STATE OF CALIFORNIA
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD

# SECTION 7.11
# SUPPLEMENTAL DOCUMENTATION FOR WINDBLOWN DUST - AGRICULTURAL LANDS

April 1997

Technical Support Division
Emission Inventory Branch
Emission Inventory Analysis Section

## SECTION 7.11

## WINDBLOWN DUST - AGRICULTURAL LANDS

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DEVELOPED BY:

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WEQMTH97.WP

## I. ASSIGNMENTS OF CATEGORIZATION

EMISSION INVENTORY SOURCE CATEGORY:
MISCELLANEOUS PROCESSES

SOURCE CATEGORY CODES AND DESCRIPTION:
83337 WINDBLOWN DUST . AGRICULTURAL LANDS (NONPASTURE).
84863 WINDBLOWN DUST . PASTURE LANDS.

EMISSION INVENTORY CODES AND DESCRIPTION:
650-650-5400-0000 WINDBLOWN DUST . AGRICULTURAL LANDS.
650-651-5400-0000 WINDBLOWN DUST . PASTURE LANDS.

SOURCE CATEGORY GROWTH AND CONTROL CODES:
110 AGRICULTURAL PRODUCTION

SOURCE CATEGORY CODE POLLUTANT SPECIATION PROFILES
411 WINDBLOWN AGRICULTURAL DUST

SOURCE CATEGORY CODE REACTIVITY FACTORS:
NOT APPLICABLE

## II. METHOD DESCRIPTION

### A. Chronology of Inventory Development

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 inventory produced from the original 1989 ARB methodology [1]. In this document, the 1989 methodology using 1987 crop acreages, and the resultant inventory, will be referred to as "inventory 1991" (the year of its production), or for brevity as Inv91. Comparisons will be made between Inv91, and the succeeding inventories: Inv95, Inv96, as well as the current Inv97. No formal revisions to the Inv91 methodology were set down at the time of the production of Inv95 and Inv96. However, discussions of Inv95 and Inv96 have been included in this methodology (Inv97) to illustrate the effect on the emissions estimate of each stage of these methodology changes:

*Inv91* - The 1989 methodology using 1987 crop acreages.

*Inv95* - The 1989 methodology using 1993 crop acreages and adjusted erodibility.

*Inv96* - The adjustments in Inv95 along with annual and monthly climatic factor adjustments.

*Inv97* - The adjustments in Inv95 and Inv96 with the addition of adjustments based on the effects of: Crop canopy cover, postharvest soil cover, postharvest replanting to a different crop, irrigation, bare field areas, and field borders. This is the current inventory.

**B. Method Applicability**

The acreages of agricultural crops used in Inv95, Inv96 and Inv97 are from the 1993 acreage data supplied by county Agricultural Commissioners to the California Department of Food and Agriculture (CDFA). The CDFA then summarized the data and provided the results to ARB staff [2].

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. The major exceptions are orchard and vineyard acreages. These have been excluded, in part because their soil is protected by canopy cover most of the year, and in part because the methodologies for determining the emissions have not been developed. Newly planted orchards and vineyards, as well as orchards and vineyards that have not leafed out, or that have no ground cover between the rows, could contribute significant windblown emissions. Even though the period of the year when the mature vineyards and orchards lack foliage is during the cooler, wetter, more stagnant periods in California; nevertheless, these excluded categories should still be examined for inclusion into the inventory in the future.

The Inv97 methodology is intended to be applied statewide. Attachments A and B, at the back of this methodology, list the 26 counties to which the Inv97 methodology has been systematically applied. Those 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.

The SJV Air Basin is the largest agricultural region in California. It will be used in this documentation as an example for basin-wide calculations, and explanatory charts, graphs, maps and tables. Cotton is the largest nonpasture crop in the SJV, and cotton growing in Fresno County will be used as an example for single crop/county calculations.

### C. 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 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 [3][4].

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)[5]. The U.S. EPA methodology was then adapted by ARB staff for Inv91 [1].

In the time since Inv91 was produced, the USDA-ARS has undertaken 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)[6] and the Wind Erosion Prediction System (WEPS)[7] models. To date, these models have not proven feasible for use by the ARB, although certain portions of these models 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.

### D. ARB's Implementation of the WEQ

#### 1. The Need to Modify the U.S. EPA's WEQ

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 Inv97 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 EPA-450/3-74-037 [5] 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 Inv97 without modification. There has been concern that the "A" factor doesn't take into account finite dust loading. The RWEQ [6] and WEPS [7] models are attempting to address that concern.

The soil erodibility ("I") was initially established 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.

"I" is a function of soil particle diameter, which has been estimated for various soil textural classes. The soil textural classes were determined by ARB staff from University of California soil maps [8]. For most of the SJV Air Basin counties an additional level of detail was achieved, by using the United States Department of Agriculture - Natural Resources Conservation Service's (NRCS) State Geographic Data Base (STATSGO) of soil data [9]. Table A-1 of the above U.S. EPA methodology allows the estimation of erodibility from predominant soil textural classes. This resource was utilized by ARB staff to determine "I" from the above soil texture data. In addition, the USDA-ARS recommended an adjustment for changes to long term erodibility due to irrigation [10]. 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 Inv96 and Inv97 revisions, ARB staff improved the input data, as well as the methods associated with developing the county wide averaged annual climatic factor. Monthly climatic factors can be obtained by slightly modifying the annual "C" factor calculation method. The aforementioned U.S. EPA methodology contained a recommended method for creating the monthly climatic factors. However, ARB staff found the results of the method to be unsatisfactory for use in California, and created a modified method (see analysis below).

Figure A-5 in the U.S. EPA methodology [5] 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 Inv97 (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 Factors Used in the WEQ**

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 that specific 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, first included in Inv96, and carried over into Inv97.

**a. The Annual Climatic "C" Factor for the WEQ**

**(1) Calculation of the Annual "C" Factor (with modifications as noted for Inv96 and Inv97 by ARB staff)**

Page 157 of EPA-450/3-74-037 [5] includes a definition of the "C" factor which agrees with the following method utilized by the NRCS [11]:

The monthly Precipitation Effectiveness (PE) is calculated as follows:

**Equation 2:** Monthly $PE = 115(P/(T-10))^{1.1111}$

where: P = average monthly precipitation where all values less than 0.5 inches have been assigned the value of 0.5 inches (this prevents the "C" factor from becoming excessively large for extremely dry climates)

T = average monthly temperature (if the value T-10 is less than 18.4°F, than T-10 is adjusted to 18.4°F (this is an empirically derived correction))

The next step is to sum the monthly PE values for all of the months in the year.

Annual PE = $\sum$ monthly PE values for year

Next the wind speed is corrected to standard height above ground:

Mean Annual Wind Speed at Height $Z_b$ = $WS_b$ mph

Mean Annual Wind Speed Corrected to 10 meters = WS

**Equation 3:** $WS = WS_b * (10\ \text{meters}/Z_b)^p$ mph

Use p=0.143 for flat terrain
Use p=0.40 for rough terrain

The "C" factor can then be calculated according to:

**Equation 4:** $C = 0.3448(WS^3/PE^2)$

where: WS = mean annual wind speed, in mph, 10 meters above the ground

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

For Inv96 and Inv97, the individual site "C" factors were input into tables along with their longitude/latitude coordinates. These tables were then used as inputs to the Surfer software kriging algorithm [12]. This produced contour maps that were then grid counted to determine the weighted average "C" factors for the agricultural production land in each county. The county weighted average annual "C" factor was then used in the WEQ as modified by ARB staff to estimate annual emissions for the 26 counties included in the Inv97 revision. For all other counties (for Inv97), either one of the above county "C" factors were used (if the county had similar climatic conditions) or else the NRCS contour plot map derived values were used. These methods are discussed in more detail below.

**(2) Sources of "C" Factor Data**

NRCS staff in Davis, California, and the staff of the USDA-ARS in Manhattan, Kansas, produced California statewide and county "C" factor contour maps [13]. The data used for producing these contour maps came from a number of sources, including: 1. "California Surface Wind Climatology" [14]; 2. "Wind in California," [15]; 3. National Oceanic and Atmospheric Administration (NOAA) weather stations [16]; 4. California Irrigation Management Information System (CIMIS) Weather Station Program weather stations that had several years of data at the time of the map revision [17].

For calculations of the "C" factor, it is best to use as much data as possible from as many sites as possible, over as long of a time period as possible, provided that there is not a great deal of unexplainable variation in the data. The NRCS "C" factor calculation methodology recommends using monthly normals of precipitation and temperature that span over 30 years. However, NRCS staff has indicated that they try to include sites with at least 5 years of data [18].

For Inv91 and Inv95, the NRCS contour maps were used. Starting with Inv96, for counties within the SJV, SV, NCC, and SCC air basins, along with Imperial County, the ARB staff did not use the NRCS maps.

The data relied on by ARB staff for the Inv96 and subsequent Inv97 revisions, both to calculate the annual "C" factors and for producing the temporal profiles, came from the CIMIS network. The CIMIS network was begun as a project at the University of California at Davis in the early 1980s, and ultimately proved so successful that it was taken over by the State of California Department of Water Resources (DWR) in 1985. There are nearly a hundred CIMIS weather sites located throughout California. As can be inferred from the name, the CIMIS system was designed specifically for agriculture, as a mechanism to assist in the optimization of irrigation management. Through the use of climatic data from the monitoring sites, the farmer is able to predict when irrigation is needed, and to more efficiently manage water resources.

For Inv96 and Inv97, staff only included the CIMIS data. However, in the future additional weather monitoring stations, such as NOAA data sites, should be added as analysis confirms that they adequately characterize the climate of the local agricultural areas. Sites should be included if their climatic data are geographically and temporally consistent.

**(3) Decision to Use CIMIS Climatic Data**

The decision to use the CIMIS data instead of the NRCS maps was primarily based on the following 6 reasons: **1.** Conversations with NRCS staff in which they indicated their agreement with the use of the updated CIMIS data to improve the "C" factors [18]; **2.** The CIMIS monitoring sites were specifically located in agricultural areas rather than at airports or in cities, as was often the case for non-CIMIS monitors used to derive data for the NRCS maps [18][19]; **3.** More CIMIS sites with sufficient years of data had become available for Inv96 than had been available to the NRCS staff and the staff of the USDA-ARS [18]; **4.** The CIMIS sites were set up in a standard fashion, were well maintained, and used aggregated minute wind speed data [18][19]. In contrast, the set up of NOAA sites varied by location, changed over time, and used unknown wind aggregations [20]; **5.** For the SJV, there was agreement between the CIMIS sites and one of the NOAA sites, less agreement for a second site, while the Bakersfield site was very divergent. This was the case even though the three NOAA sites were much closer to each other in their height above the ground than they were to the CIMIS stations, and even though all of the CIMIS sites located near NOAA sites agreed with the NOAA sites with respect to temperature and precipitation. NRCS staff noted that the NRCS map referred to old data for the Bakersfield site, and that it was not surprising that the CIMIS data yielded "C" factors so much lower, since the NOAA Bakersfield data may have represented an unusually windy period [18]; **6.** Using the CIMIS site data yielded "C" factors and resultant emissions more in line with the expected results [21][22][23].

The height of the anemometer above the ground relates to several of the above reasons. The "C" factor equation as provided to the ARB by NRCS staff calls for correcting the wind data to a height of 10 meters. The question is whether the 2-meter elevation of the CIMIS sites makes them less valid than the NOAA sites, which are at higher elevations above the ground, and often are closer to the prescribed 10 meters. At this point, ARB staff cannot provide a conclusive answer to that question. The CIMIS sites are more susceptible to the effects of ground roughness. However, it is not clear that the wind speeds aloft provide a better determinant than ground speeds that incorporate the surface effects.

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The NOAA sites, as well as other weather monitoring sites outside the CIMIS system, need to be further analyzed by ARB staff for their appropriateness. Until this analysis is completed, staff recommends using only the CIMIS data for the "C" factor calculations.

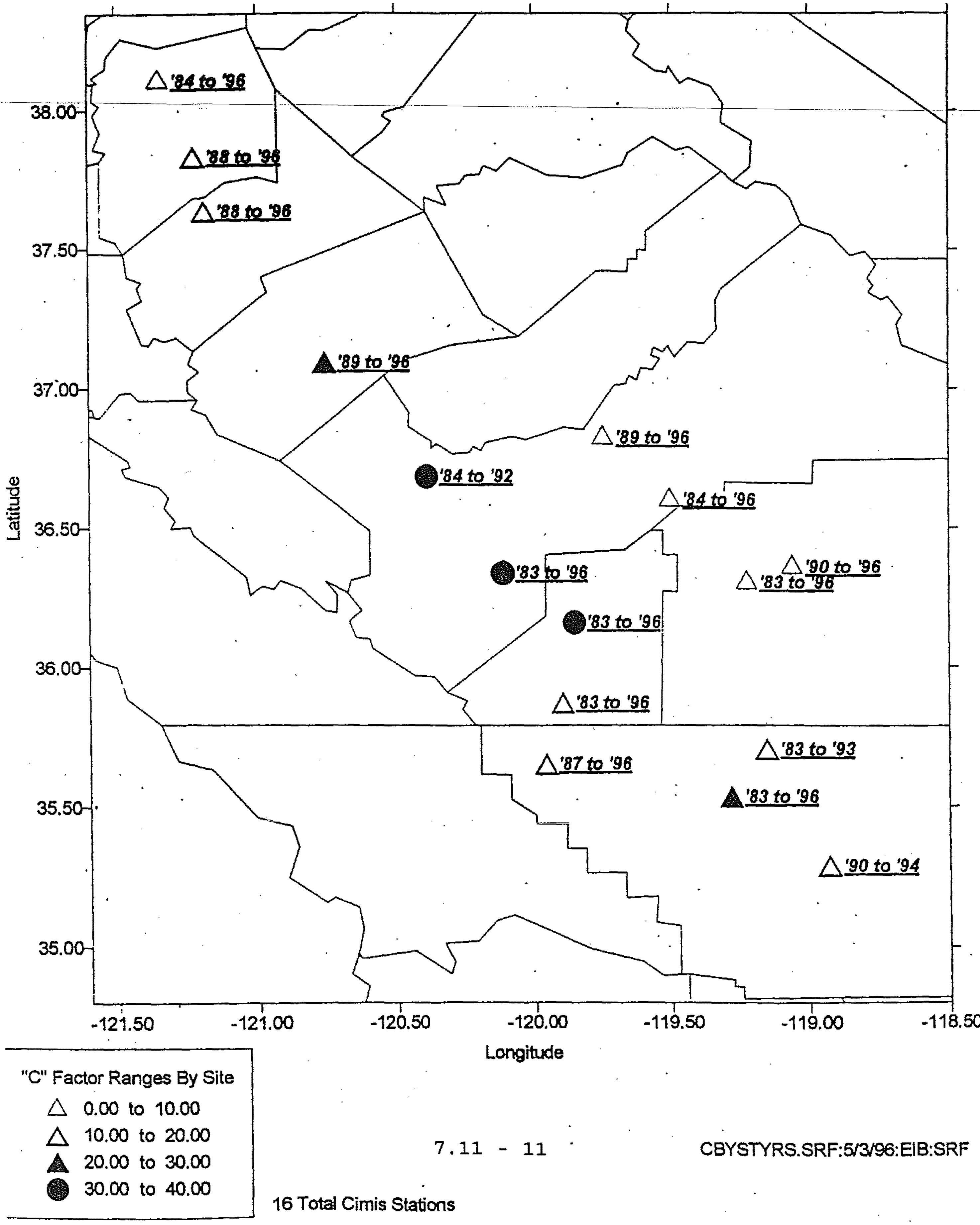
**(4) Quality Control of 1983 Through 1996 CIMIS Data**

The CIMIS data were downloaded by ARB staff, from the CIMIS computer located at the DWR in Sacramento. These data included the monthly average temperature and wind speed, as well as the monthly rainfall totals. The first data available were from the year 1983, and the last data included in the analysis were from September 1996. The map in Figure 1 shows the CIMIS weather station locations within the SJV Air Basin, as well as the time periods that weather data were available. Not all weather stations were represented by data during all time periods. Many weather stations were added at various times between 1983 and the present, and some weather stations were closed. However, the weather data were collected year round in all locations.

