are from the 1993 harvested acreage data provided to ARB staff by the California Department of Food and Agriculture (CDFA).[3] This revision of the windblown dust methodology has been applied to nearly all of the crops in the CDFA data base that might be expected to produce windblown emissions. Orchard and vineyard acreages have been excluded, because the methodologies for determining the emissions have not been developed.

This revised methodology is intended to be applied statewide, and has been systematically applied to the 26 counties included in attachments A and B at the end of this document. They include all counties in the San Joaquin Valley (SJV), Sacramento Valley (SV), North Central Coast (NCC), and the South Central Coast (SCC) air basins, along with Imperial County in the Southeast Desert (SED) Air Basin. Those counties represent the bulk of the agricultural acreage in California. The remaining counties in California have had, or will have in the near future, emission factors and monthly profiles derived in part from the county among the above 26 counties to which they are the most similar. There are a few exceptions, such as the South Coast Air Basin, where the South Coast Air Quality Management District has taken responsibility to develop its own emission inventory methodology.

B. Choosing the Wind Erosion Equation as the Base for the ARB's Windblown Dust Emissions Estimation Methodology

For windblown dust emissions on agricultural lands, the final emissions inventory result is obtained by multiplying the process rate (acres of crop in cultivation) by an emission factor (tons of PM per acre per year). The standard methodology for estimating the emission factor for windblown emissions from agricultural lands, which was used for the 1989 ARB methodology, is the wind erosion equation or WEQ, and is well established, though still controversial. The WEQ was developed by the United States Department of Agriculture - Agricultural Research Service (USDA-ARS) during the 1960's, for the estimation of wind erosion on agricultural land.[4,5]

The United States Environmental Protection Agency (U.S. EPA) adapted the USDA-ARS methodology for use in estimating windblown PM emissions from agricultural lands in 1974 (page 144 et seq. of EPA-450/3-74-037).[6] The U.S. EPA methodology was then adapted by ARB staff for the 1989 ARB methodology.[1]

In the time since the 1989 ARB methodology was produced, the USDA-ARS has been conducting ambitious programs to replace the WEQ with improved wind erosion prediction models. These USDA-ARS programs include the development of the Revised Wind Erosion Equation (RWEQ)[7] and the Wind Erosion Prediction System (WEPS)[8] models. To date, these models have not proven feasible for use by the ARB, although certain portions of the RWEQ have been incorporated into the ARB methodology with this revision. The WEQ (with modifications) continues to be the best available, feasible method for estimating windblown agricultural emissions in California.

C. ARB's Implementation of the WEQ: The ARBWEQ

1. Summary of ARB's Implementation

Much of the controversy surrounding the WEQ has related to its tendency to produce inflated emission estimates. Some of the reasons for the inflated emissions relate to the fact that it was developed in the Midwestern United States, and that it does not take into account many of the environmental conditions and farm practices specific to California. In this revised methodology, which will also be referred to as the ARBWEQ, ARB staff has added adjustments to the WEQ to improve its ability to estimate windblown emissions from California agricultural lands.

On page 144 et seq. of the EPA-450/3-74-037 document[6] the U.S. EPA established the following modification of the USDA-ARS WEQ:

Equation 1: E_S = AIKCL'V' ,

where: E_S = suspended particulate fraction of wind erosion losses of tilled fields, tons/acre/year
A = portion of total wind erosion losses that would be measured as suspended particulate, estimated to be .025
I = soil erodibility, tons/acre/year
K = surface roughness factor, dimensionless
C = climatic factor, dimensionless
L' = unsheltered field width factor, dimensionless
V' = vegetative cover factor, dimensionless

The "A" factor has been used in the ARBWEQ without modification. There has been concern that the "A" factor doesn't take into account finite dust loading. The RWEQ[7] and WEPS[8] models are attempting to address that concern.

The soil erodibility ("I") was initially established for the WEQ for a large, flat, bare field in Kansas. Kansas has relatively high winds, along with hot summers, and low precipitation. The "K", "C", "L'" and "V'" factors serve to adjust the equation for applicability to field conditions that differ from the original Kansas field.

In the WEQ, "I" is a function of soil particle diameter, which can be estimated for various soil textural classes from Table A-1 of the above U.S. EPA methodology. The soil textural classes were determined by ARB staff from University of California soil maps.[9] For most of the SJV Air Basin counties an additional level of detail was included in the ARBWEQ by using the United States Department of Agriculture - Natural Resources Conservation Service's (NRCS) State Geographic Data Base (STATSGO) of soil data.[10] In addition, the USDA-ARS recommended an adjustment for changes to long term erodibility due to irrigation.[11] This affects a property known as cloddiness, and refers to the increased tendency for a soil to form stable agglomerations after being exposed to irrigation water.

The "K" factor reflects the reduction in wind erosion due to ridges, furrows, and soil clods. The "K" factor is crop specific. The values for "K" were derived from Table A-2 in the above U.S. EPA methodology. Similar crops were assigned similar "K" values.

