MODELING ANALYSIS

INTRODUCTION

The modeling analysis evaluates the air quality measurements that violate the federal air quality standards. The evaluations use statistical methods and computer modeling to understand the meteorology and emission sources that are associated with each of the observed events. The measurements that violate the standard must also be evaluated to determine their relationship to the average of all measurements collected during a year (annual average) at each site. Based on the results of this analysis, a baseline connection between emissions and air quality is established for each site that violates one of the air quality standards. Using this relationship, and projection of what the emissions are expected to be in future years, the modeling analysis predicts how much additional emission reduction is needed to comply with the air quality standards. The proposed control measures can then be evaluated to determine if they are sufficient to provide enough additional emission reduction to achieve compliance in future years.

The modeling analysis is developed from the results of a series of analyses conducted pursuant to the modeling plan or protocol (Protocol). Air quality modeling analyses described in the Protocol are performed to support development of control plans and to demonstrate that the proposed control strategy is sufficient to achieve compliance of the federal annual and 24-hour PM10 National Ambient Air Quality Standards (NAAQS) in accordance with EPA guidance for the State Implementation Plans (SIP). Procedures for analysis have been selected to use the best available data to establish objective and reliable conclusions with the highest confidence. The modeling analysis establishes an attainment demonstration by successfully addressing all identifiable exceedances in the nonattainment area.

FEDERAL MODELING REQUIREMENTS

As required by federal guidance, air quality modeling analyses are performed to demonstrate that a proposed control strategy provides for attainment and maintenance of the PM10 NAAQS. The SIP submittals must include a description of how the modeling analysis was conducted by providing information on what models are used and why they were selected; model version and configuration information; assumptions involved in model application; discussion of model input data including meteorological data and ambient monitoring data; and description of model output data. The Protocol contains the required elements and can be found in Appendix K, identified as the “San Joaquin Valley Air Pollution Control District State Implementation Plan PM10 Modeling Protocol.” In accordance with federal guidance the Protocol was submitted to the EPA for review during development of the modeling analysis.

CHARACTERIZATION OF PM10 FOR MODELING

Characterizing PM10 for modeling requires scientific understanding of the physical and chemical properties, and sources and behavior of PM10. PM10 particle size, formation, composition, and chemistry provide a basis for addressing issues such as local contribution, regional contribution, and background pollutant levels. Developing an understanding of the principal factors and influences of PM10 concentrations provides a greater degree of certainty that the proposed control strategy reductions will have the desired and expected results, and that a projection of attainment has the highest degree of reliability achievable with current information.

Origins, Sources, and Properties of Particles

Airborne PM10 is not a single pollutant, but a mixture of many pollutants containing many different materials. Atmospheric PM10 occurs as fine and coarse particles that differ in size ranges, formation mechanisms, physical and chemical composition, and sources. Fine (PM1.0-PM2.5) and coarse (PM2.5-PM10) particles typically exhibit different behavior in the atmosphere and generally have distinct sources. The particle's formation mechanism affects the final size of the particle.

PM10 may be emitted from the same types of devices that contribute to other pollutants, such as, motor vehicle exhaust, fuel combustion, and industrial processes, where emissions are controlled through stacks or ducts. PM10 is also emitted from natural sources and formed in the atmosphere by a variety of physical and chemical processes that are not necessarily controlled by stacks or ducts. Fugitive dust is the term used for PM10 that comes from anthropogenic or natural activities emitted into the air without passing through a stack or duct that is designed to control flow, including emissions caused by movement of soil, vehicles, equipment and windblown dust.

A variety of diverse activities contribute to particulate matter concentrations: fugitive dust, such as road dust, motor vehicles, and wood smoke are the major contributors to ambient PM10 samples; and nitrates and organic carbon are the major secondary components. Other sources include fuel combustion from vehicles, power generation, and industrial facilities, residential fireplaces, agricultural burning, atmospheric formation from gaseous precursors largely produced from fuel combustion, wind blown dust, and construction and demolition activities. These diverse sources provide the mixture of substances that comprise PM10.

Most of the coarse fraction particles are emitted directly as particles and result from mechanical disruption and abrasion of surfaces, such as crushing, grinding, tire friction and evaporation of sprays, suspensions of dust from construction, agricultural operations, mining and wind erosion. In urban areas, much of the crustal material arises from soil that is tracked onto roads during wet periods, and is later pulverized and tossed into the air by vehicular traffic when it is in a dry state. A

variety of industrial operations, such as construction and demolition, freight hauling, rail traffic, and grain handling generate coarse particles. In rural areas, tilling, wind blowing over disturbed soil, or vehicles traveling on unpaved roads can generate coarse particles.