ARB staff checked through the data for unusual data points by grouping the data temporally and geographically. Obvious errors were omitted from the data files. For example, data from two sites in the SJV Air Basin were eliminated entirely due to factors that affected one or more climatic input variables during all time periods.

# Figure 1

## CIMIS Weather Stations and Years of Operation in SJV Air Basin




16 Total Cimis Stations



CBYSTYRS.SRF:5/3/96:EIB:SRF

### (5) Producing County Average Data From "C" Factor Contour Maps

#### (a) Production of the 1983 Through 1996 CIMIS Data Derived "C" Factor Contour Map

The contour map of the SJV Air Basin, shown in Figure 2, was produced by analyzing the CIMIS weather data derived "C" factors using the Surfer 3-dimensional analysis software [12]. Surfer calculates a surface from the longitude, latitude, and "C" factor data, by creating a grid of points. The X-axis is longitude, the Y-axis is latitude, and the Z-axis is the "C" factor value. The Z-axis value at any given grid point is determined by a method called kriging which uses a weighted average technique that assigns more weight to points closest to a given grid point. While there are many possible methods of surface estimation, kriging has proven to be one of the best in many situations, and yielded good results in this instance.

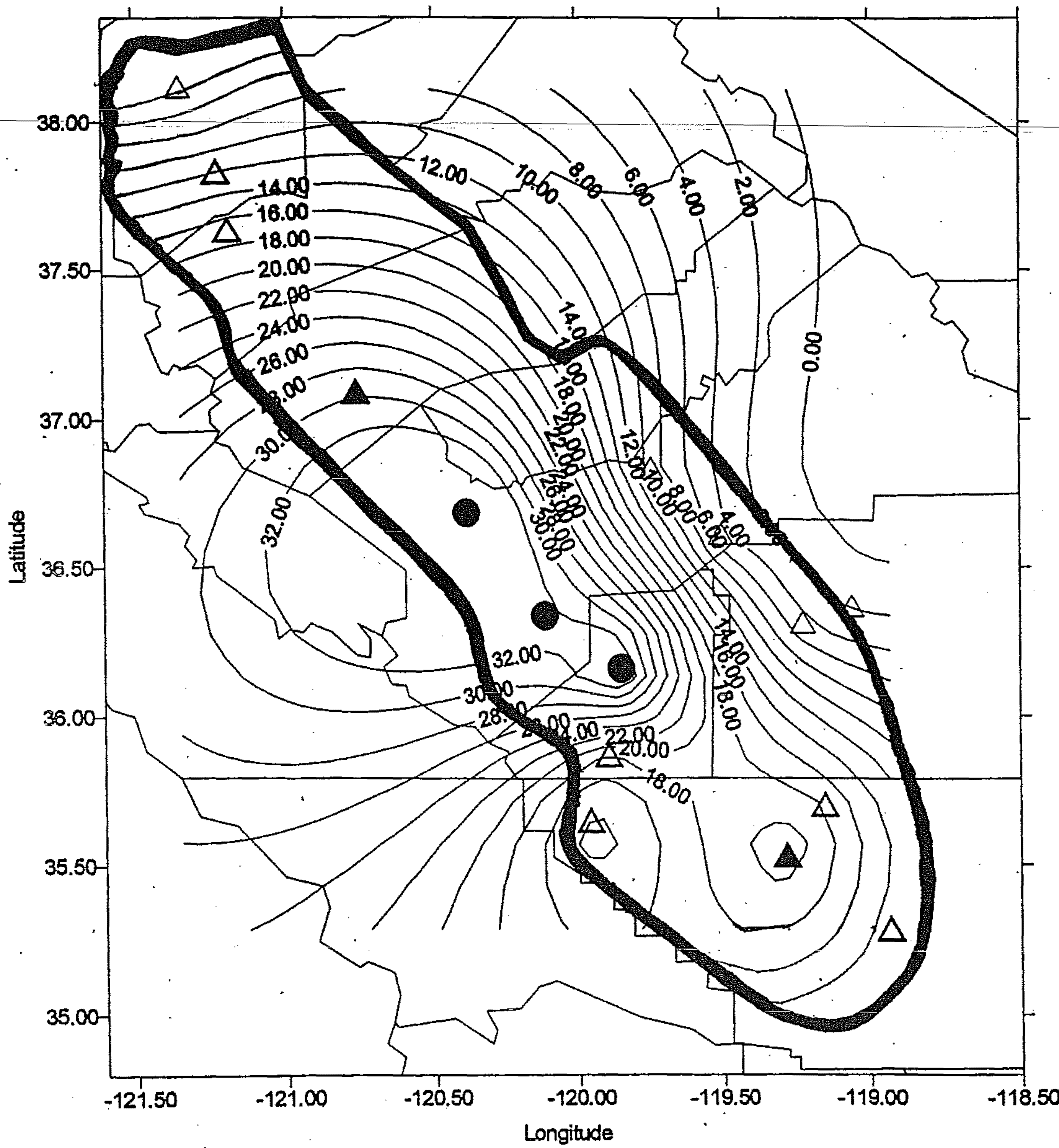
Surfer optimizes the surface to better reflect the valley's geographic influences, as well as maintaining trend continuity. The Surfer software then creates "C" factor contour lines on the surface, allowing the estimation of weighted average "C" factors for geographic areas.

#### (b) Use of Grid Counting Methodology for Calculation of the Annual "C" Factor

The "C" factors used in Inv91 and Inv95 were derived from the NRCS maps [13] by an unknown estimation method. These factors are depicted in the column labeled Inv91&95 in Table 1. Note that for maps "C" factors are shown as percents not fractions. For the Inv96 and Inv97 county emission estimates, staff applied the grid counting method to estimate areas in each county that were contained in each contour of the CIMIS data derived maps. The counts for each contour were multiplied by the average of the "C" factor values for the surrounding contour lines, and then summed, and then the total was divided by the sum of the counts to derive the weighted average "C" factor for the county. The Inv96&97 column in Table 1 was derived in this manner from Figure 2. Only the region on Figure 2 within the heavy dark line, which defined the boundary of the agricultural area in the SJV Air Basin, was grid counted. Although the contours in Figure 2 lose significance in areas distant from the weather station data points, in the agricultural region, bounded by the heavy dark line, they are well defined.

# Figure 2

Climatic factors were calculated from individual CIMIS Sites (not county averages)




C" Factor Ranges By Site

- △ 0.00 to 10.00
- △ 10.00 to 20.00
- ▲ 20.00 to 30.00
- ● 30.00 to 40.00

CFCBYSTC.SRF:5/2/96:EIB:SRF

16 Total Cimis Stations

**Table 1**

**Annual "C" Factors: Previous vs Revised**

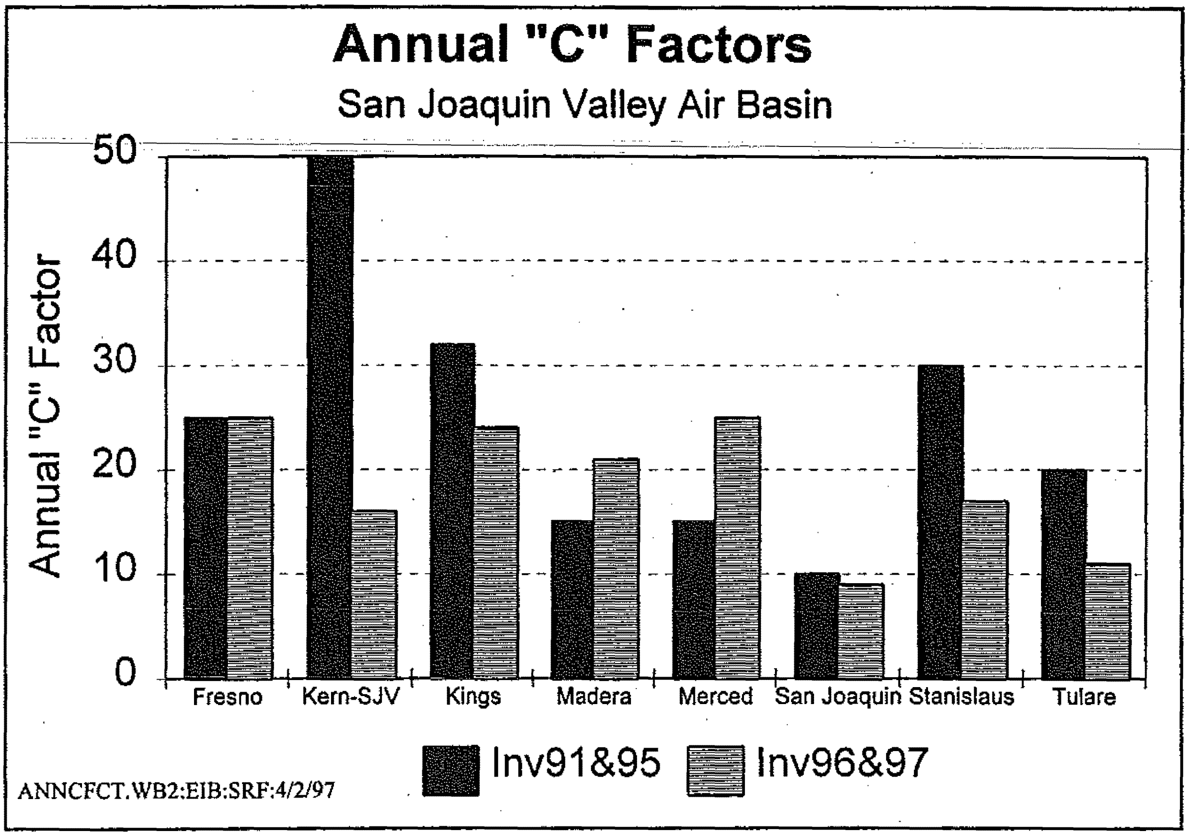
| SJV Air Basin County | C Factor (Inv91&95) | C Factor (Inv96&97) | C Factor Change | C Factor Percent Change |
|---|---|---|---|---|
| San Joaquin | 10 | 9 | -1 | -10 |
| Stanislaus | 30 | 17 | -13 | -43 |
| Merced | 15 | 25 | 10 | 67 |
| Madera | 15 | 21 | 6 | 40 |
| Fresno | 25 | 25 | 0 | 0 |
| Kings | 32 | 24 | -8 | -25 |
| Tulare | 20 | 11 | -9 | -45 |
| Kern | 50 | 16 | -34 | -68 |

The grid counting for Inv96 and Inv97 was performed manually, which limited the extent to which the methodology could be used. In the future, programming will probably be used to estimate the areas within the contours, once certain data mapping files are created. At that time, the contour area/grid counting calculation method for determining county averages would be extended to counties statewide. The contour area/grid counting method could also be used to estimate the monthly "C" factor profiles for the counties, which are instead estimated in this inventory revision using county average climatic data.

**(c) Effects of Annual "C" Factor Changes**

Table 1 and Figure 3 show significant differences in "C" factors between the Inv96&97 grid-counted CIMIS-derived "C" factors and the NRCS map derived "C" factors from Inv91&95. The most notable example is Kern County, which was affected in the Inv91&95 versions by unrealistically high average wind speeds for Bakersfield. Based on conversations with the NRCS personnel that helped to establish the number, there is concern that the Kern number was derived from old data from a historically windy period [18]. The new CIMIS-based number, used in Inv96&97 is much more consistent with the surrounding weather station data. The subtracted differences in Table 1 are more meaningful than the percentage differences, since the percentage difference between two small "C" factors could be large, but the actual difference in resultant emissions would be small.

Figure 3




The changes in "C" factors between Inv91&95 and Inv96&97 for counties outside of the SJV Air Basin were similar to those found in the SJV. Some had larger "C" factors using the Inv96&97 methodology, and some smaller.

**b. The Monthly "C" Factor for the WEQ**

There are several ways to create a climate-based monthly profile for the WEQ. All of the climate-based approaches discussed here either rely solely on adjustments to the "C" factor in the WEQ, or establish a separate factor not included in the standard WEQ, such as is done for the erosive wind energy (EWE) approach.

Because the WEQ 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 "C" factors were normalized to a total of 1.0 for the year. Next, each month's normalized monthly "C" factor was multiplied by the annual emissions. This helped to limit the effect of extreme monthly values on the annual emissions estimate.

Particulate emission source apportionment estimates have been derived from the analysis of ambient air samples in the SJV Air Basin [22][23][24][25]. Based on these estimates, the expected windblown agricultural emissions profile should exhibit negligible emissions in the cool, wet, stagnant periods of winter. Higher emissions should be observed in the warm, dry, windy periods of spring, summer and fall. However, the addition of nonclimate-based profiles, such as the crop canopy cover, irrigation, postharvest soil cover and replanting can all adjust the curve. A strong peak may then be exhibited in the spring, when crop canopies for some major crops, such as cotton, are immature. These complete profiles, with both climate based and nonclimate-based components, are compared to the apportionment profiles later, in Section VI of this document.

**(1) Calculation of the "C" Factor Monthly Profile by Viewing a "Month-as-a-Year" (Inv96 and Inv97)**

The U.S. EPA/NRCS methodology for calculating the annual "C" factor was described above in equations 2 through 4. When calculating the annual "C" factor, the monthly PE values are summed for all of the months in the year. However, to calculate the month-as-a-year "C" factor, ARB staff instead multiplied each month's PE by 12. Then each month's PE*12 was input into the "C" factor equation along with the mean monthly wind speed for that same month, the result was a "C" factor which would apply if the climate for that month were instead the year round climate. By then summing all of the monthly "C" factors for the year and then dividing each individual month by the sum, the month-as-a-year "C" factor was normalized to 1.0. These normalized monthly numbers provide the climate based temporal profile. They are multiplied by the annual WEQ results to produce monthly emissions. The Inv97 revision further modifies the temporal profile calculation, by also modifying nonclimate-based WEQ factors, but the profiles displayed in this section reflect only the climate-based calculations.

The pronounced curves listed as Inv96&97 in figures 4 through 11, are the month-as-a-year climate-based profiles. There are 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.