The annual climatic factor "C" is based on data that show that erosion varies directly with the wind speed cubed, and as the inverse of the square of surface soil moisture. For the ARBWEQ, ARB staff improved the input data, as well as the methods associated with developing the county wide averaged annual climatic factor. Monthly climatic factors were obtained by modifying the annual "C" factor calculation method.

Figure A-5 in the U.S. EPA methodology[6] allows the calculation of the unsheltered field width factor ("L'") from the unsheltered field width ("L") and the product of erodibility ("I") and surface roughness ("K"). The values for "L" were derived from Table A-2 in the above U.S. EPA methodology. Similar crops were assigned similar "L" values.

The vegetative cover factor "V'" is especially problematic for California, and was completely replaced by a series of factors in the ARBWEQ (see analysis below). The "V'" factor assumes a certain degree of cover year round based upon postharvest soil cover. This factor does not account for barren fields from land preparation, growing canopy cover, or replanting of crops during a single annual cycle. All of these factors are very important in the estimation of windblown agricultural dust emissions in California. Therefore, ARB staff replaced the "V'" factor with separate crop canopy cover, postharvest soil cover, and postharvest replant factors.

2. Climate-based Improvements in the ARBWEQ

The calculation of the "C" factor requires mean monthly temperature, monthly rainfall, and mean annual wind speed for a given location as data inputs. The "C" factor estimates climatic effects on an annual basis. In order to make estimates of emissions using the WEQ that are specific to different seasons, it is necessary to estimate the "C" factor that would apply to each season. The changes to the agricultural windblown emissions inventory discussed here, include modifications to both the annual and the monthly "C" factor profile determination methodology included in the ARBWEQ.

a. The Annual Climatic "C" Factor for the ARBWEQ

Page 157 of the EPA-450/3-74-037 document[6] includes a definition of the "C" factor which agrees with the method utilized by the NRCS.[12] It incorporates the monthly precipitation effectiveness derived from precipitation and temperature, along with monthly average windspeeds. Garden City, Kansas is assigned a factor of 1.0 and the "C" factors for all other sites are adjusted from this using the "C" factor calculation.

For the 1989 methodology, ARB staff used USDA-produced California statewide and county "C" factor contour maps.[13] The data used for producing these contour maps came from a number of sources (see supplemental documentation[2] for reference list). For the ARBWEQ, the ARB staff produced contour maps using updated California Irrigation Management System (CIMIS) data,[14] that were then grid counted to determine the weighted average "C" factors for the agricultural production land in each county.

b. The Monthly "C" Factor for the ARBWEQ

There are several ways to create a climate-based monthly profile for the ARBWEQ. Because the ARBWEQ is an annual emission estimation model, ARB staff did not directly estimate monthly emissions using the monthly "C" factor. Instead, the annual "C" factor was used to determine annual emissions, and then the monthly normalized "C" factors were multiplied by the annual emissions. This helped to limit the effect of extreme monthly values on the annual emissions estimate.

ARB staff devised a method termed the “month-as-a-year” method which produced “C” factors which would apply if the climate for a given month were instead the year round climate. These monthly numbers, once normalized, provided the climate-based temporal profile. The improvements arising from the use of the month-as-a-year method are due to the fact that it relies on temperature, and precipitation inputs, in addition to wind. The ARBWEQ further modified the temporal profile calculation, by also adding nonclimate-based temporal factors.

The month-as-a-year method in the ARBWEQ produces pronounced curves with small “C” factors (resulting in lower emissions) in the cool, wet and more stagnant periods, and large “C” factors (and higher emissions) in the hot, dry, and windy periods. The U.S. EPA method yields gentler profiles, which are shifted into the cooler and wetter months from the ARBWEQ profiles. The 1989 ARB methodology established one erosive wind energy distribution statewide. This resulted in an unrealistic, nearly flat distribution, with very little seasonality. Therefore, the ARBWEQ month-as-a-year method provides a more realistic picture of the windblown dust temporal profile (see supplemental documentation[2] for comparison curves, and supporting references).

3. Nonclimate-Based Improvements in the ARBWEQ

Among the nonclimate-based factors that influence windblown agricultural emissions are soil type, soil structure, field geometry, proximity to wind obstacles, crop, soil cover by crop canopy or postharvest vegetative material, irrigation, and replanting of the postharvest fallow land with a different crop. Several of the above factors are particularly applicable to California agriculture, and yet are not included in the standard WEQ. ARB staff has attempted to correct many of these limitations in the ARBWEQ. Many of the corrections are temporally based, and rely upon the establishment of accurate crop calendars to reflect field conditions throughout the year. The long-term irrigation-based adjustment to erodibility, due to soil cloddiness, is not temporally based, and is therefore applied for the entire year.[11] The change in erodibility varies based on soil type, but, for the ARB inventory, often results in a reduction in the tons per acre value for irrigated crops of about one-third.

a. Crop Calendars: Quantifying Temporal Effects

Factors such as crop canopy cover, postharvest soil cover, irrigation, and replanting to another crop have a major effect on windblown emissions. Estimating the effects of these factors requires establishing accurate crop calendars. The planting and harvesting dates are principal components of the crop calendar. The list of references consulted to establish the planting and harvesting dates is included in the supplemental documentation.[2]

Each planting month for a given crop was viewed by ARB staff as a separate cohort (maturation class). Since a single planting cohort may be harvested in several months, each cohort was split into cohort-plant/harvest date pairs. The cohort-plant/harvest date pairs were then assigned based upon a first-in-first-out ordering. The fraction of the total annual crop assigned to a given cohort-plant/harvest date pair was derived by multiplying the fraction of the total annual crop planted in a given month (cohort) by the fraction of the cohort harvested in a given month.