Fine particulate matter is formed by the condensation of gases emitted from combustion chambers; the condensation of atmospheric precursor gases, some of which may undergo further reactions in particles; and the condensation of low vapor pressure photochemical reaction products. Fine particles are usually formed from gases in three ways: (1) nucleation (the coming together of gas molecules to form a new particle), (2) condensation of gases onto existing particles, and (3) by liquid phase reactions. Gases may dissolve in a liquid or react with another dissolved gas. When fog and cloud droplets evaporate, particulate matter usually remains in the fine particle mode. Particles formed from nucleation also coagulate to form relatively larger particles, although such particles normally do not grow into the coarse size range. Major sources of these fine mode substances are fossil fuel combustion by electric utilities, industry, motor vehicles and vegetation burning. Major components of fine particles are: sulfate, strong acid, ammonium, nitrate, organic compounds, trace elements (including metals), and elemental carbon.

Chemistry and Physics of Atmospheric Particles

The major chemical constituents of PM10 are sulfates, nitrates, carbonaceous compounds (both elemental and organic carbon compounds), acids, ammonium ions, metal compounds, water, and crustal geologic materials. The amounts of these components vary from place to place, and over time. Fine and coarse particles generally have distinct chemical composition, solubility, and acidity.

Coarse particulate matter sources are primarily crustal, biological, or industrial in nature. Crustal material, from soil or rock, primarily consists of compounds that contain silicon, iron, potassium, aluminum and magnesium. This material is commonly present as aluminosilicates and other oxides of crustal elements in soil dust. It is also derived from fugitive dust from roads, industry, agriculture, construction and demolition. Additional contributions are from plant and animal material. Biological material, including fungal spores, pollen, and plant and insect fragments, are examples of natural bioaerosols, which are also suspended as coarse particles.

Fine particulate matter in the atmosphere is mainly composed of varying proportions of six major components: sulfates, acids, nitrates, elemental carbon, organic carbon, and trace elements, such as metals. Fine particulate matter is derived from combustion material that has volatilized and then condensed to form primary particulate matter or from precursor gases reacting in the atmosphere to form secondary particulate matter. Sulfur oxides (SOx), nitrogen oxides (NOx), and certain volatile organic compounds (VOC) are major precursors of fine secondary particulate matter. Fine particles or vapors that rapidly form fine particles are emitted during the combustion of fossil fuels, and incineration of wastes. Fine

particles are formed by the nucleation of gas phase species, and grow by coagulation (existing particles combining) or condensation (gases condensing on existing particles). Fine particles can be thought of in terms of two modes or stages of formation: a nuclei or ultrafine mode of freshly generated particles, and an accumulation mode where particles grow into particles from precursor gases and remain stable in the accumulated larger size. Chain agglomerates of very small elemental carbon particles are formed during combustion, such as in open-hearth fireplaces, wood stoves and diesel engines. Incomplete combustion forms hundreds of organic compounds with low enough vapor pressure to be present in the atmosphere as organic carbon particles. Small amounts of iron and potassium are also found among fine-mode particles, but they come from different sources, such as brake wear (iron) and wood combustion (soluble potassium).

Sampling and analysis are used to establish the typical components found in the emissions of a source. This source signature or fingerprint is referred to as a speciation profile. Many sources have components in common. For example, the PM10 emitted by the tires of a vehicle on a road is almost identical to windblown emissions from the adjacent land. To the extent which these signatures can support reliable identification, the various signatures are used in modeling to identify the contributing sources to observed events.

Analysis of filters reveals that different meteorological conditions and sources affect particle formation. Colder, frequently stagnant conditions occurring in December and January favor formation of ammonium nitrate. Secondary PM10 species, such as ammonium nitrate, ammonium sulfate, and organic particles are formed through chemical interactions from directly emitted SOx, NOx, VOC and ammonia. Particulate sulfate and nitrate can form via both gas and aqueous phase pathways. In the aqueous phase, which is the main pathway during winter fog and cloud conditions, secondary ammonium nitrate and ammonium sulfate form when nitric acid and sulfur dioxide (SO_2) dissolve in water droplets and then react with dissolved ammonia. Since the sulfate and nitrate ions compete with each other for the available ammonia, pollutants such as, SOx, NOx, and ammonia must be treated as a coupled system in order to adequately understand the interactions and subsequent formation of nitrate and sulfate particles.

Atmospheric Behavior, Transport and Fate of Airborne Particles

Coarse particles are large enough so that the force of gravity exceeds the buoyancy forces of the air. Coarse particles remain in the atmosphere for a few minutes or up to several hours, rapidly falling out of the air unless kept aloft by vigorous mixing and convection that occurs during dust storms and high winds. Coarse particles tend to be less evenly dispersed around urban areas than smaller particles, exhibiting more localized elevated concentrations downwind of their emission point and traveling as little as a kilometer to as much as twenty or thirty kilometers.