Figure 4: Fresno County

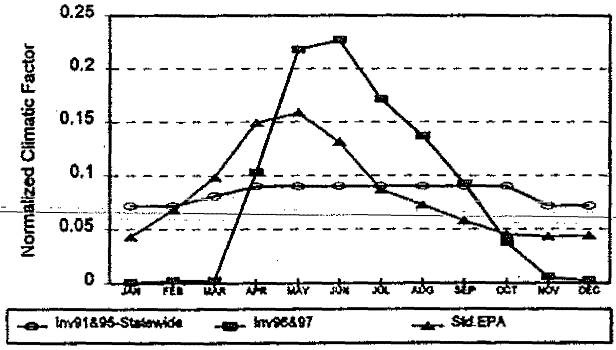



Figure 5: Kern County

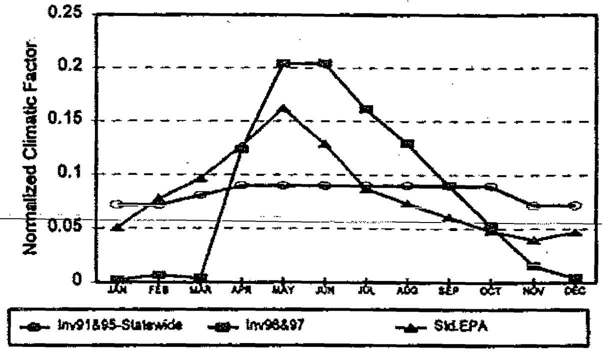



Figure 6: Kings County

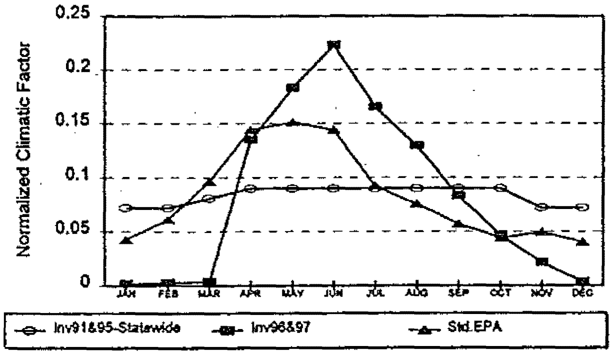



Figure 7: Madera County

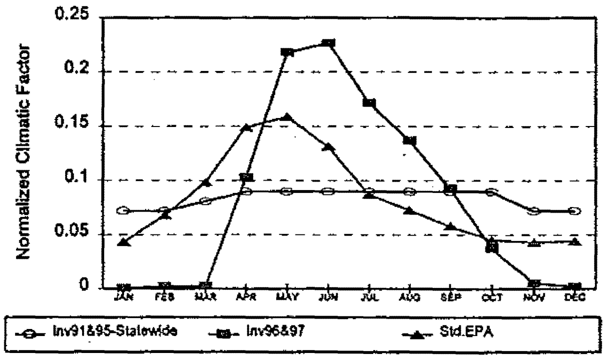



Figure 8: Merced County

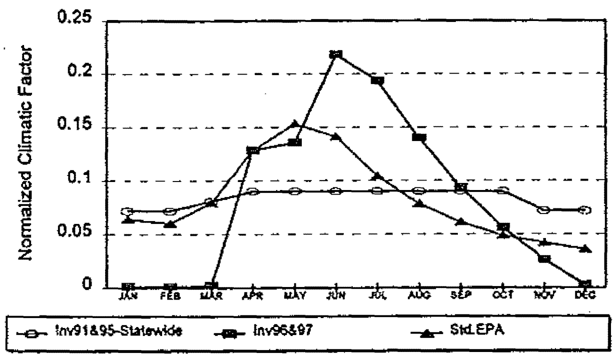



Figure 9: San Joaquin County

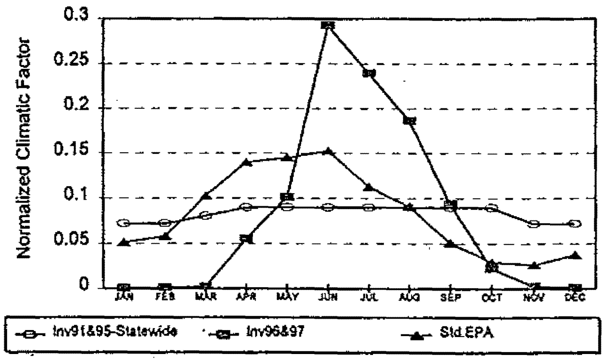



Figure 10: Stanislaus County

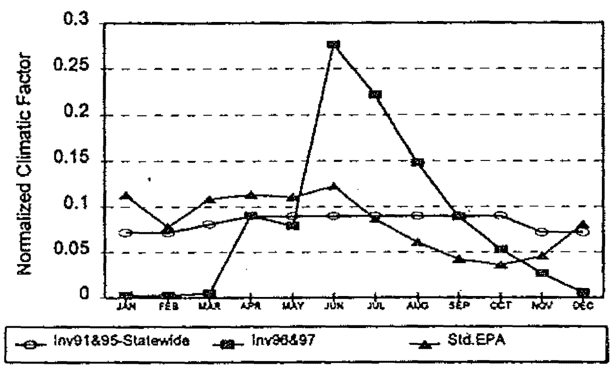
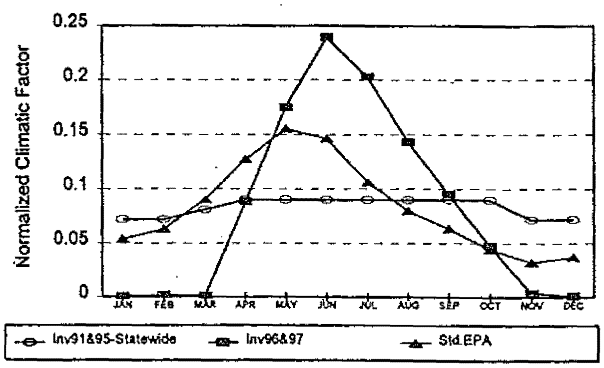



Figure 11: Tulare County




(7CRPMYTGA.WB1:EIB:SRF:4/3/97)

**(2) Standard Method of U.S. EPA: Substitution of the Monthly Mean Wind Velocity for the Annual Mean Wind Velocity in the Climatic Factor Equation (methodology not used in ARB inventory)**

This method is recommended in the U.S. EPA methodology (page 157 of EPA-450/3-74-037) [5]. The only difference between this method and the calculation of the annual "C" factor is that the mean monthly wind speed is substituted for the mean annual wind speed.

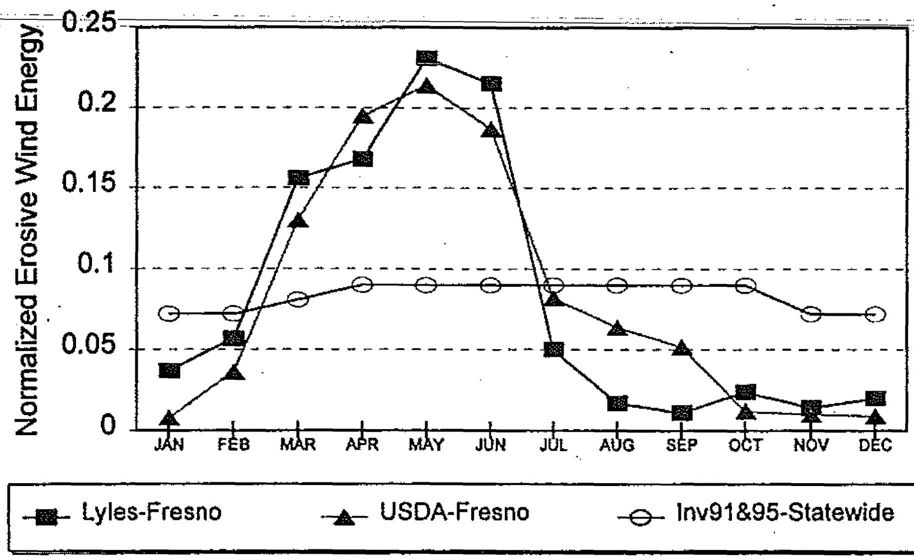
Figures 4 through 11 contrast the profiles produced by the month-as-a-year method, discussed in the previous section, and the monthly mean wind speed substitution method included in the U.S. EPA's methodology [5]. As can be seen in these figures, the U.S. EPA method (labeled Std.EPA) yields gentler profiles. The Std.EPA profiles are shifted into the cooler and wetter months from the Inv96&97 profiles. Therefore, the Inv96&97 month-as-a-year method provides a more realistic picture of the windblown dust temporal profile. The improvements arising from the use of the month-as-a-year method are due to the fact that it includes temperature and precipitation inputs, instead of just wind.

**(3) Multiply the Results of the WEQ by the Fraction of Annual Erosive Wind Energy for Each Month (method used by ARB for Inv91 and Inv95, but superseded by month-as-a-year methodology for Inv96 and Inv97)**

According to Leon Lyles [26]: "Erosive wind energy is defined by months as the sum of the cube of wind speeds between 8 and 20 meters per second (18-45 miles/hour) in 1-meter-per-second (2.2-mile/hour) increments." Leon Lyles [26] and the USDA-ARS [27] independently calculated monthly EWE distributions for several sites, including Fresno in the SJV. The Inv91 and Inv95 ARB methodology used Leon Lyles' calculations of EWE to establish the normalized temporal profile for windblown agricultural PM emissions [1]. The three normalized distributions are shown on Figure 12.

Figure 12

## Erosive Wind Energy Profiles




(7CRPEWET.WB1:EIB:SRF:3/31/97)

The Lyles and USDA-ARS EWE methods exhibit strong distributions that are shifted somewhat earlier in the year than expected. The EWE distributions are not as close to the expected curve as the month-as-a-year distribution labeled Inv96&97 in Figure 4, but are still more pronounced than the U.S. EPA's substitution of mean monthly wind speed for mean annual wind speed (labeled Std.EPA in Figure 4). The EWE method is based on wind speed, and does not take into account precipitation and temperature.

The ARB methodology used in Inv91 and Inv95 (labeled "Inv91&95-Statewide" on Figures 4 through 11) attempted to establish one EWE distribution statewide. This resulted in a nearly flat distribution, with very little seasonality in comparison to any of the other discussed methods. Because of the lack of seasonality, the Inv91&95-Statewide profile was replaced in Inv96&97.

**(4) County-wide Average Climatic Data Derived Temporal Profile Versus Contour Surface Area Derived Temporal Profile**

The month-as-a-year "C" factor temporal profiles, labeled Inv96&97 in figures 4 through 11, rely on county-wide averaged weather station data. By contrast, the contour surface area method was used to determine the above annual "C" factors, and ideally should also be used to determine the monthly profile. However, for the Inv96 and Inv97 revisions, the necessary map data files were not available. Therefore, the county-wide average climatic data were used to calculate one "C" factor for each month for each county.

In the future, the map data files and programs can be developed, to allow the calculation of the contour surface area derived "C" factor profiles. It is unclear how much effect this will have on the profiles, but experience has shown that the effect on the profile is somewhat masked by normalization. This is because the extreme weather data sites tend to skew data for many months in the same direction. This results in overall increases or decreases for groups of months, but smaller differences between months.

**3. Nonclimate-Based Changes to the WEQ**

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 analysis (Inv91 and Inv95). ARB staff has attempted to correct many of these limitations in the WEQ. Many of the corrections are temporally based, and rely upon the establishment of accurate crop calendars to reflect field conditions throughout the year.

**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.

Agricultural experts from production agriculture [28][29][30], academia [31][32], and University of California Cooperative Extension [33], local air pollution control districts [34], Bureau of Reclamation [35], as well as many documents produced by University of California Cooperative Extension [36,37,38,39,40,41,42,43], academia [44], government [45], private consultants [46][47], and others [48] were consulted to establish the planting and harvesting dates.

Each planting month for a given crop was viewed by ARB staff as a separate cohort (maturation class). In order to simplify calculations, it was usually assumed that all planting and harvesting took place at mid-month. 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 it. The acreage that is not assigned to the growing canopy fraction is the harvested acreage, and will be affected by postharvest soil cover, and by replanting to a different crop.

The use of cohort-plant/harvest date pairs greatly simplified the analysis, as did the assumption of mid-month planting. 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 adjustments discussed below were assigned to individual cohort-plant/harvest date pairs, except for the long-term erodibility adjustment (cloddiness), which had the same value assigned to all cohorts for the entire year.

**b. Adjusting the Soil Erodibility Based on the Long-term Effects of Irrigation: Cloddiness of Soil**

USDA-ARS staff provided the ARB with methodology and data (Table 3) for adjusting the long-term erodibility, based upon differences between irrigated and nonirrigated soils [10]. This adjustment takes into account changes in cloddiness of the soil. Table 3 lists suggested irrigated erodibility values for assigned nonirrigated erodibility ("I") values. The change in "I" varies based on soil type, but, for the ARB inventory, often results in a reduction in the tons/acre value for irrigated crops of about one-third.

Using simple interpolation, irrigated erodibilities can be assigned for nonirrigated erodibilities that fall between those shown in the table. The irrigated erodibilities are used in place of the nonirrigated erodibilities for all irrigated crops, with the exception of field border regions. ARB staff has added a correction to the WEQ to address field borders, and has assumed that border regions are nonirrigated.

**Table 3**
**Long-term Effect of Irrigation on Erodibility: Cloddiness [10]**

| Nonirrigated I | Irrigated I |
|---|---|
| 310 | 310 |
| 250 | 250 |
| 220 | 220 |
| 180 | 160 |
| 160 | 134 |
| 134 | 104 |
| 86 | 56 |
| 56 | 38 |
| 48 | 21 |
| 38 | 21 |
| 21 | 12 |
| 12 | 5 |

**c. Adding a Short-term Irrigation Factor for Wetness to the WEQ**

The USDA-ARS also provided the ARB with methodology for adjusting short-term erodibility based upon differences in surface soil wetness due to irrigation [10]. This adjustment takes into account the overall soil texture, number of irrigation events, and fraction of wet days during the time period (one month for the purposes of the ARB inventory).

The irrigation events are then used to calculate irrigation factors according to the following equation:

**Equation 5:** IrrFctr = (#daysInMonth-wetDaysInMo)/(#daysInMo)

**Equation 6:** wetDaysInMo = (#ofIrrig)*textureWetnessFctr

textureWetnessFctr => 1=coarse, 2=medium, 3=fine

(all 26 counties' typical soil qualified as medium [49])

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Both a 0.5 inch sprinkle and a 6-inch furrow irrigation count as one irrigation event. Irrigation events for multi-day pre-irrigation to fill the water table require special treatment. ARB staff estimated the number of events (#ofIrrig) to assign for pre-irrigation events, by dividing the number of days of pre-irrigation by 2, to a minimum of 1.0 irrigation events. Dividing by 2 is a rough way of accounting for the clustering of multi-day irrigation events. Future studies of pre-irrigation practices might improve this methodology.

Agricultural experts from production agriculture [28][30], academia [31][32], local air pollution control districts [34], Bureau of Reclamation [35], as well as many documents produced by University of California Cooperative Extension [36,37,38,39,40,41,42,43], USDA [6][50], DWR [45][51][52], academia [44][53], private consultants [46][47], and others [48][54] were consulted to establish the irrigation profiles.

For irrigation to have a major influence on windblown emissions, there must be frequent enough irrigations to maintain soil surface wetness for a significant number of days during the month. For most crops included in the windblown agricultural emissions inventory, there are relatively few irrigations per month. 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 much lower.