The fraction of a cohort-plant/harvest date pair that has been planted, but not harvested at any given time, is termed the growing canopy fraction, or GCF (although the canopy may or may not actually be increasing at any given time). The growing canopy fraction determines the fraction of the acreage that will have the crop canopy factor applied to its emission calculations. The acreage that is not assigned to the growing canopy fraction is the postharvest/preplant (PHPP) acreage. The PHPP acreage will have the postharvest soil cover, and replanting to a different crop factors applied when calculating its emissions.

The effect of using cohort-plant/harvest date pairs is to blend the crop canopy, soil cover, replanting, and irrigation effects over both the planting and harvesting periods. This approach provides a more realistic estimate of the temporal windblown emissions profile during these periods. All of the monthly factor profile adjustments described below are calculated for each month of the year, for each cohort-harvest/plant date pair, for each crop, for each county.

b. Adding a Short-term Irrigation Factor for Wetness

This adjustment takes into account the overall soil texture, number of irrigation events, and fraction of wet days during the time period[11] (one month for the purposes of the ARB inventory). The list of references consulted to establish the irrigation profiles is included in the supplemental documentation.[2] The irrigation factor for months in which irrigations take place will typically be greater than 0.80. In other words, the irrigations will result in a reduction in erodibility of less than 20%. This is only an estimate for a typical case during the growing season. When averaged over the year, the overall reduction in erodibility is lower.

c. Replacement Factors to Address Problems with the "V'" Vegetative Soil Cover Factor in the WEQ

There are many problems with the "V'" factor. For example, the "V'" factor is applied to the acreage year round, even during the growing season. This ignores the effect of disk-down and other land preparation operations on postharvest vegetative soil cover. The factor also does not account for canopy cover during the growing season. In addition, the WEQ was derived based on agricultural practices typical of the Midwestern United States. In California, crops such as alfalfa have full canopy cover for nearly the entire year. There is also a large amount of acreage in California that is used for more than one crop per year, and there was no provision in the "V'" factor for estimating the effects on emissions of this replanting.

Whether the land is to be immediately replanted to a different crop, or is going to remain fallow until the next planting of the same crop, it is common practice in California to disk under the harvested crop within a month or two of harvest. The "V'" factor for the most part assumes that the postharvest debris remains undisturbed. References to support this agricultural practice information are included in the supplemental documentation.[2] ARB staff replaced the "V'" factor in the ARBWEQ with the three adjustments discussed below to approximate the effects on windblown agricultural PM emissions of: 1.) crop canopy cover during the growing season; 2.) changes to postharvest soil cover; 3.) postharvest planting of a different crop on the harvested acreage.

(1) Crop Canopy Factor

Crop canopy cover is the fraction of ground covered by crop canopy when viewed directly from above. USDA-ARS staff provided the ARB with methodology from the RWEQ for estimating the effects of crop canopy cover on windblown dust emissions.[7] The soil loss ratio (SLRcc) is defined as the ratio of the soil loss for a soil of a given canopy cover divided by the soil loss from bare soil.

SLRcc is the factor which is multiplied by the erodibility to adjust the erodibility for canopy cover. The greater the canopy cover, the smaller the SLRcc, and the greater the reduction in erodibility. SLRcc defines an exponential curve that demonstrates major differences in the erodibility reduction for the range of zero to 30 percent canopy cover (typically achieved within a few months after planting). Thereafter, reductions occur much more slowly, and eventually the curve flattens out. This results in a rapid decrease in emissions in the first few months following planting, until the emissions are only a very small fraction of the bare soil emissions. The canopy cover then will remain, and the windblown emissions will consequently stay very low until harvest. Senescence affects (late growing season reduction in canopy) have been excluded from this model, and the rationale for that exclusion has been discussed in the supplemental documentation.[2] The list of references consulted to establish the crop canopy cover profiles is included in the supplemental documentation.[2]

(2) Postharvest Soil Cover Factor

Postharvest soil cover is the fraction of ground covered by vegetative debris when viewed directly from above. USDA-ARS staff provided the ARB with methodology from the RWEQ for estimating the effects of postharvest soil cover on windblown dust emissions.[7] The soil loss ratio (SLRsc) is defined as the ratio of the soil loss for a soil of a given soil cover divided by the soil loss from bare soil. SLRsc is the factor which is multiplied by the erodibility to adjust the erodibility for postharvest soil cover. The greater the postharvest soil cover, the smaller the SLRsc, and the greater the reduction in erodibility. The list of references consulted to establish the postharvest soil cover profiles is included in the supplemental documentation.[2]

(3) Postharvest "Replant-to-Different-Crop" Factor

As discussed above, the "V'" factor does not include any adjustments for harvested acreages that are quickly replanted to a different crop. This multiple cropping is very common in

California, and has been accounted for in this methodology by removing from the inventory calculation the fraction of the harvested acreage that is replanted, at the estimated time of replanting. This removed fraction is based on information provided by agricultural authorities (see reference list in supplemental documentation[2]). The net result of the application of the fraction is that the postdisk-down acreage (one to two months after harvest), and resultant emissions, is reduced by the fraction of harvested acreage converted to a new crop.

d. Bare and Border Soil Adjustments

Most fields will have some cultivated areas that are barren. These bare areas could be due to uneven ground (e.g., water accumulation), uneven irrigation, pest damage, soil salinity, etc. Most fields will have some type of border. In some cases there is a large barren border, in other cases it is overgrown with vegetation. Many border areas are relatively unprotected, and prone to wind erosion. The ARB staff established approximate fractions of cultivated acreage that would be barren and border areas, respectively.

These barren and border acreage adjustments result in emission increases disproportionate to the acreage involved. The reason that the bare acreage-based increase is so large is that the bare acreage does not have either a crop canopy or postharvest soil cover factor applied. The same reasons apply to the border adjustment, but the border region is also assumed to be nonirrigated. Therefore, no irrigation factor (wetness), and no long-term irrigation adjustment to erodibility (cloddiness) are applied. No border adjustment was applied to the pasture acreage, since pasture areas frequently lack a barren border.

D. Annual Emission Factors by Basin by County

Attachment A, at the back of this document, shows the nonpasture emission factors for the 26 counties, for which the ARBWEQ calculations have been performed. Attachment B shows the pasture emission factors for the same 26 counties. The emission factors for the other counties in the California emissions inventory have been established in one of the following three ways: 1.) assigning emission factors from one of the above 26 counties based on geographic, climatic and agricultural production similarities; 2.) assigning emission factors based on separate calculations performed by the local air pollution control district; 3.) assigning emission factors based on some retained factors from the 1989 methodology as well as new factors, and the 1993 acreages.

The emission factors shown in Attachment A are weighted averages for all nonpasture crops within a county, for a given air basin. Therefore, if the crop acreages or acreage mix within a county change, the factors must be recalculated. The emission factors cannot simply be applied to the total acreage in a county irrespective of the crop acreage mix. The only exception would be if all of the acreages of all crops were scaled upward by the same percentage in a given county. The emission factors are most simply obtained by performing the complete emissions calculation for a given county within a given basin, summing emissions for all crops, and then dividing by the total crop acreage in the county within the air basin. The units are in tons per acre per year.

TEMPORAL INFORMATION

For the 1989 ARB methodology, the temporal profile was based on an estimated statewide erosive wind energy profile. The profile, implemented in the ARBWEQ included wind, precipitation and temperature climatic effects, along with the addition of the effects of crop canopy, postharvest soil cover, postharvest replanting to a different crop, and irrigation. In addition, the inclusion of bare ground and field border effects also adjusted the profile in the ARBWEQ. The profile produced for the ARBWEQ is no longer a separate profile applied to annual emissions, as was the case for the 1989 methodology, but is now an intermediate output produced during the estimation of annual emissions. The final nonpasture temporal profiles for the 26 counties that had their profiles recalculated in this revision are shown in Table 1 below. The final pasture temporal profiles (combined irrigated and nonirrigated pasture) for the same 26 counties are shown in Table 2 below.