The Imperial County Air Pollution Control District staff used a different approach to account for irrigation effects. They incorporated irrigation effects into the climatic or "C" factor, by viewing irrigation as equivalent to rainfall [54]. The problem with that method, is that rainfall events and irrigation events are climatically and temporally very different. The "C" factor explicitly includes temperature and wind effects as well as water. The "C" factor also implicitly includes other climatic effects not accounted for by simple irrigation reporting. This is due to the fact that Garden City, Kansas is given the "C" factor value of 1.0, and all other sites vary from there. Rainfall typically occurs during periods of higher humidity and cloud cover (lower incident solar radiation) that extend the effects of the precipitation event. The rainfall will also tend to land on ground that has more retained moisture, whereas irrigation is often performed on soil initially depleted of moisture. Moisture depleted soil is likely to rapidly absorb the water to below surface level, dissipating the effect of the water.

In addition, inches of irrigation water will usually be deposited more rapidly than equivalent amounts of rainfall. Because irrigation events tend to be relatively large, inputting them as monthly totals in the "C" factor equation causes estimated emissions to be excessively depressed. This occurs because the "C" factor equation assumes that a standard precipitation pattern is experienced, which will have a standard effect, based upon a given amount of monthly precipitation. For all of the above reasons, the ARB staff has chosen to incorporate the separate irrigation factor, rather than attempt to incorporate irrigation as rainfall.

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

The "V'" vegetative soil cover factor for the WEQ is primarily based on the amount of postharvest vegetative mass left on the soil surface. Erosion data from harvested land with different masses of postharvest vegetative matter, with the other WEQ parameters known, were used to estimate the effects of varying the amount of postharvest vegetative cover on soil wind erosion. The results were then plotted in charts and included in the U.S. EPA agricultural windblown dust methodology [5]. From these charts, estimates of "V'" can be made.

There are many problems with this approach. 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. In Inv91 and Inv95 the "V'" factor for alfalfa was set to zero, even though there was no postharvest cover estimated, and the WEQ emissions were zeroed out. Zeroing out emissions ignores variations in the emissions due to planting, canopy development, and harvest. There is also a large amount of acreage in California that is used for more than one crop per year. The trend of increasing land value in California, promises to push more and more acreage into high value crops cultivated year round [28][31][34]. There was no provision in the "V'" factor for estimating the effects on emissions of 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 [28][31][34]. The "V'" factor for the most part assumes that the postharvest debris remains undisturbed.

ARB staff replaced the "V'" factor in Inv97 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 [6]. 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. The ARB staff averaged the canopy cover on a weekly basis. The soil loss ratio due to canopy cover is calculated from the following equation:

**Equation 7:** $SLRcc = EXP(-0.201*(CanopyCoverPercent)^{0.7366})$

The weekly average SLRcc values are assigned, based upon planting and harvesting dates, to the months of the calendar year. The monthly averages are then calculated from the weekly averages that fall in a given month.

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). Canopy cover of 10 percent reduces emissions by 67 percent, 20 percent canopy cover reduces emissions by 84 percent, and 30 percent canopy cover reduces emissions by 91 percent. 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.

For most crops a single crop canopy cover development profile was used for each season. However, certain crops, such as cotton, had different canopy cover development profiles assigned for different planting months (cohorts) in the same season. Agricultural experts on cotton indicated that the second cohort of cotton planting catches up with the first month by midsummer. Therefore, there is no distinction between planting cohorts as to when cotton harvesting will take place [28][34].

Speeding up canopy growth for later plantings may, in some cases, significantly affect emissions. These types of adjustments should be made to the model as time allows and improved data are available. However, the major effect on emissions would be localized to the period of time when canopy is developing between zero and about 30 percent.

The effect on postharvest emissions of allowing a later cohort's crop canopy cover to catch up to the earlier cohort's cover will be small. This is because the harvesting dates were not established by determining how long a theoretical crop would take to mature, but by querying agricultural sources about the harvesting calendar. This included estimating what fraction of the acreage would be harvested in a given month irrespective of the planting cohorts.

For most California crops, senescence, resulting in lower canopy cover late in the growing season, is not a major factor. The RWEQ incorporates a senescence effect reducing a Texas cotton crop canopy cover from 100% down to 50% [6]. However, California cotton, which is irrigated, not dry farmed like Texas cotton, does not demonstrate this senescence, retaining nearly all of its canopy cover [28][34]. In addition, due to the exponential relationship defined earlier, the actual difference in emissions between 100% and 50% canopy cover is not very large.

Shortly before harvest, cotton is treated with a chemical that causes the foliage to drop off. For the purposes of this model the canopy cover following the leaf fall is considered to still be at 100%. Experience has shown that when the foliage falls off, it covers the ground as effectively as the canopy [28][34].

Agricultural experts from production agriculture [28][30], academia [31][32], Bureau of Reclamation [35], local air pollution control districts [34], as well as many documents produced by University of California Cooperative Extension [37,38,39,40,41], USDA-ARS [6], DWR [45][52], and academia or academic journals [44,55,56,57,58,59,60,61,62] were consulted to establish the crop canopy cover profiles.

**(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 [6]. The soil loss ratio (SLRcc) 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. The ARB staff implemented the postharvest soil cover by averaging on a weekly basis. The soil loss ratio due to postharvest soil cover is calculated from the following equation:

**Equation 8:** $SLRsc = EXP(-0.0438*(SoilCoverPercent))$

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 RWEQ manual also includes methods for estimating the effects of standing stubble and soil cover deterioration. However, ARB staff lacked sufficient data to estimate those effects. Therefore, only the effects of postharvest soil cover are included. As improved data on standing stubble, soil cover, and soil cover deterioration rates (due to decomposition as well as land preparation operations) become available, they can be added to the model.

Typical California crops will experience some reduction in soil cover due to the harvest operation. In addition, there may be foliage deterioration due to the elimination of irrigation or senescence. The combined reduction will vary by crop. For most crops the reduction will be on the order of 25% to 50% canopy cover, and will remain until the postharvest residue is disked under within a month or two after harvest [28][30][34]. The Inv97 methodology establishes two major postharvest through preplanting periods, defining two distinct soil cover regimes. The first is harvest to just prior to the disking-under operation. This will usually have a stable soil cover that remains the same for this one to two month period. In some cases the assigned soil cover in the ARB model may decrease during this period if evidence exists to support a declining factor. The second postharvest/preplant period follows the disking-under operation, and typically is assigned a very low cover of approximately 5%. Currently, this 5% cover remains until planting, with no assumed deterioration.

Agricultural experts from production agriculture [28][30], academia [31][32], Bureau of Reclamation [35], local air pollution control districts [34], as well as many documents produced by University of California Cooperative Extension [37,38,39,40,41,43], USDA-ARS [6], private consultants [46][47], and others [48] were consulted to establish the postharvest soil cover profiles.

**(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 on the same acreage during a given year is common in California, and is becoming ever more prevalent on the increasingly valuable SJV agricultural land. Multiple cropping 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 [28][30][31][34]. 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. This fraction varies from 0 to 1.0 depending on the crop.

There are many reasons for replanting quickly to a different crop. Overall, the longer the time period between harvesting and planting for a given crop, the more the likelihood that the land will be replanted to another crop. Crop rotation schemes will often require replanting to a different crop shortly after harvest. There are also crop combinations that occur frequently, such as small grain crops harvested in the early summer, followed by corn for silage. These types of compatible crop combinations tend to increase the amount of acreage that is quickly replanted to another crop.

For cotton, the largest nonpasture crop in the SJV, the fraction replanted to another crop is assumed to be one third of the harvested acreage [28][34]. Although this is a large reduction in acreage, because the reduction occurs during the less windy, cooler, and wetter periods, the reduction in emissions is smaller than might be expected. The actual reduction in emissions associated with replanting to a different crop depends both on the fraction assumed replanted, as well as the period of the year in which the replanted crop replaces otherwise fallow ground.

**e. Bare Soil Adjustment: Assumed to be 0.5% of Planted Acreage (0.05% for pasture)**

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. The ARB staff established an approximate fraction of cultivated acreage that would be barren, by visual inspection of farmland. The average across the observed nonpasture acreages was estimated to be less than 0.5% of the crop acreage. For pasture, the bare percentage was estimated as 0.05%. Additional investigations should further improve these estimates. The bare acreage percentage is subtracted from the overall acreage to avoid double counting.

The bare acreage adjustment results in emission increases disproportionate to the acreage involved. Often this adjustment will be on the order of 5% of the emissions attributable to the nonborder/nonbare acreage. The reason that this increase is so large is that the bare acreage does not have either a crop canopy or postharvest soil cover factor applied.

**f. Border Adjustment: Assumed to be 0.5% of Planted Acreage (0.0% for pasture)**

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. Based on observations in the field, ARB staff estimated that the average nonpasture border region exposed to wind erosion would be less than 0.5% of the crop acreage. Again, this 0.5% is subtracted from the overall acreage to avoid double counting. No border adjustment was applied to the pasture acreage, since pasture areas frequently lack a barren border.

As was the case with the bare areas, the border adjustment results in emission increases disproportionate to the acreage involved. Often this adjustment will be on the order of 7.5% of the emissions attributable to the nonborder/nonbare acreage. The calculated emissions increase will typically be even larger than that attributable to the bare areas. This occurs because the border region is assumed to be nonirrigated. Therefore, no irrigation factor (wetness), and no long-term irrigation adjustment to erodibility (cloddiness) are applied. In addition, the border areas do not have either a crop canopy or postharvest soil cover factor applied. It might be argued that the unsheltered width for the border region should be modified. However, since the border surrounds the field on all sides, using the same unsheltered width as the rest of the field is adequate.

**E. 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 Inv97 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 retained factors from the Inv95 methodology (Inv91 methodology with 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 changes, they 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. The units are in tons per acre per year.

## III. TEMPORAL INFORMATION

For Inv91 and Inv95 the temporal profile was based on an estimated statewide erosive wind energy profile. The profile, implemented in Inv96 included wind, precipitation and temperature climatic effects. The Inv96 adjustments were retained in Inv97 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 Inv97. The profile produced for Inv97 is no longer a separate profile applied to annual emissions, as was the case for Inv91 through Inv96, 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 4 below. The final pasture temporal profiles (combined irrigated and nonirrigated pasture) for the same 26 counties are shown in Table 5 below.

Table 4

# Final Normalized Monthly Emission Profiles for Inv97: Non-Pasture

| Air Basin Code | County Name | Normalized Monthly Profile | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| NCC | Monterey | 0.001225 | 0.002679 | 0.002913 | 0.061920 | 0.111143 | 0.246492 | 0.208807 | 0.161958 | 0.113459 | 0.066959 | 0.017814 | 0.004632 |
| NCC | San Benito | 0.000204 | 0.000921 | 0.001675 | 0.015782 | 0.065854 | 0.270764 | 0.234869 | 0.205703 | 0.189258 | 0.010298 | 0.002195 | 0.002477 |
| NCC | Santa Cruz | 0.000608 | 0.000491 | 0.003471 | 0.045288 | 0.021986 | 0.200193 | 0.260463 | 0.192458 | 0.136386 | 0.096231 | 0.041485 | 0.000940 |
| SCC | Santa Barbara | 0.002417 | 0.004234 | 0.003180 | 0.154549 | 0.110527 | 0.173668 | 0.137528 | 0.109830 | 0.137023 | 0.117648 | 0.041151 | 0.008245 |
| SCC | San Luis Obispo | 0.004612 | 0.006250 | 0.003689 | 0.078692 | 0.126481 | 0.144383 | 0.136538 | 0.144399 | 0.137135 | 0.127847 | 0.074188 | 0.015786 |
| SCC | Ventura | 0.000479 | 0.000502 | 0.000932 | 0.087726 | 0.121735 | 0.087902 | 0.172065 | 0.168515 | 0.146119 | 0.132899 | 0.078609 | 0.002518 |
| SED | Imperial | 0.005689 | 0.039360 | 0.055726 | 0.108196 | 0.175662 | 0.145953 | 0.131038 | 0.126958 | 0.097027 | 0.065903 | 0.036780 | 0.011710 |
| SJV | Fresno | 0.003242 | 0.007583 | 0.008150 | 0.271164 | 0.217378 | 0.088964 | 0.084882 | 0.114150 | 0.114856 | 0.067601 | 0.014527 | 0.007503 |
| SJV | Kern | 0.008233 | 0.017122 | 0.010815 | 0.298530 | 0.202499 | 0.096987 | 0.084858 | 0.089713 | 0.079840 | 0.066946 | 0.031365 | 0.013093 |
| SJV | Kings | 0.006205 | 0.008434 | 0.010971 | 0.368849 | 0.169039 | 0.060584 | 0.055161 | 0.067696 | 0.089381 | 0.089555 | 0.060640 | 0.013485 |
| SJV | Madera | 0.003534 | 0.007049 | 0.008439 | 0.299243 | 0.227875 | 0.079547 | 0.096321 | 0.121309 | 0.091604 | 0.045440 | 0.011523 | 0.008118 |
| SJV | Merced | 0.005545 | 0.003189 | 0.007343 | 0.328137 | 0.141570 | 0.075783 | 0.091001 | 0.108653 | 0.096868 | 0.077381 | 0.054933 | 0.009597 |
| SJV | San Joaquin | 0.002395 | 0.003103 | 0.006660 | 0.130304 | 0.129565 | 0.169030 | 0.158657 | 0.185521 | 0.149614 | 0.051890 | 0.007378 | 0.005884 |
| SJV | Stanislaus | 0.009141 | 0.005565 | 0.011983 | 0.183836 | 0.087068 | 0.146298 | 0.154774 | 0.150993 | 0.105679 | 0.075143 | 0.051449 | 0.018071 |
| SJV | Tulare | 0.003763 | 0.005995 | 0.005093 | 0.288175 | 0.215736 | 0.092888 | 0.116696 | 0.119751 | 0.085562 | 0.053901 | 0.008124 | 0.004318 |
| SV | Butte | 0.011390 | 0.031573 | 0.033326 | 0.269656 | 0.215608 | 0.055650 | 0.125299 | 0.097673 | 0.049771 | 0.072147 | 0.022737 | 0.015170 |
| SV | Colusa | 0.003710 | 0.007492 | 0.017060 | 0.186756 | 0.181781 | 0.146118 | 0.099764 | 0.114111 | 0.109859 | 0.116851 | 0.010633 | 0.005865 |
| SV | Glenn | 0.003964 | 0.011570 | 0.016197 | 0.231099 | 0.085869 | 0.211432 | 0.077283 | 0.046565 | 0.062271 | 0.165174 | 0.076395 | 0.012180 |
| SV | Placer | 0.005170 | 0.008066 | 0.012951 | 0.273298 | 0.261048 | 0.096170 | 0.087746 | 0.096433 | 0.102412 | 0.041079 | 0.010731 | 0.004895 |
| SV | Sacramento | 0.001532 | 0.002454 | 0.004636 | 0.119911 | 0.144323 | 0.328602 | 0.129959 | 0.101191 | 0.129705 | 0.030645 | 0.004623 | 0.002420 |
| SV | Shasta | 0.001868 | 0.007077 | 0.008186 | 0.075574 | 0.098438 | 0.337096 | 0.221949 | 0.143852 | 0.043599 | 0.055040 | 0.005486 | 0.001835 |
| SV | Solano | 0.000794 | 0.001130 | 0.002064 | 0.046102 | 0.088429 | 0.186519 | 0.142257 | 0.145012 | 0.187450 | 0.190194 | 0.008736 | 0.001313 |
| SV | Sutter | 0.003768 | 0.005746 | 0.008841 | 0.184568 | 0.208293 | 0.204181 | 0.090584 | 0.099014 | 0.143255 | 0.039671 | 0.008448 | 0.003632 |
| SV | Tehama | 0.002127 | 0.005453 | 0.005904 | 0.052780 | 0.066575 | 0.371433 | 0.214918 | 0.157030 | 0.066415 | 0.050496 | 0.004738 | 0.002129 |
| SV | Yolo | 0.001484 | 0.002178 | 0.003632 | 0.078686 | 0.130927 | 0.237664 | 0.107903 | 0.105403 | 0.168242 | 0.152830 | 0.009141 | 0.001909 |
| SV | Yuba | 0.007589 | 0.011960 | 0.018221 | 0.274503 | 0.256441 | 0.115812 | 0.076787 | 0.047818 | 0.080356 | 0.066016 | 0.037238 | 0.007260 |