Table 1

Final Normalized Monthly Emission Profiles for 1993: Nonpasture

Air Basin	County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NCC	Monterey	0.0012	0.0027	0.0029	0.0619	0.1111	0.2465	0.2088	0.1620	0.1135	0.0670	0.0178	0.0046
	San Benito	0.0002	0.0009	0.0017	0.0158	0.0659	0.2708	0.2349	0.2057	0.1893	0.0103	0.0022	0.0025
	Santa Cruz	0.0006	0.0005	0.0035	0.0453	0.0220	0.2002	0.2605	0.1925	0.1364	0.0962	0.0415	0.0009
SCC	San Luis Obispo	0.0046	0.0063	0.0037	0.0787	0.1265	0.1444	0.1365	0.1444	0.1371	0.1278	0.0742	0.0158
	Santa Barbara	0.0024	0.0042	0.0032	0.1545	0.1105	0.1737	0.1375	0.1098	0.1370	0.1176	0.0412	0.0082
	Ventura	0.0005	0.0005	0.0009	0.0877	0.1217	0.0879	0.1721	0.1685	0.1461	0.1329	0.0786	0.0025
SED	Imperial	0.0057	0.0394	0.0557	0.1082	0.1757	0.1460	0.1310	0.1270	0.0970	0.0659	0.0368	0.0117
SJV	Fresno	0.0032	0.0076	0.0081	0.2712	0.2174	0.0890	0.0849	0.1142	0.1149	0.0676	0.0145	0.0075
	Kern	0.0082	0.0171	0.0108	0.2985	0.2025	0.0970	0.0849	0.0897	0.0798	0.0669	0.0314	0.0131
	Kings	0.0062	0.0084	0.0110	0.3688	0.1690	0.0606	0.0552	0.0677	0.0894	0.0896	0.0606	0.0135
	Madera	0.0035	0.0070	0.0084	0.2992	0.2279	0.0795	0.0963	0.1213	0.0916	0.0454	0.0115	0.0081
	Merced	0.0055	0.0032	0.0073	0.3281	0.1416	0.0758	0.0910	0.1087	0.0969	0.0774	0.0549	0.0096
	San Joaquin	0.0024	0.0031	0.0067	0.1303	0.1296	0.1690	0.1587	0.1855	0.1496	0.0519	0.0074	0.0059
	Stanislaus	0.0091	0.0056	0.0120	0.1838	0.0871	0.1463	0.1548	0.1510	0.1057	0.0751	0.0514	0.0181
	Tulare	0.0038	0.0060	0.0051	0.2882	0.2157	0.0929	0.1167	0.1198	0.0856	0.0539	0.0081	0.0043
SV	Butte	0.0114	0.0316	0.0333	0.2697	0.2156	0.0556	0.1253	0.0977	0.0498	0.0721	0.0227	0.0152
	Colusa	0.0037	0.0075	0.0171	0.1868	0.1818	0.1461	0.0998	0.1141	0.1099	0.1169	0.0106	0.0059
	Glenn	0.0040	0.0116	0.0162	0.2311	0.0859	0.2114	0.0773	0.0466	0.0623	0.1652	0.0764	0.0122
	Placer	0.0052	0.0081	0.0130	0.2733	0.2610	0.0962	0.0877	0.0964	0.1024	0.0411	0.0107	0.0049
	Sacramento	0.0015	0.0025	0.0046	0.1199	0.1443	0.3286	0.1300	0.1012	0.1297	0.0306	0.0046	0.0024
	Shasta	0.0019	0.0071	0.0082	0.0756	0.0984	0.3371	0.2219	0.1439	0.0436	0.0550	0.0055	0.0018
	Solano	0.0008	0.0011	0.0021	0.0461	0.0884	0.1865	0.1423	0.1450	0.1875	0.1902	0.0087	0.0013
	Sutter	0.0038	0.0057	0.0088	0.1846	0.2083	0.2042	0.0906	0.0990	0.1433	0.0397	0.0084	0.0036
	Tehama	0.0021	0.0055	0.0059	0.0528	0.0666	0.3714	0.2149	0.1570	0.0664	0.0505	0.0047	0.0021
	Yolo	0.0015	0.0022	0.0036	0.0787	0.1309	0.2377	0.1079	0.1054	0.1682	0.1528	0.0091	0.0019
	Yuba	0.0076	0.0120	0.0182	0.2745	0.2564	0.1158	0.0768	0.0478	0.0804	0.0660	0.0372	0.0073

Table 2

Final Normalized Monthly Emission Profiles for 1993: Pasture

Air Basin	County	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NCC	Monterey	0.0008	0.0023	0.0025	0.0517	0.0905	0.2223	0.2101	0.1929	0.1357	0.0710	0.0172	0.0030
	San Benito	0.0001	0.0006	0.0011	0.0113	0.0522	0.2713	0.2677	0.2270	0.1590	0.0071	0.0014	0.0011
	Santa Cruz	0.0003	0.0004	0.0024	0.0334	0.0187	0.1960	0.2671	0.2180	0.1428	0.0859	0.0345	0.0006
SCC	San Luis Obispo	0.0021	0.0041	0.0026	0.0654	0.1272	0.1904	0.2006	0.1753	0.1036	0.0764	0.0450	0.0072
	Santa Barbara	0.0014	0.0030	0.0022	0.1216	0.0980	0.1726	0.1641	0.1463	0.1397	0.1051	0.0403	0.0057
	Ventura	0.0003	0.0004	0.0008	0.0799	0.1177	0.0866	0.1843	0.1810	0.1450	0.1274	0.0750	0.0016
SED	Imperial	0.0024	0.0164	0.0261	0.0551	0.0967	0.0867	0.0646	0.0720	0.0488	0.2472	0.2732	0.0108
SJV	Fresno	0.0007	0.0019	0.0021	0.0804	0.1702	0.1770	0.1336	0.1068	0.2201	0.1006	0.0050	0.0017
	Kern	0.0020	0.0051	0.0032	0.0958	0.1581	0.1583	0.1249	0.1003	0.2066	0.1283	0.0138	0.0035
	Kings	0.0013	0.0021	0.0028	0.1036	0.1405	0.1707	0.1265	0.0990	0.1991	0.1320	0.0195	0.0029
	Madera	0.0007	0.0019	0.0021	0.0812	0.1719	0.1788	0.1351	0.1079	0.2179	0.0959	0.0050	0.0017
	Merced	0.0011	0.0008	0.0018	0.0930	0.0981	0.1570	0.1390	0.1005	0.2194	0.1640	0.0231	0.0021
	San Joaquin	0.0005	0.0009	0.0019	0.0430	0.0788	0.2265	0.1848	0.1442	0.2412	0.0746	0.0025	0.0012
	Stanislaus	0.0021	0.0019	0.0037	0.0647	0.0565	0.1964	0.1571	0.1050	0.2152	0.1694	0.0238	0.0041
	Tulare	0.0007	0.0014	0.0011	0.0681	0.1350	0.1848	0.1565	0.1104	0.2198	0.1179	0.0034	0.0009
SV	Butte	0.0010	0.0029	0.0031	0.0294	0.0515	0.0940	0.3024	0.2379	0.2041	0.0688	0.0034	0.0015
	Colusa	0.0005	0.0009	0.0022	0.0291	0.0582	0.2180	0.1974	0.1610	0.2281	0.1018	0.0019	0.0008
	Glenn	0.0006	0.0018	0.0025	0.0412	0.0287	0.2338	0.1275	0.0827	0.2331	0.2277	0.0185	0.0020
	Placer	0.0005	0.0008	0.0013	0.0314	0.0677	0.2348	0.1734	0.1379	0.3101	0.0399	0.0017	0.0005
	Sacramento	0.0004	0.0006	0.0012	0.0360	0.0571	0.2216	0.1705	0.1299	0.3310	0.0495	0.0016	0.0006
	Shasta	0.0007	0.0019	0.0021	0.0214	0.0365	0.3573	0.2451	0.1440	0.1219	0.0665	0.0018	0.0007
	Solano	0.0002	0.0003	0.0007	0.0182	0.0447	0.1497	0.1480	0.1119	0.2964	0.2266	0.0028	0.0004
	Sutter	0.0005	0.0007	0.0012	0.0286	0.0617	0.2125	0.1566	0.1249	0.3636	0.0477	0.0016	0.0005
	Tehama	0.0007	0.0019	0.0021	0.0217	0.0370	0.3624	0.2488	0.1461	0.1147	0.0621	0.0018	0.0007
	Yolo	0.0003	0.0005	0.0009	0.0226	0.0528	0.1794	0.1598	0.1228	0.2924	0.1656	0.0025	0.0004
	Yuba	0.0004	0.0006	0.0010	0.0169	0.0356	0.1527	0.1783	0.1611	0.4092	0.0405	0.0033	0.0004

ASSUMPTIONS

See the supplemental information document[2] for the assumptions associated with the development of this methodology.

SUMMARY OF CHANGES IN METHODOLOGY

For the ARBWEQ, the 1993 crop acreages were obtained from the CDFA, replacing the 1987 acreages used in the 1989 methodology. The annual "C" factors for the ARBWEQ are now generated using the CIMIS data and surface contour/grid count methods. The windblown agricultural PM temporal emissions profile now uses the "month as a year" estimation method. The erodibility has been adjusted using STATSGO data for most of the SJV Air Basin counties. The annual erodibility was adjusted to account for the long-term effects of irrigation (cloddiness). A monthly irrigation factor was added to account for the short-term effects of irrigation on erodibility (surface wetness).

The annual "V'" factor for the WEQ was replaced with the following three adjustments, calculated on a temporal (monthly) basis to account for the short-term effects on erodibility. The first adjustment accounts for the effect on emissions of the growth of crop canopy from planting through harvest. The second adjustment accounts for the effect on emissions of variations in postharvest soil cover from harvest to planting of next crop. The third adjustment accounts for the portion of harvested acreage replanted to a different crop within a short time following harvest. Because there are typically bare areas and border regions in agricultural fields, these areas were treated separately in the ARBWEQ.

DIFFERENCES BETWEEN THE 1987 AND 1993 EMISSION ESTIMATES

Pasture crops were not included in the 1989 methodology (1987 emissions estimate), and, therefore, only the nonpasture acreage will be included in the comparisons in this section. Table 3 compares the 1987 and the 1993 (ARBWEQ methodology) nonpasture crop annual particulate matter emissions estimates.

The effects on the emissions of the updated acreages, varied directly with the increase or decrease in acreage. However, in general, the other adjustments overwhelmed any effects due to changes in acreage. A notable exception is Yolo County, where the 1993 emissions were greater than the 1987 emissions. The biggest factors contributing to the increase in Yolo County emissions were the inclusion in the ARBWEQ of large acreages of safflower and "field crops, unspecified," which had not been included in the 1989 methodology.

The STATSGO-based erodibility changes applied to most of the counties in the SJV were significant in some cases. The most notable changes resulted in emissions increases for Kings County, and emissions decreases for Fresno and Kern counties.