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Table 5

# Final Normalized Monthly Emission Profiles for Inv97: Pasture

| Air Basin Code | County Name | Normalized Monthly Profile | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| NCC | Monterey | 0.000754 | 0.002266 | 0.002535 | 0.051750 | 0.090453 | 0.222284 | 0.210089 | 0.192916 | 0.135678 | 0.071004 | 0.017223 | 0.003048 |
| NCC | San Benito | 0.000089 | 0.000578 | 0.001126 | 0.011311 | 0.052248 | 0.271256 | 0.267742 | 0.226994 | 0.159049 | 0.007090 | 0.001405 | 0.001111 |
| NCC | Santa Cruz | 0.000341 | 0.000365 | 0.002401 | 0.033440 | 0.018745 | 0.195997 | 0.267064 | 0.217964 | 0.142797 | 0.085870 | 0.034463 | 0.000552 |
| SCC | Santa Barbara | 0.001444 | 0.003023 | 0.002232 | 0.121614 | 0.097959 | 0.172619 | 0.164110 | 0.146268 | 0.139717 | 0.105104 | 0.040254 | 0.005656 |
| SCC | San Luis Obispo | 0.002104 | 0.004079 | 0.002638 | 0.065440 | 0.127210 | 0.190429 | 0.200561 | 0.175289 | 0.103575 | 0.076448 | 0.044986 | 0.007239 |
| SCC | Ventura | 0.000286 | 0.000411 | 0.000777 | 0.079931 | 0.117739 | 0.086597 | 0.184265 | 0.180986 | 0.145048 | 0.127371 | 0.074975 | 0.001614 |
| SED | Imperial | 0.002396 | 0.016392 | 0.026112 | 0.055088 | 0.096743 | 0.086729 | 0.064588 | 0.071972 | 0.048774 | 0.247227 | 0.273190 | 0.010791 |
| SJV | Fresno | 0.000682 | 0.001876 | 0.002053 | 0.080414 | 0.170216 | 0.176965 | 0.133608 | 0.106798 | 0.220143 | 0.100573 | 0.004985 | 0.001687 |
| SJV | Kern | 0.002032 | 0.005079 | 0.003159 | 0.095817 | 0.158122 | 0.158317 | 0.124932 | 0.100277 | 0.206640 | 0.128312 | 0.013826 | 0.003486 |
| SJV | Kings | 0.001294 | 0.002146 | 0.002764 | 0.103557 | 0.140536 | 0.170735 | 0.126527 | 0.098967 | 0.199107 | 0.131955 | 0.019474 | 0.002938 |
| SJV | Madera | 0.000688 | 0.001893 | 0.002072 | 0.081190 | 0.171899 | 0.178835 | 0.135080 | 0.107929 | 0.217877 | 0.095866 | 0.004970 | 0.001702 |
| SJV | Merced | 0.001114 | 0.000843 | 0.001798 | 0.093038 | 0.098055 | 0.157038 | 0.139012 | 0.100488 | 0.219395 | 0.164016 | 0.023108 | 0.002093 |
| SJV | San Joaquin | 0.000492 | 0.000917 | 0.001882 | 0.042957 | 0.078773 | 0.226518 | 0.184775 | 0.144221 | 0.241172 | 0.074588 | 0.002513 | 0.001192 |
| SJV | Stanislaus | 0.002113 | 0.001900 | 0.003678 | 0.064709 | 0.056538 | 0.196433 | 0.157092 | 0.105009 | 0.215160 | 0.169386 | 0.023837 | 0.004146 |
| SJV | Tulare | 0.000686 | 0.001425 | 0.001076 | 0.068084 | 0.135044 | 0.184805 | 0.156547 | 0.110368 | 0.219764 | 0.117937 | 0.003381 | 0.000882 |
| SV | Butte | 0.001038 | 0.002891 | 0.003078 | 0.029368 | 0.051526 | 0.094009 | 0.302363 | 0.237884 | 0.204149 | 0.068815 | 0.003393 | 0.001485 |
| SV | Colusa | 0.000462 | 0.000946 | 0.002225 | 0.029141 | 0.058207 | 0.217954 | 0.197421 | 0.160995 | 0.228106 | 0.101841 | 0.001937 | 0.000765 |
| SV | Glenn | 0.000607 | 0.001778 | 0.002508 | 0.041154 | 0.028697 | 0.233826 | 0.127452 | 0.082743 | 0.233084 | 0.227683 | 0.018480 | 0.001988 |
| SV | Placer | 0.000500 | 0.000780 | 0.001258 | 0.031351 | 0.067743 | 0.234806 | 0.173399 | 0.137925 | 0.310148 | 0.039923 | 0.001661 | 0.000504 |
| SV | Sacramento | 0.000358 | 0.000603 | 0.001233 | 0.036046 | 0.057101 | 0.221615 | 0.170507 | 0.129894 | 0.331010 | 0.049480 | 0.001567 | 0.000586 |
| SV | Shasta | 0.000706 | 0.001860 | 0.002121 | 0.021385 | 0.036534 | 0.357273 | 0.245130 | 0.144028 | 0.121945 | 0.066545 | 0.001785 | 0.000689 |
| SV | Solano | 0.000224 | 0.000341 | 0.000703 | 0.018227 | 0.044656 | 0.149715 | 0.147973 | 0.111900 | 0.296425 | 0.226648 | 0.002831 | 0.000356 |
| SV | Sutter | 0.000459 | 0.000715 | 0.001153 | 0.028576 | 0.061674 | 0.212511 | 0.156647 | 0.124930 | 0.363561 | 0.047688 | 0.001624 | 0.000463 |
| SV | Tehama | 0.000714 | 0.001882 | 0.002145 | 0.021659 | 0.037011 | 0.362436 | 0.248777 | 0.146082 | 0.114683 | 0.062138 | 0.001776 | 0.000696 |
| SV | Yolo | 0.000313 | 0.000482 | 0.000888 | 0.022641 | 0.052765 | 0.179391 | 0.159757 | 0.122792 | 0.292394 | 0.165648 | 0.002519 | 0.000410 |
| SV | Yuba | 0.000399 | 0.000628 | 0.000955 | 0.016896 | 0.035567 | 0.152726 | 0.178326 | 0.161112 | 0.409197 | 0.040462 | 0.003317 | 0.000415 |

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## IV. ASSUMPTIONS

The WEQ from which this methodology is derived is an empirically based model. There are extensive sets of assumptions associated with each factor used in the WEQ. Some of the most basic are:

1. The WEQ can be extended from estimating erosion to estimating emissions.

2. That 2.5% of eroded material becomes PM emissions, and ~~0.5%~~ 50% of the PM emissions are PM10. The constant application of these numbers ignores variations in material properties (e.g., particle size fractions, adherence, and air silt loading), and the effects of varying conditions (e.g., soil moisture, relative humidity, and air movement).

3. No limit on the capacity of the air to contain dust. Newer methods such as the RWEQ, referred to above, are attempting to account for finite dust loading, but are still being refined.

4. The WEQ is based on the erosive potential of a bare ground site in Kansas. Many assumptions arise from the attempt to draw conclusions from that site. Many of the revisions included in this methodology are attempts to correct for deviations in conditions and farm practices between the Kansas site and the California agricultural lands.

5. For most of the SJV counties, the erodibility factor ("I") was determined using small sections of counties as the level of detail, for the rest of California, the "I" factor was determined from county-wide soil texture data. The finer the detail, the more assurance that the "I" factor accurately reflects the soil texture for the agricultural lands in the county.

6. High wind events are not accounted for, except as they contribute to the overall average wind speed.

7. Windblown dust emissions from orchards and vineyards are not included.

8. For nonpasture crops 0.5% of the planted crop land remains barren, and 0.5% of the land dedicated to a crop is utilized for the border. For pasture crops the barren acreage drops to 0.05%,

and border acreage is assumed to be zero. These are very rough estimates. As better estimates of bare and border areas emerge, they should be incorporated.

9. The planting and harvesting dates for crops were what was considered typical for each basin. In the future, county-specific planting harvesting dates may improve the estimate, though the differences should be relatively small.

10. The same canopy growth curves were often used for a given crop, regardless of the planting date or region. In the future, additional county and season specific canopy growth curves may improve the estimate, although, again, the differences should be relatively small.

11. Crop descriptive data (other than acreages) were often extended from the data of similar crops.

Refer to the Method Description section above, and the references listed in that section, for further details on the above assumptions and other assumptions associated with the Inv97 methodology revision.

## V. SUMMARY OF CHANGES IN METHODOLOGY FROM INV91 TO INV97

This is a summary of the changes in methodology that occurred between Inv91 and Inv97. For more detailed information refer to the Method Description section.

### A. Climatic "C" Factor Adjustments

1. **Annual:** Adjusted the annual "C" factors for the WEQ to the CIMIS surface contour/grid count generated "C" factors.

2. **Temporal:** Adjusted the windblown agricultural PM temporal emissions profile to the profile generated using the "month as a year" estimation method.

### B. Nonclimate-based Adjustments

1. **Erodibility adjusted based on STATSGO data:** Erodibility was adjusted using STATSGO data for most of the SJV Air Basin counties.

2. **1993 Crop Acreages Obtained from CDFA:** 1993 crop acreages were obtained from the CDFA, replacing the 1987 acreages used in the 1989 methodology.

3. **Irrigation based long-term erodibility adjustment:** Adjusted the current annual erodibility for the WEQ to account for the long-term effects of irrigation on erodibility (cloddiness).

4. **Irrigation factor:** Added a temporally (monthly) calculated irrigation factor to the WEQ to account for the short-term effects of irrigation on erodibility (surface wetness).

5. **Vegetative factor ("V'"):** Replaced the annual "V'" factor for the WEQ with the following three adjustments, calculated on a temporal (monthly) basis to account for the short-term effects on erodibility:

    a. **Crop canopy factor:** To account for growth of crop canopy from planting through harvest.

    b. **Postharvest soil cover factor:** To account for variations in postharvest soil cover from harvest to planting of next crop.

    c. **Postharvest "replant-to-different-crop" factor:** To account for the portion of harvested acreage replanted to a different crop within a short time following harvest, resulting in a net reduction in acreage assigned to the crop for the time period from the "replant-to-different-crop" date through the planting date for the original crop.

6. **Bare soil adjustment:** Assumed to be 0.5% of planted acreage for nonpasture; and 0.05% of acreage for pasture: To account for planted regions that are barren of crop. No canopy or soil cover factors are applied, however, the long-term irrigation erodibility adjustment, irrigation factor, and replant-to-different-crop adjustment are applied.

7. **Border adjustment:** Assumed to be 0.5% of planted acreage for nonpasture; pasture is assumed to have no border area, and, therefore, no border adjustment: To account for field border regions. No canopy or soil cover factors are applied, and no irrigation factor nor long-

term irrigation erodibility adjustment are applied, however, the replant-to-different-crop adjustment is applied.

## VI. DIFFERENCES BETWEEN INV91, INV95, INV96, AND INV97 EMISSION ESTIMATES

As was discussed earlier, changes in methodology have occurred since the inventory produced from the 1989 methodology and the 1987 crop acreages (Inv91). Inv91 and the succeeding inventories Inv95, Inv96, as well as the current Inv97, will be compared in this section:

*Inv91* - Original ARB methodology: 1989 methodology using 1987 crop acreages.

*Inv95* - Revised acreage/erodibility: 1989 methodology using 1993 crop acreages and adjusted erodibility based on the STATSGO data.

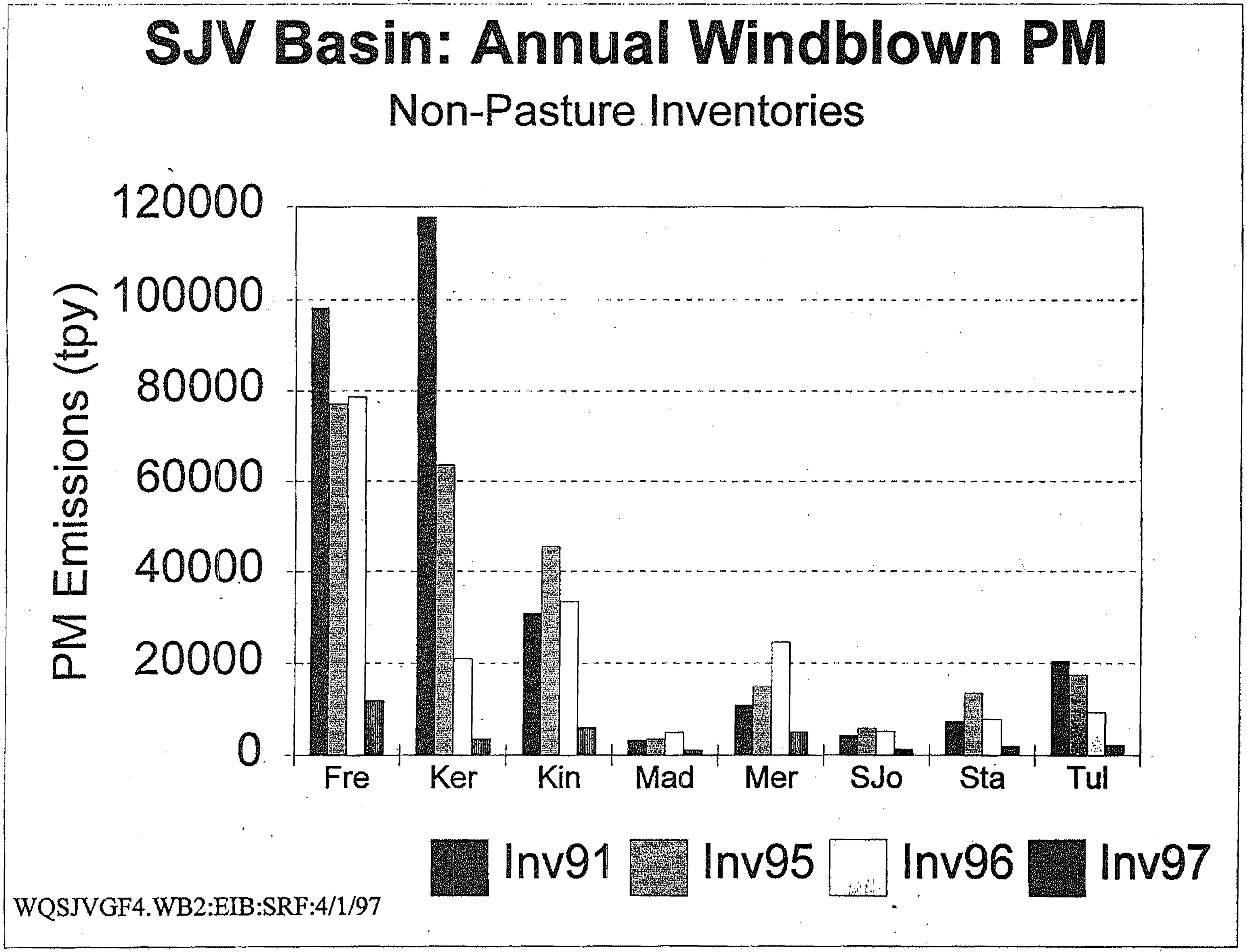
*Inv96* - Inv95 plus annual/monthly "C" factor adjustments: Inv95 with climatic factor adjustments, including the use of CIMIS climatic data, grid counting methodology for annual "C" factor, and month-as-a-year methodology for climatic monthly profile.