Table 3

Nonpasture Windblown Agricultural Emissions

Air Bsn	County Name	1987 PM Emiss (tpy)	1993 PM Emiss (tpy)
NCC	Monterey	12,283	5,717
	San Benito	2,946	797
	Santa Cruz	513	37
SCC	Santa Barbara	1,565	258
	San Luis Obispo	1,850	754
	Ventura	2,707	1,005
SED	Imperial	615,458	69,474
SJV	Fresno	98,479	11,891
	Kern	117,862	3,537
	Kings	30,963	6,092
	Madera	3,230	1,138
	Merced	11,013	4,983
	San Joaquin	4,334	1,366
	Stanislaus	7,400	2,080
	Tulare	20,519	2,213
SV	Butte	123	135
	Colusa	4,959	1,080
	Glenn	877	922
	Placer	na	15
	Sacramento	920	292
	Shasta	na	32
	Solano	2,804	574
	Sutter	1,241	797
	Tehama	99	84
	Yolo	2,242	2,532
	Yuba	31	55

The most striking effect on emissions due to the adjustment to the annual climatic factors was for Kern County. There was a large decrease due to the fact that the NRCS "C" factor contour map used for the 1989 methodology incorporated National Oceanic and Atmospheric Administration (NOAA) data from Bakersfield which exhibited excessively high wind speeds.

For many important crops, the large monthly climatic factors in the summer shift the emissions into the summer months, when many crop canopy covers are at their maximum. This results in a large decrease in the annual emissions estimate between 1987 and 1993. The short-term irrigation factor (wetness) may reduce the emissions by 10% to 20% during the months when the "C" factor profile peaks. The long-term irrigation erodibility adjustment due to cloddiness, included in the ARBWEQ, often results in annual reductions in the range of 30 percent from the 1989 methodology levels. Emissions are also reduced due to the postharvest soil cover, and the replant factor, but these are occurring during periods when the "C" factor profile is lower, and so have less of an effect. For most counties, the largest portion of the emission reductions between the 1987 and 1993 estimates are due to the long term irrigation factor (cloddiness) adjustments, and the combination of the "C" factor profile and the crop canopy cover. A notable exception is Kern County, where the improved wind data resulted in the largest decrease in the emissions estimate.

RECOMMENDATIONS

See the supplemental information document[2] for the recommendations for future inventory work.

SAMPLE CALCULATIONS

See the supplemental information document[2] for the sample calculations.

DEFINITION OF TERMS

bare soil adjustment = Adjusts windblown emissions for the planted acreage on which plants do not establish

border adjustment = Adjusts windblown emissions for the nonplanted regions of the acreage dedicated to a given crop that separate it from surrounding regions

climatic factor "C", annual = Factor used to estimate the effects of climate on soil erodibility. Garden City, Kansas is set to 1.0 and temperature, wind and precipitation are used to adjust the factor

climatic factor "C", monthly = Estimated by modifying the annual "C" factor equation. The U.S. EPA uses mean monthly wind in place of the annual wind. This revision of the ARB methodology uses the month-as-a-year method *cloddiness* = The level of relatively stable agglomerations in the soil caused by exposure to water

cohort (maturation class) = Planting of a given crop that occurs in a given month (see also plant/harvest date pair)

crop calendar = Temporal distribution of agricultural activities (e.g., planting and harvesting dates)

crop canopy cover factor[7] = Adjusts the windblown emissions based on the crop canopy cover

crop canopy cover = The fraction of land covered by canopy, viewed directly from above

erosive wind energy (EWE) = Sum of the wind speed between 18 and 45 mph cubed, in 2.2 mph increments

grid counting method = Method used to estimate areas contained between contour lines of maps

growing canopy fraction (GCF) = Determines the fraction of the acreage that will have the crop canopy cover factor applied to it

irrigation factor (wetness) = Adjusts the erodibility due to surface wetness from irrigation events

long-term irrigation-based erodibility adjustment[11] = This adjustment takes into account changes in cloddiness of the soil, based upon differences between irrigated and nonirrigated soils

month-as-a-year = Term coined by ARB staff to describe method of calculating the "C" factor profile by assuming that each month's data for a given site describes a unique annual climatic regime

precipitation effectiveness (PE) = Thornthwaite's precipitation-evaporation index (sum of 12 monthly PE values (ratios of precipitation to actual evapotranspiration))

plant/harvest date pair = For this methodology planting cohorts were often split between harvest months using the fraction of the total crop planted in a given month with the fraction of the total crop harvested in a given month

postharvest soil cover factor[7] = Adjusts the windblown emissions based on postharvest soil cover

postharvest soil cover = The fraction of land covered after harvest when viewed directly from above

replant-to-different-crop factor = Adjusts windblown emissions for harvested acreages that are quickly replanted to a different crop

Revised Wind Erosion Equation (RWEQ)[7] = Model that is intermediate in complexity between the WEQ and the WEPS. Several components from the RWEQ have been incorporated by ARB staff into this methodology revision

soil cover deterioration = Reduction in postharvest soil cover due to the effects of weather, sunlight, insects, microbes, etc.

soil loss ratio (SLR) = The ratio of the soil loss for a soil of a given cover divided by the soil loss from bare soil

soil classes (types) = Classifications used by soil scientists: Representative erodibilities have been measured, which allow soil maps to be used to estimate erodibilities for agricultural land

<u>*State Geographic Data Base*</u> (STATSGO)[10] = Database of soil data produced and maintained by the NRCS

Wind erosion equation (WEQ)[3,4,5] = Originally developed in the 1960s and 1970s to estimate wind erosion from agricultural lands. Modified in the 1970s by U.S. EPA to use for estimating PM emissions

Wind Erosion Prediction System (WEPS)[8] = Detailed simulation model currently in development. May be useful in future, especially for episodic modeling

ADDITIONAL CODES

SOURCECATEGORY GROWTH AND CONTROL CODES
110 Agricultural Production

SOURCE CATEGORY CODE POLLUTANT SPECIATION PROFILES
411 Windblown Agricultural Dust

SOURCE CATEGORY CODE REACTIVITY FACTORS
Not Applicable

DEVELOPED BY

Stephen R. Francis
July 1997

REFERENCES

(See the reference 2, below, for the complete reference list)

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14. California Irrigation Management Information System, CIMIS Weather Station Program (Contact: David Moellenberndt, Manager), Water Conservation Office, Department of Water Resources, Sacramento, California.

ATTACHMENT A
1993 AREA SOURCE EMISSIONS

ACTIVITY: NATURAL SOURCES
PROCESS: UNSPECIFIED PROCESSES
ENTRAINMENT: DUST
DIMN: WIND EROSION AGRICULTURAL LANDS NONPASTURE
CES: 83337
PROCESS RATE UNIT: ACRES

Air Basin Code	County Name	Emission Factor (tons/acre/yr)	Process Rate (acres)	PM Emissions (tons/year)
NCC	Monterey	0.020478	279,178.00	5,717.07
	San Benito	0.015936	50,009.00	796.96
	Santa Cruz	0.002485	14,873.00	36.97
SCC	San Luis Obispo	0.006876	109,694.00	754.20
	Santa Barbara	0.003190	80,732.00	257.56
	Ventura	0.018418	54,568.00	1,005.02
SED	Imperial	0.141666	490,409.00	69,474.43
SJV	Fresno	0.013761	864,164.00	11,891.35
	Kern	0.008662	408,313.48	3,536.73
	Kings	0.012856	473,817.00	6,091.62
	Madera	0.008032	141,617.00	1,137.47
	Merced	0.013659	364,804.00	4,982.86
	San Joaquin	0.003527	387,278.00	1,365.96
	Stanislaus	0.009052	229,805.00	2,080.26
	Tulare	0.004693	471,664.00	2,213.29
SV	Butte	0.001154	116,869.00	134.87
	Colusa	0.004702	229,747.00	1,080.31
	Glenn	0.004957	186,067.00	922.39
	Placer	0.002172	6,962.90	15.12
	Sacramento	0.002479	117,770.00	291.92
	Shasta	0.001065	29,750.00	31.69
	Solano	0.003751	152,945.60	573.77
	Sutter	0.004151	191,965.00	796.81
	Tehama	0.003551	23,777.00	84.44
	Yolo	0.007911	320,072.00	2,532.08
	Yuba	0.001315	41,526.00	54.60

Fraction of PM10 (FRPM10): 0.50
(PM10 Emissions = PM x FRPM10)

ATTACHMENT B
1993 AREA SOURCE EMISSIONS

ACTIVITY: NATURAL SOURCES
PROCESS: UNSPECIFIED PROCESSES
ENTRAINMENT: DUST
DIMN: WIND EROSION AGRICULTURAL LANDS PASTURE

CES: 84863

PROCESS RATE UNIT: ACRES

Air Basin Code	County Name	Emission Factor (tons/acre/yr)	Process Rate (acres)	PM Emissions (tons/year)
NCC	Monterey	0.00110562	1,108,000	1,225.03
	San Benito	0.00109336	512,000	559.80
	Santa Cruz	0.00016050	8,000	1.28
SCC	Santa Barbara	0.00021801	602,913	131.44
	San Luis Obispo	0.00046964	1,102,500	517.78
	Ventura	0.00050356	210,918	106.21
SED	Imperial	0.00867346	158,449	1,374.30
SJV	Fresno	0.00149089	907,300	1,352.69
	Kern	0.00082834	1,527,603	1,265.37
	Kings	0.00146875	142,777	209.70
	Madera	0.00116178	421,000	489.11
	Merced	0.00155578	642,700	999.90
	San Joaquin	0.00052280	167,700	87.67
	Stanislaus	0.00107875	434,300	468.50
	Tulare	0.00063424	713,400	452.47
SV	Butte	0.00014292	288,500	41.23
	Colusa	0.00046444	181,900	84.48
	Glenn	0.00048846	256,575	125.33
	Placer	0.00026499	65,656	17.40
	Sacramento	0.00019538	118,000	23.05
	Shasta	0.00034146	459,000	156.73
	Solano	0.00039453	131,360	51.83
	Sutter	0.00037084	71,500	26.51
	Tehama	0.00035146	955,350	335.76
	Yolo	0.00061919	136,870	84.75
	Yuba	0.00023892	207,600	49.60

Fraction of PM10 (FRPM10): 0.50
(PM10 Emissions = PM x FRPM10)