*Inv97* - Inv96 plus all additional adjustments: Inv96 with the addition of all the remaining adjustments included in this revision of the methodology. This is the current inventory.

Attachments A and B, at the back of this methodology, list the Inv97 estimated annual emissions for nonpasture and pasture crops respectively. Pasture crops were not included in Inv91, Inv95, or Inv96, and, therefore, only the nonpasture acreage will be included in the comparisons in this section.

Figure 13 compares the Inv91, Inv95, Inv96 and Inv97 nonpasture windblown agricultural PM emission results for the SJV Air Basin by county.

Figure 13



SJV Basin: Annual Windblown PM
Non-Pasture Inventories
PM Emissions (tpy)
120000
100000
80000
60000
40000
20000
0
Fre
Ker
Kin
Mad
Mer
SJo
Sta
Tul
Inv91
Inv95
Inv96
Inv97
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**A. Comparing Inv91 and Inv95: Effects of 1993 Acreages and STATSGO-based Erodibility**

For Inv95, ARB staff acquired 1993 crop acreage estimates from the CDFA to replace the 1987 data previously used. ARB staff also improved on the erodibility factor estimation method for counties in the SJV Air Basin, by incorporating geographic information system-based soil data from the STATSGO database [9]. In addition, the "L'" and "V'" factors were updated for several crops [2].

Whether the emissions increase or decrease between Inv91 and Inv95 depends on the county. For the SJV Air Basin, in Figure 13, four counties see increases in emissions from Inv91 to Inv95, and 3 counties exhibit decreases. Madera County emissions remain about the same. The most notable changes are the emissions increase for Kings County, and emission decreases for Fresno and Kern counties. These changes are primarily due to the use of the STATSGO derived erodibilities in Inv95 for all of the SJV Air Basin counties except for Stanislaus County.

**B. Comparing Inv95 and Inv96: Effects of "C" Factor Changes**

**1. Effects of Annual "C" Factor Changes**

The NRCS maps were used to determine the Inv91 and Inv95 annual "C" factors, whereas, ARB staff implemented the use of the CIMIS data derived (grid-counted contour surface) "C" factors with Inv96. As with the comparison between Inv91 and Inv95, whether the emissions increase or decrease between Inv95 and Inv96 depends on the county. For the SJV Air Basin, in Figure 13, emissions for three counties increase from Inv95 to Inv96, and five counties exhibit decreases.

The most striking change is for Kern County. This large decrease is due to the fact that the NRCS map used for the Inv95 used NOAA data from Bakersfield exhibited excessively high wind speeds. The CIMIS wind data for Bakersfield were much more consistent with the surrounding weather station wind data.

Fresno County still has a very high number, however, the large acreage cultivated in Fresno County can always be expected to demonstrate a relatively large emissions value. In addition, there was basic agreement between the NRCS map (for "C" factors) and the CIMIS-generated contour map in the Fresno County area.

Information from ARB staff and others indicates that even after the Inv96 emission adjustments, the estimates for windblown agricultural dust were excessive [21][22][23][24][25].

### 2. Effects of Normalized Monthly "C" Factor Profile Changes

Changing the normalized monthly "C" factor profile, without including the Inv97 nonclimate based monthly profile revisions discussed below, does not change the annual emissions level. However, the distribution of emissions throughout the year is dramatically affected, and would follow the profiles shown earlier in figures 4 through 11. The Inv95 (and Inv91) methodology, using the statewide estimate of EWE, resulted in a windblown agricultural PM temporal emissions profile that was much flatter than the Inv96 profile. While the Inv96 profile exhibited strong seasonality, seasonality was nearly obscured in Inv95. Strong seasonal profiles for windblown emissions are supported by source apportionment research [22][23][24].

## C. Comparing Inv96 and Inv97: Effects of Remaining Adjustments

The adjustments newly implemented in Inv97 include the long-term irrigation erodibility adjustment (cloddiness), and the short-term irrigation erodibility adjustment (wetness). They also include the crop canopy cover factor, the postharvest soil cover factor, the replant (multiple plantings during an annual crop cycle) factor, and the bare acreage and border acreage adjustments.

The long-term irrigation erodibility adjustment can be quite significant, often in the range of 30 percent. It is applied on an annual basis.

The "C" factor profile is applied as a normalized profile, and, therefore, by itself does not change the annual emissions estimate. However, the combination of the "C" factor profile with the additional monthly nonclimatic adjustments, can cause larger annual emissions changes than would have occurred without the "C" factor profile. For example, for many important crops the crop canopy cover is largest at the same time of the year as the climatic factor. The large monthly climatic factor in the summer shifts the emissions into the summer months, when many crop canopy covers are the greatest. This results in a very large decrease in annual emissions between Inv96 and Inv97 (Figure 13).

Crops that are planted in the spring, and maintain canopy cover through the fall exhibit the largest decreases between Inv96 and Inv97. Cotton falls into this category, and is also the largest nonpasture crop in the SJV Air Basin. The reductions in emissions are quite dramatic in the cotton growing region of the southern SJV Air Basin.

The short-term irrigation factor (wetness) may reduce the emissions by 10% to 20% during the months when the "C" factor profile peaks. 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. The bulk of the emission reductions between Inv96 and Inv97 are due to the long term irrigation factor (cloddiness) adjustments, and the combination of the "C" factor profile and the crop canopy cover.

The border emissions for nonpasture, as well as the bare ground emissions are both calculated separately and then added to the remaining 99 percent. For pasture there is no border adjustment and the remainder is 99.95 percent. The bare and border adjustments prevent the emissions from bottoming out during the summer months due to full canopy cover. This is important, since there will nearly always be some exposed ground, even during periods of maximum canopy cover. Maintaining estimated windblown agricultural emissions above certain minimum levels during summertime maximum canopy cover periods is also supported by emissions apportionment studies [22][23][24][25].

## D. Comparing Inv91 and Inv97: SJV, SV, NCC and SCC Air Basins

### 1. Annual Emissions Estimates

Table 6 lists the Inv91 and Inv97 windblown agricultural PM emissions for the 26 counties for whom emissions were recalculated using the Inv97 methodology. Figures 14 and 15 demonstrate that the same scale of emission reductions occurred in many of the counties in the NCC, SCC, and SV air basins that were depicted in Figure 13 for the SJV Air Basin. A notable exception is Yolo County (Figure 15), where the Inv97 emissions were greater than the Inv91 emissions. This occurred

## Table 6

### Nonpasture Windblown Agricultural Emissions

| Air Bsn | County Name | Inv91 PM Emiss (tpy) | Inv97 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 |

Figure 14

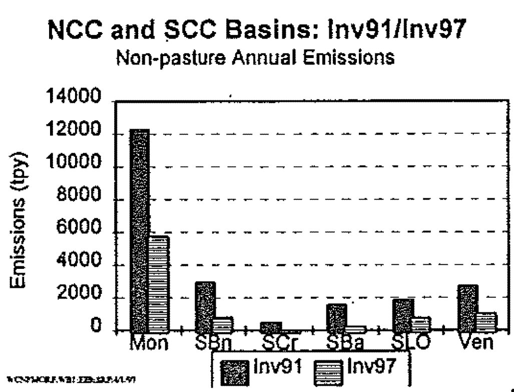
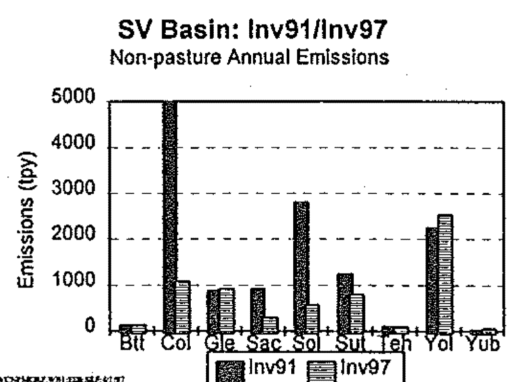



Figure 15



because of a combination of factors. The biggest factors contributing to the increase in Yolo County emissions were the inclusion in Inv97 of large acreages of safflower and "field crops, unspecified", which had been left out of Inv91.

**2. Monthly Emissions Profiles**

Figures 16 through 21 compare the Inv91 and Inv97 final emissions profiles for six selected counties from the SJV, SV, NCC and SCC air basins, and Imperial County. There are two important comparisons to make. The first comparison is between the Inv91 (statewide erosive wind energy based) profile and the Inv97 profile. Figures 16 through 21 all demonstrate the strong seasonal component in the Inv97 profiles, and the lack of one in the Inv91 profiles. Of course the Inv91 profile was the same for all counties of the State.

As was discussed earlier for the "C" factor-based profiles, the source apportionment analyses currently available support minimal geological source emissions during the winter, and higher emissions during the spring, summer, and fall [22][23][24][25]. This is the overall pattern represented by the Inv97 plots in figures 16 through 21. Unfortunately, current apportionment analyses do not allow differentiation between different geological sources. Therefore, the contributions of specific sources, such as agricultural tillage and windblown agricultural emissions can't be estimated. In the future, the capabilities may exist to differentiate these sources, and create emission apportionment profiles specific to agricultural windblown dust. At that time, the profiles represented by figures 16 through 21 may be adjusted.

The second comparison is between the Inv97 final emissions profiles in figures 16 and 19, and the purely "C" factor-based profiles in figures 4 and 9 (labeled Inv96&97), respectively. Figure 4, for Fresno County, shows the usual month-as-a-year "C" factor profile, with very low emissions in the winter months, and a peak in the summer. Figure 16 has, in addition to the month-as-a-year "C" factor profile; the crop canopy, postharvest soil cover, replanting, and irrigation profiles incorporated. The peak shown in April is due to a jump in the "C" factor combined with the massive planting of cotton in March and April. The sudden drop-off that follows the peak is due, for the most part, to the subsequent cotton crop canopy development. Figure 9, for San Joaquin County, has the same basic form of the

Figure 16: Fresno County

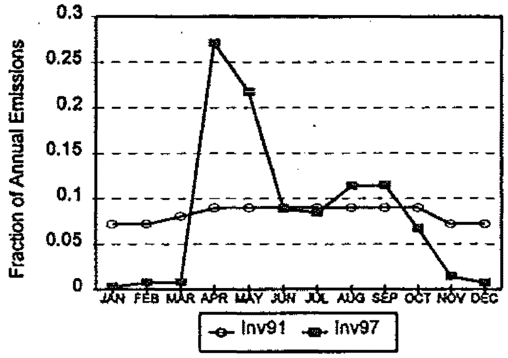



Figure 17: Imperial County

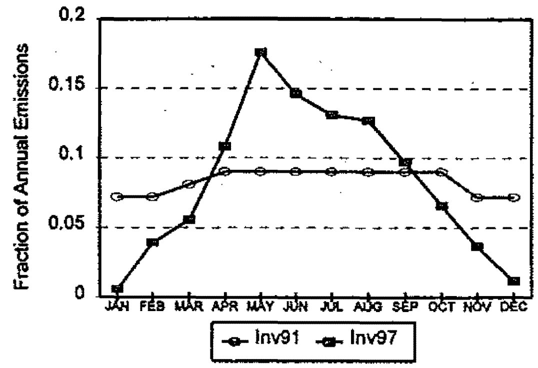



Figure 18: Monterey County

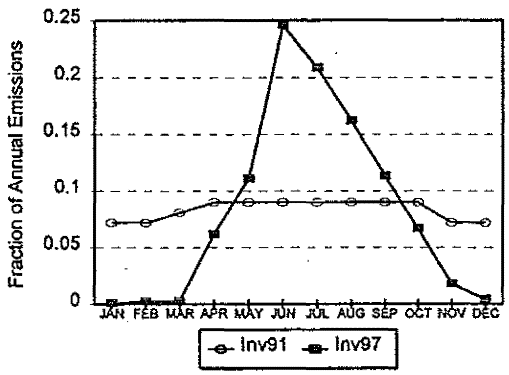



Figure 19: San Joaquin County

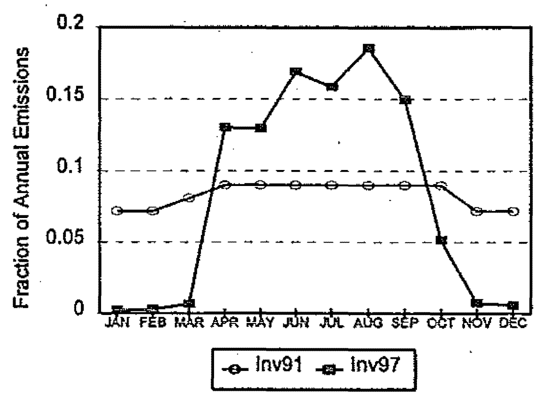



Figure 20: Ventura County

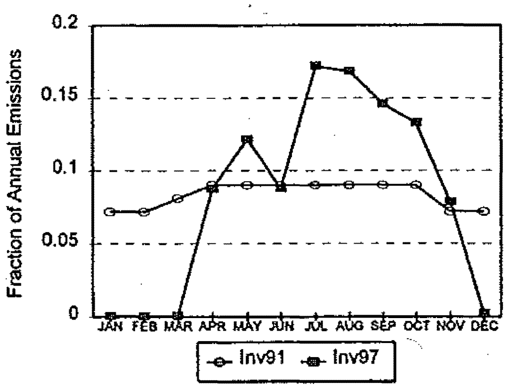
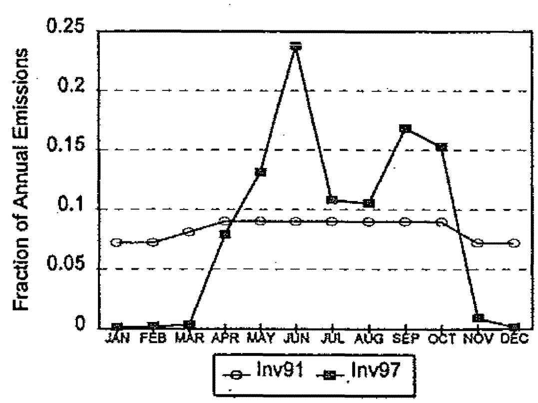



Figure 21: Yolo County

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month-as-a-year "C" factor profile as Fresno County in Figure 4. Figure 19 also shows the same sharp rise in the final emissions profile in April, due to the jump in the "C" factor, for San Joaquin County as is present in Figure 16 for Fresno County. However, there is no sudden drop-off following April for San Joaquin County in Figure 19, but, instead, consistently high emissions throughout the summer. This is because San Joaquin County does not have a single crop with a narrow planting window, like cotton in Fresno County, dominating its profile.

As discussed above, source apportionment profiles specific to windblown agricultural dust are not currently available. Therefore, the only inference that can be drawn from the geological dust source apportionment profiles, related to the comparison between "C" factor profiles (Inv96&97) and the Inv97 profiles, is that they are both more valid than the Inv91 profile. However, unlike the Inv91, Inv95 and Inv96 methodologies, the Inv97 methodology uses the monthly profile to calculate annual emissions. The resultant Inv97 emissions allow the overall geological emission contribution to be more in line with the fraction predicted by the source apportionment profiles. Therefore, the source apportionment profiles indirectly support the overall effect produced by the Inv97 profile.

VII. RECOMMENDATIONS

1. Make the same revisions included for Inv97 to inventories for the remainder of the counties in California (i.e., those counties outside the SJV, SV, NCC, SCC, and Imperial County). This recommendation does not apply to the South Coast Air Basin, for which the South Coast Air Quality Management District has taken responsibility for producing the windblown inventory.

2. Replace county-wide average climatic data generated "C" factor profiles with contour/grid count/weighted average generated "C" factor profiles. In the current revision only the annual "C" factors are grid counted.

3. Continue analysis of all weather sites for applicability in "C" factor generation. Attempt to better understand how the stations' setup, and environment effect wind speed measurements (e.g., height of anemometer, surrounding obstacles, etc.).

4. Follow the development of the RWEQ model [6], and the Wind WEPS model [7]. Examine how they incorporate: Limits on the capacity of air to entrain PM, stochastics in wind effects, precipitation and irrigation effects, field geometry, wind obstructions, soil properties, etc. The RWEQ is out for review, however, the WEPS model is still in the midst of development, and requires data well beyond even the extensive data requirements of the RWEQ model. The RWEQ and WEPS both require data inputs currently unavailable to the ARB. However, both the RWEQ and WEPS models promise the ability to predict emissions, rather than estimate past emissions, and to calculate emissions for short time frames, rather than on an annual or monthly basis as the WEQ allows. These capabilities could greatly assist both temporal and episodic inventory efforts. Currently, both the crop canopy and postharvest soil cover factors used by ARB staff use the exponential equations derived for the RWEQ.

5. Continue collecting information on crop activity calendars, irrigation practices, crop canopy growth, planted ground that is barren, field borders, postharvest soil cover, replanting to different crops after harvest, etc., from the agricultural community.

6. Continue to improve the geographic detail of soil type, climate, crop acreage, agricultural practice and activity calendars. This will improve county emission estimates, as well as enhancing the ability to link to geographic information systems (GIS). Also work to incorporate additional GIS data into the windblown agricultural dust inventory analysis.

7. Determine whether orchards and vineyards, can and/or should be included in the windblown agricultural emissions inventory. Emissions for newly planted orchards and vineyards could be significant. Emissions for nonleafed-out orchards/vineyards, and/or orchards/vineyards without vegetative cover between the rows could also be significant.

8. Use the agricultural windblown dust specific source apportionment research results, as they become available to verify the annual emission estimates, as well as the monthly emission profiles.

## VIII. SAMPLE CALCULATIONS

As was discussed in detail in the Method Description section (Equation 1), above, the ARB methodology for estimating the annual windblown agricultural emissions using the WEQ is for the most part that recommended by the U.S. EPA on page 144 et seq. of EPA-450/3-74-037 [5]. Among the improvements that ARB staff has incorporated since Inv91 are improved annual climatic calculations, temporal effects of climatic conditions, as well as several nonclimate-based adjustments.

The sample calculations, below, start with the annual and monthly profile factor calculations. These include explanations of how to calculate the annual "C" factor, the month-as-a-year "C" factor profile, long term irrigation-based erodibility adjustment (cloddiness), growing canopy fraction, postharvest/preplant fraction, irrigation factor, canopy cover factor, postharvest soil cover factor, and replant factor. The other factors will not be covered here, since they were adequately discussed in the previous Method Description section.

Next, the factors are applied to calculate the emissions in a two-step process. The first step is to calculate the "intermediate annual emissions" (IAE), which includes all the adjustments made on an annual basis. The second step is to apply the monthly based adjustments to the IAE to obtain the final monthly emissions.

The above calculations are done separately for the bare acreage, the border acreage, and the nonbare/nonborder acreage (referred to as the 99% acreage). These three results are then added together to obtain the emissions for a single cohort-plant/harvest date pair. In this case, upland cotton in Fresno County with a March planting date and a September harvest date has been used for the example calculations. The calculations must be repeated for all cohort-plant/harvest date pairs for each crop. Only one month, March, has been calculated here, but the remaining months in the year follow the same calculation methodology. To obtain the annual emissions, the monthly emissions are calculated for all 12 months, and then summed.

### A. Annual and Monthly Factor Calculations

The WEQ is primarily a bare field emission estimate for a particular climate, that then has a series of factors applied to it to adjust for different crops and conditions. The basis and derivation of the "A" factor (fraction of eroded material that becomes airborne PM), the "K" factor (surface roughness), and the "L'" factor (unsheltered width) were adequately covered in the Method Description section above. However, the "C" factor (climatic), the "I" variable (erodibility), and the factors that will replace the "V'" factor (vegetative cover) all require additional explanation. Example calculations for the latter are included in this section; along with example calculations for the irrigation factor, replant factor, and bare and border adjustments.

First the climate-based factor calculations will be covered, followed by the nonclimate based.

**1. Climate-based Sample Calculations**

**a. Annual "C" Factor Calculation**

The annual "C" factor is calculated as shown below, with results displayed in Table 7. This example calculation uses 1983 through 1996 CIMIS data for Site #2, at Five Corners, in Fresno County. First the climatic variables for each month are averaged for all available years. Then the all-year averages for each month are input into equations 2 through 4 from the Method Description section:

Monthly PE for January = $115((1.9\text{ in})/(45.38\,°F-10\,°F))^{1.1111} = 4.45$

Annual PE = $\sum$ monthly PE values for year = 18.77

CIMIS anemometer height = 2 meters

Mean Monthly Wind Speed for January at 2 meters = 4.70 mph

Mean January Wind Speed Corrected to 10 meters =

$$= 4.70\text{ mph}*(10\text{ meters}/2\text{ meters})^{0.143} = 5.92\text{ mph}$$

(use 0.143 for flat terrain: According to NRCS staff, undulating ground or similar geographic features qualify as rough terrain, therefore, the CIMIS stations included in this analysis qualify as flat terrain [18])

Next calculate the mean annual wind speed by averaging the mean monthly wind speeds for all months of the year:

Mean Annual Wind Speed = 6.93 mph

The "C" factor can then be calculated according to:

"C" $= .3448((6.93 \text{ mph})^3/18.77^2) = 0.3252$

**Table 7**

**Climatic Factor Calculation Results for CIMIS Site #2**

| Month | Avg Daily Temp | Temp Minus 10° F | Total Prec | Prec Corr | PE | Mean Wind | Wind Corr to 10m |
|---|---|---|---|---|---|---|---|
| | F° | F° | inch | inch | | mph | mph |
| JAN | 45.38 | 35.38 | 1.90 | 1.90 | 4.45 | 4.70 | 5.92 |
| FEB | 50.58 | 40.58 | 1.62 | 1.62 | 3.21 | 5.32 | 6.69 |
| MAR | 56.38 | 46.38 | 1.88 | 1.88 | 3.27 | 6.04 | 7.60 |
| APR | 61.69 | 51.69 | 0.40 | 0.50 | 0.66 | 6.84 | 8.61 |
| MAY | 69.67 | 59.67 | 0.26 | 0.50 | 0.57 | 6.62 | 8.34 |
| JUN | 74.92 | 64.92 | 0.07 | 0.50 | 0.52 | 6.21 | 7.81 |
| JUL | 78.08 | 68.08 | 0.06 | 0.50 | 0.49 | 5.35 | 6.73 |
| AUG | 77.50 | 67.50 | 0.09 | 0.50 | 0.49 | 5.24 | 6.60 |
| SEP | 72.79 | 62.79 | 0.38 | 0.50 | 0.54 | 4.99 | 6.28 |
| OCT | 65.43 | 55.43 | 0.57 | 0.57 | 0.71 | 4.89 | 6.15 |
| NOV | 52.64 | 42.64 | 0.82 | 0.82 | 1.43 | 4.94 | 6.21 |
| DEC | 45.23 | 35.23 | 1.10 | 1.10 | 2.43 | 4.90 | 6.17 |
| Annual | | | | sum->18.77 | | avg->6.93 | |
| Annual "C" Factor -> **0.3252** (as a fraction) | | | | | | | |

The individual site "C" factors are input into tables along with their longitude/latitude coordinates. These tables are then used as inputs to the <u>Surfer</u> software program kriging algorithm [12]. This produces contour maps that can then be grid counted to determine the weighted average "C" factors for the agricultural production land in each county. The county weighted average annual "C" factor is then used in the WEQ to estimate annual emissions.

**b. Calculation of the "C" Factor Monthly Profile by Viewing a Month-as-a-Year**

The monthly "C" factor calculation follows the method for calculating the annual "C" factor. However, instead of summing the monthly PE values for all of the months in the year, each month's PE is multiplied by 12. Then each month's PE*12 is input into the "C" factor equation along with the mean monthly wind speed for that same month. The result is a "C" factor which would apply if the climate for that month were instead the year round climate. By then summing all of the monthly "C" factors for the year and then dividing each individual month by the sum, the month-as-a-year "C" factor is normalized to 1.0. These normalized monthly numbers provide the climate based temporal profile.

**2. Nonclimate-based Sample Calculations**

The nonclimate-based calculations are divided below into the factors that are applied to all months, and those that are specific to a given month. The latter combine with the climatic factor monthly profile to establish the overall monthly emissions profile.

**a. Calculations Applied to All Months**

**(1) Adjusting the Soil Erodibility Based on the Long-term Effects of Irrigation: Cloddiness of Soil**

This adjustment was covered in detail in the Method Description Section, but, since it is new to Inv97, a quick summary is included here. It is based upon differences in cloddiness between irrigated and nonirrigated soils. Table 3 in the Method Description section, lists suggested irrigated erodibilities for assigned nonirrigated erodibilities ("I"). Using simple interpolation, irrigated erodibilities can be assigned for nonirrigated erodibilities that fall between those shown in the table. The irrigated erodibilities are used in place of the nonirrigated erodibilities for all irrigated crops, except for those regions of a given crop's field assigned as "border" regions. ARB staff has added a correction to the WEQ to address field borders, and has assumed that border regions are nonirrigated.

**b. Month Specific Calculations**

The month-specific, nonclimatic factors used in these calculations include the crop canopy, postharvest soil cover, irrigation, and replanting factors.

A given crop may be planted during a number of months in different regions of California, or even within a given air basin in California. Plantings on a single farm may often occur in more than one month as well. For the purposes of this revision, basin-wide crop planting/harvesting dates; and crop canopy, postharvest soil cover, irrigation, and replanting profiles were used. In the future, more detail can be added to the model, by refining all of the above data to the county level.

For crops that are grown throughout the air basin, ARB staff selected data typical of the central region of the air basin. Fresno County was often used as the typical central county in the SJV Air Basin.

**(1) Growing Canopy Fraction (GCF) and Postharvest/Preplant Fraction (PHPP) Sample Calculation**

The planting month (cohort) and harvesting month, along with the fraction of total annual acreage planted in a cohort, and fraction of a cohort harvested in a given month, establish the growing canopy fraction (GCF) and the postharvest/preplant fraction (PHPP) for a crop. In practice, the GCF and PHPP are calculated for each cohort-plant/harvest date pair and then the plant fractions and harvest fractions are applied to calculate the weighted average. The GCFs, for a particular cohort-plant/harvest pair indicate the fraction of acreage represented by that pair that was planted, but not yet harvested by a given month. Although this is termed the GCF by staff, the canopy may or may not actually be increasing at any given time. The GCF determines the fraction of the acreage that will have the crop canopy factor applied to it (not including bare and border acreages). Whereas, the PHPP determines the fraction of crop acreage that will have the postharvest soil cover, and replanting factors applied. Because, in most instances, the planting and harvesting dates are assigned as mid-month, the GCF for a given cohort-plant/harvest date pair will be 0.5 in the planting and harvesting months. The GCF will be 1.0 in months after planting and before harvest months, and 0.0 for months after harvest and before planting. The PHPP as a rule will be the complement of the GCF, in other words: PHPP = 1-GCF, for an individual cohort-plant/harvest date pair.

All of the monthly factor profiles that follow are calculated for each month of the year, for each cohort-harvest/plant date pair, for each crop, for each county.

**(2) Irrigation Factor Sample Calculation**

The short-term irrigation-based erodibility adjustment (wetness) takes into account the overall soil texture, and the number of irrigation events. From the soil texture, irrigation events, and days in the month, the fraction of dry days during the month can be calculated [10]. This fraction is the irrigation factor, which is multiplied by the monthly emissions.

The irrigation factor is calculated according to equations 5 and 6 from the Method Description section:

<u>First calculate the number of wet days in the month:</u>

wetDaysInMo = (#ofIrrig.)*textureWetnessFctr

textureWetnessFctr => 1=coarse, 2=medium, 3=fine

(all basin counties' typical soil qualified as medium)

if: #ofIrrig. = 1.5
    textureWetnessFctr = 2

then: wetDaysInMo = (1.5)*2 = 3

<u>Next calculate the irrigation factor:</u>

IrrFctr = (#daysInMonth-wetDaysInMo)/(#daysInMo)

if: #daysInMonth = 31

then: IrrFctr = (31-3)/31 = 0.903

**(3) Sample Calculations for Replacement Factors to Address Problems with the "V'" Vegetative Cover Factor in the WEQ**

Because of the many problems associated with the use of the "V'" factor in California, the ARB staff replaced the "V'" factor in

Inv97 with the three adjustments discussed below. These adjustments approximate the effects on windblown agricultural PM emissions of: 1. crop canopy cover during the growing season; 2. postharvest soil cover; 3. postharvest planting of a different crop on the harvested acreage (replanting).

**(a) Canopy Development Profile Sample Calculation**

The crop canopy cover factor is calculated from the crop canopy cover percent. 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 [6]. The crop canopy cover is listed for the end of a given week, and the soil loss ratio due to canopy cover is calculated from Equation 7 from the Method Description section:

SLRcc = EXP(-0.201*(CanopyCoverPercent)^0.7366)

if: CanopyCoverPercent = 20

then: SLRcc = EXP(-0.201*(20)^0.7366) = 0.161

SLRcc is the canopy cover factor, and is averaged for all of the weeks in each month based upon the cohort-plant/harvest date pair.

**(b) Postharvest Soil Cover Profile Sample Calculation**

The postharvest soil cover factor is calculated from the postharvest soil-cover percent [6]. The postharvest soil cover is listed for the start of a given week, and the soil loss ratio (SLRsc) due to postharvest vegetative cover is calculated from Equation 8 from the Method Description section:

SLRsc = EXP(-0.0438*(SoilCoverPercent))

if: SoilCoverPercent = 75

then: SLRsc = EXP(-0.0438*(75)) = 0.037

SLRsc is the postharvest soil cover factor, and is averaged for all of the weeks in each month based upon the cohort-plant/harvest date pair.

**(c) Postharvest Replant-to-Different-Crop Factor Sample Calculation**

With Inv97, ARB staff adjusted for the rapid replanting of harvested land to another crop. Staff removed from the inventory calculation the fraction of the harvested land replanted. The replanted fraction is removed at the estimated time of replanting and thereafter. The net result of the application of the replanting fraction is that the postdisk-down acreage (one to two months after harvest), and resultant emissions for the effected months, are reduced by the fraction of harvested acreage converted to a new crop. This fraction varies from 0 to 1.0 depending on the crop.

For cotton, the largest crop in the SJV, the fraction replanted to another crop is assumed to be one third of the harvested acreage. This fraction is assumed to be replanted at mid-month, one month after harvest.

**B. Emission Calculations from Annual and Monthly Factors**

After all the separate factors have been calculated, the results can be used to estimate the emissions. First the emissions are calculated separately for the nonbare/nonborder, the bare, and the border crop acreage regions, as specified below. Then these three results are added together to arrive at the final emissions for the month for the cohort-plant/harvest date pair for a given crop, in a given county. The emission calculations below are for upland cotton in Fresno County for the cohort-plant/harvest date pair that was planted in March and harvested in September. If the annual emissions are desired, the process is repeated for the remaining months, and then all 12 months are summed. To calculate the individual crop emissions for each county, the cohort-plant/harvest date pairs are added together for each crop. Alternatively, all cohort-plant/harvest date pairs for all crops for the county are summed if the total county emissions are desired.

**1. 99% of Acreage that is Neither Bare Nor Border (99.95% for pasture)**

The calculation of the nonbare/nonborder emissions for the Fresno County upland cotton March planting/September harvest date pair is done in two phases: 1. annual based factors are applied to create an intermediate annual emissions result; 2. the intermediate annual emissions result is multiplied by the monthly profile factors to create the monthly emissions.

Intermediate Annual Windblown Emissions Calculation for 99% Acreage for Upland Cotton in Fresno County (March Plant/September Harvest)

| | | |
|---|---|---|
| Total Acreage | = Ac | = 338,000 acres |
| 99%Acreage | = 99Ac | = 334,620 acres |
| Suspended Fraction | = A | = 0.025 |
| Erodibility NonIrrigated | = I | = 68 |
| Erodibility Irrigated | = IIrr | = 45.2 |
| Climatic Factor, Annual | = C | = 0.254744 |
| Surface Roughness Factor | = K | = 0.5 |
| Unsheltered Width Factor | = L' | = 0.79 |

**Equation 9:** Intermediate Annual PM Emissions 99% = IAE99 =

= 99Ac * A * IIrr * C * K * L' =

= 334,620 * 0.025 * 45.2 * 0.254744 * 0.5 * 0.79 =

= 38,047.9 tons/year

Next the intermediate annual PM Emissions (IAE99) are multiplied by each month of the monthly profile adjustment factors. The results are the estimated monthly emissions, which can then be summed to derive the estimated annual emissions for the 99% acreage. Note that there are two subtotals: the growing canopy emissions, and the postharvest emissions. Different sets of factors are used to create these emissions subtotals, as shown in the calculation below. These two subtotals are then added to create the 99% acreage emissions total for each month. Only March is shown, but the remaining months are calculated in the same manner:

Final Monthly Emissions Calculation for 99% Acreage for Upland Cotton in Fresno County (March Plant/September Harvest)

| | | |
|---|---|---|
| Intermed.Annual Emiss.99%(tpy) | = IAE99 | = 38047.9 |
| Normalized C-Factor | = NCF | = 0.00263 |
| Irrigation Factor | = IrrF | = 1.0 |
| Replant Fraction | = RF | = 0.166667 |
| Canopy Cover Factor | = CCF | = 0.71643 |
| Postharvest Soil Cover Factor | = PHSCF | = 0.80332 |

Growing Canopy Fraction = GCF = 0.5
Postharvest/Preplant Fraction = PHPP = 0.5

**Equation 10:** 99%Growing Canopy Emissions Subtotal = 99GCES =

= IAE99 * NCF * IrrF * CCF * GCF =

= 38047.9 * 0.00263 * 1.0 * 0.71643 * 0.5 = 35.8

**Equation 11:** 99%Postharvest Emissions Subtotal = 99PHES =

= IAE99 * NCF * (1-RF) * PHSCF * PHPP =

= 38047.9 * 0.00263 *(1 - 0.166667) * 0.80332 * 0.5 = 33.4

**Equation 12:** 99%AcreEmissTotal = 99GCES + 99PHES =

= 35.8 + 33.4 = <u>69.2 tons per month for March</u>

**2. Bare Soil Adjustment: Assumed to be 0.5% of Planted Acreage for Nonpasture and 0.05% for Pasture Crops**

Most fields will have some areas that are barren. This may be due to uneven ground causing water accumulation, uneven irrigation, pest damage, soil salinity, soil toxicity, etc. Visual inspection of nonpasture farmland led to a determination that the average barren acreage would be less than 0.5% of the total crop acreage. This 0.5% is subtracted from the overall acreage to avoid double counting. For pasture the estimate was 0.05% of crop acreage. Additional investigations should further improve these estimates.

The intermediate annual emissions value (IAEBare) for the bare acreage is calculated almost the same as the IAE99 emissions calculation for the 99% (nonbare/nonborder) acreage. The only difference is that 0.5% of the acreage is used instead of 99% of the total acreage:

<u>Intermediate Annual Windblown Emissions Calculation for Bare Acreage for Upland Cotton in Fresno County(March Plant/September Harvest)</u>

Total Acreage = Ac = 338,000 acres

Bare Acreage = BareAc = 0.005 * 338,000 acres = 1,690 acres

**Equation 13:** Intermediate Annual PM Emissions Bare = IAEBare =

= BareAc * A * IIrr * C * K * L' =

= 1,690 * 0.025 * 45.2 * 0.254744 * 0.5 * 0.79 =

= <u>192.2 tons/year</u>

The final emissions calculation for the bare acreage is performed in the same manner as the 99% acreage, except that the bare regions do not have canopy cover or postharvest soil cover adjustments applied. The bare regions do have both long-term (cloddiness) and short-term (surface wetting) effects of irrigation, as well as the replant factor applied. The growing canopy emissions and the postharvest emissions subtotals are summed in the same manner as for the 99% acreage.

<u>Final Monthly Emissions Calculation for Bare Acreage for Upland Cotton in Fresno County (March Plant/September Harvest)</u>

Intermed.Annual Emiss.Bare(tpy) = IAEBare = 192.2

**Equation 14:** Bare Growing Canopy Emissions Subtotal = BareGCES =

= IAEBare * NCF * IrrF * GCF =

= 192.2 * 0.00263 * 1.0 * 0.5 = 0.25

**Equation 15:** Bare Postharvest Emissions Subtotal = BarePHES =

= IAEBare * NCF * (1 - RF) * PHPP

= 192.2 * 0.00263 * (1 - 0.166667) * 0.5 = 0.21

**Equation 16:** BareAcreEmissTotal = BareGCES + BarePHES =

= 0.25 + 0.21 = <u>0.5 tons per month for March</u>

**3. Border Adjustment: Assumed to be 0.5% of Planted Acreage for NonPasture and None for Pasture Crops**

All fields will have some type of border. Quite often the border area is relatively unprotected, and prone to wind erosion. Based on observations in the field, ARB staff estimated that, for nonpasture crops, the average border region would be less than 0.5% of the crop acreage. Again, this 0.5% is subtracted from the overall acreage to avoid double counting. Since pasture regions will usually not have a defined barren border region, no border adjustment was made for pasture acreage.

The intermediate annual emissions value (IAEBrdr) for the border acreage is calculated almost the same as the IAE99 emissions calculation for the 99% (nonbare/nonborder) acreage. The only differences are that 0.5% of the acreage is used instead of 99% of the total acreage, and the nonirrigated erodibility ("I") is used instead of the irrigated erodibility (IIrr):

<u>Intermediate Annual Windblown Emissions Calculation for Border Acreage for Upland Cotton in Fresno County (March Plant/September Harvest)</u>

Total Acreage = Ac = 338,000 acres

Border Acreage = BrdrAc = 0.005 * 338,000 acres = 1,690 acres

**Equation 17:** Intermediate Annual PM Emissions Border = IAEBrdr =

= BrdrAc * A * I * C * K * L' =

= 1,690 * 0.025 * 68 * 0.254744 * 0.5 * 0.79 =

= <u>289.1 tons/year</u>

The final emissions calculation for the bare acreage is performed in the same manner as the 99% acreage, except that the bare regions do not have canopy cover, postharvest soil cover adjustments, nor irrigation factors applied. The growing canopy emissions and the postharvest emissions subtotals are summed in the same manner as for the 99% acreage.

<u>Final Monthly Emissions Calculation for Border Acreage for Upland Cotton in Fresno County (March Plant/September Harvest)</u>

Intermed.Annual Emiss.Border(tpy) = IAEBrdr = 289.1

**Equation 18:** Border Growing Canopy Emiss. Subtotal = BrdrGCES =

= IAEBrdr * NCF * GCF

= 289.1 * 0.00263 * 0.5 = 0.38

**Equation 19:** Border Postharvest Emissions Subtotal = BrdrPHES =

= IAEBrdr * NCF * (1-RF) * PHPP

= 289.1 * 0.00263 * (1-0.166667) * 0.5 = 0.32

**Equation 20:** BorderAcreEmissTotal = BrdrGCES + BrdrPHES =

= 0.38 + 0.32 = <u>0.7 tons per month for March</u>

The calculated emission increase for the border regions will typically be even larger than that attributable to the bare areas. This is because the border regions are assumed to be nonirrigated. No irrigation factor (wetness), and no long-term irrigation adjustment to erodibility (cloddiness) are applied. In addition, the border regions don't have either a crop canopy or postharvest soil cover factor applied. As was the case with the bare soil adjustment above, the border regions also have the replanting adjustment applied.

**4. Final Single Cohort-Plant/Harvest Pair Emissions**

The final emissions for the Fresno County upland cotton cohort-plant/harvest pair, planted in March and harvested in September, is calculated by summing the emissions calculated for the nonbare/nonborder (99%) acreage, the bare acreage, and the border acreage:

**Equation 21:** SingleCohort-Plant/Harvest Pair Emissions =

= 99%AcreEmissTotal + BareAcreEmissTotal + BorderAcreEmissTotal =

= 69.2 tpm + 0.5 tpm + 0.7 tpm =

= **<u>70.4 tons per month for March</u>**

This process must be repeated for each cohort-plant/harvest date pair for upland cotton in Fresno County. To calculate the annual emissions, repeat the above process and then sum for all 12 months. Note that the bare and border emissions for the March planting month, calculated here, are a very small fraction of the overall emissions. As the canopy cover matures, in succeeding months, the bare and border emissions will become larger and larger portions of the total monthly emissions.

## IX. DEFINITION OF TERMS

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

*border adjustment* = Adjusts windblown emissions for the non planted 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* = Tendency of the soil to form large, relatively stable agglomerations upon 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* [6] = 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)= Used to estimate wind erosion. According to Leon Lyles [26]: "Erosive wind energy is defined by months as the sum of the cube of wind speeds between 8 and 20 meters per second (18-45 miles/hour) in 1-meter-per-second (2.2-mile/hour) 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

*kriging algorithm* = Calculation system for creating grids to generate 3-dimensional plots

*land preparation* = Usually postharvest and preplanting earth manipulation, including disking, plowing, chiseling, subsoiling, etc.; to breakup, turnover, level, shape, etc.

*long-term irrigation-based erodibility adjustment* [10] = This adjustment takes into account changes in cloddiness of the soil, based upon differences between irrigated and non irrigated 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

*monthly "C" factor profile* = Normalized profile of "C" factors including each month of the year

*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 fractions derived by comparing 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* [6] = 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

*replanting* (postharvest)= Multiple crops during a single annual cycle

*Revised Wind Erosion Equation* (RWEQ)[6] = 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. The model as a whole is still under study

*senescence* = Late-growing-season plant aging, often resulting in decreased canopy cover

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

*soil loss ratio* = 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 *soil texture wetness factor* [10] = Number of days for soil surface to dry after wetting. Based on testing of speed of drying of different soils (1 day for coarse soil, 2 for medium, 3 for fine)

*State Geographic Data Base* (STATSGO) [9] = Database of soil data produced and maintained by the NRCS

*Wind erosion equation* (WEQ) = 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) [7] = Detailed simulation model currently in development. May be useful in future, especially for episodic modeling

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April 22, 1997
WEQMTH97.WP

**ATTACHMENT A**
**1993 AREA SOURCE EMISSIONS**

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

**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 | Santa Barbara | 0.003190 | 80,732.00 | 257.56 |
| | San Luis Obispo | 0.006876 | 109,694.00 | 754.20 |
| | 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

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 | 1,108,000.00 | 1,225.03 |
| | San Benito | 0.00109336 | 512,000.00 | 559.80 |
| | Santa Cruz | 0.00016050 | 8,000.00 | 1.28 |
| SCC | Santa Barbara | 0.00021801 | 602,913.00 | 131.44 |
| | San Luis Obispo | 0.00046964 | 1,102,500.00 | 517.78 |
| | Ventura | 0.00050356 | 210,918.00 | 106.21 |
| SED | Imperial | 0.00867346 | 158,449.00 | 1,374.30 |
| SJV | Fresno | 0.00149089 | 907,300.00 | 1,352.69 |
| | Kern | 0.00082834 | 1,527,603.00 | 1,265.37 |
| | Kings | 0.00146875 | 142,777.00 | 209.70 |
| | Madera | 0.00116178 | 421,000.00 | 489.11 |
| | Merced | 0.00155578 | 642,700.00 | 999.90 |
| | San Joaquin | 0.00052280 | 167,700.00 | 87.67 |
| | Stanislaus | 0.00107875 | 434,300.00 | 468.50 |
| | Tulare | 0.00063424 | 713,400.00 | 452.47 |
| SV | Butte | 0.00014292 | 288,500.00 | 41.23 |
| | Colusa | 0.00046444 | 181,900.00 | 84.48 |
| | Glenn | 0.00048846 | 256,575.00 | 125.33 |
| | Placer | 0.00026499 | 65,656.00 | 17.40 |
| | Sacramento | 0.00019538 | 118,000.00 | 23.05 |
| | Shasta | 0.00034146 | 459,000.00 | 156.73 |
| | Solano | 0.00039453 | 131,360.00 | 51.83 |
| | Sutter | 0.00037084 | 71,500.00 | 26.51 |
| | Tehama | 0.00035146 | 955,350.00 | 335.76 |
| | Yolo | 0.00061919 | 136,870.00 | 84.75 |
| | Yuba | 0.00023892 | 207,600.00 | 49.60 |

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