Fine particles may be directly emitted (primary PM10) or formed by atmospheric transformation of gases to particles (secondary PM10). Atmospheric transformation

can take place locally during stagnations or during transport over long distances. Since fine particles may remain suspended for much longer periods of time and travel much farther than coarse fraction particles, these particles tend to be more uniformly dispersed than coarse fraction particles across urban or large geographic areas. Fine particles are small enough to be kept aloft by the buoyancy forces of the air and as a result are not easily traced back to their source of origin. Ultrafine or nuclei-mode particles tend to exist as individual particles for very short periods of time (less than minutes) in the ambient atmosphere, and they tend to age rapidly into larger accumulation particles that may be dispersed more widely over long distances. Fine particles formed from accumulation processes have very long half-lives in the atmosphere, may travel long distances, and tend to be more uniformly distributed over large geographic areas than coarse particles. Fine accumulation particles have the potential to remain in the atmosphere for days or weeks traveling as much as hundreds to thousands of kilometers. However, removal occurs when the particles absorb water, grow into cloud droplets, grow further to raindrops, and fall out as precipitation. This process reduces the typical atmospheric half-life to a few days.

The transport of PM10 has not been definitively quantified. The transport of a pollutant is when it originates from a source in one area of an air basin or from another air basin, and it becomes transported to another area or air basin where it contributes to the condition of the air quality. Currently available monitoring and speciation techniques are not able to identify the origin of PM10 sources with sufficient detail to indicate if the SJVAB is experiencing transport from outside the air basin or contributing transport of PM10 to other air basins. PM10 readings in the SJVAB are most severe during the fall and winter periods when wind speed and direction are not conducive to interregional transport. Transport of some PM10 precursors has been studied as part of ozone transport evaluation, which consisted of identifying transport of ozone and ozone precursors from and to other air basins surrounding the SJVAB. The transport of ozone was documented during the summer when the highest ozone readings are more likely to occur. This transport includes precursors of ozone and PM10; however, the amount of PM10 that could be generated in the SJVAB or other air basins from such transport has not been quantified. Pollution from areas outside of the SJVAB may or may not contribute to high PM10 levels within the SJVAB.

UNDERSTANDING LOCAL EPISODES AND ANNUAL CONCENTRATIONS

Types of particulates include directly emitted (primary) particulates, and indirectly emitted (secondary) particulates, which are emitted as gases, but become particles in the atmosphere due to a variety of processes. The secondary particulates include increases in elemental and organic carbon, and nitrate and sulfate particulates. The carbon of secondary particulates is associated with motor vehicles, residential and agricultural wood combustion, industrial emissions, and charbroiling. Sulfates are associated with diesel emissions, and nitrates are associated with motor vehicle and industrial emission of nitrogen oxides.

Prior source apportionment receptor modeling has identified the major contributors at all sites as primary geological material during the summer and fall, and secondary ammonium nitrate during the winter. Other contributions that were considered significant at one or more sites on one or more occasions included motor vehicle exhaust, field and fireplace vegetative burning, construction, secondary formation of ammonium sulfate, secondary formation of organic particulates from anthropogenic and biogenic VOC emissions, oil combustion, and marine aerosols in some portions of the SJVAB.

Ambient Air Quality Data

The EPA requires that the state and the District measure the ambient levels of air pollution to determine compliance with the NAAQS. The District and the state operate the ambient monitoring network to gain a better understanding of actual conditions and to comply with this mandate. The required network has also been supplemented by conducting major field studies to collect additional information to improve understanding of the observed episodes, and their causes and contributing sources. Ambient monitoring samples were analyzed to determine the chemical make-up of the PM10 collected on the filter. Ambient air quality samples indicate that different causes are related to elevated PM10 levels occurring in different seasons.

Extensive seasonal variation has been established for sources contributing to PM10 concentrations and the atmospheric processes that contribute to particle formation and retention. The period of October through January generally includes the most frequent and severe exceedances of the federal 24-hour PM10 standard. During the October to January period, the PM10 concentrations undergo a shift from dominance by primary particles to dominance by secondary particles. Secondary particles are a major fraction in colder, wetter periods, but are present in smaller amounts before mid-November. The October through January period is discernable as dividing into two overlapping periods that develop different event types. The first of the two periods of the year is during the months of October and November, occasionally extending into December. The seasonal transition date ranges from mid-November to mid-December. Nitrates start increasing in mid-November, and geologic materials do not decline until there is significant rainfall, which can occur anytime from mid-November to mid-December. The second type of episode distribution is linked to a regional change in meteorology. Air monitoring data indicates that when meteorological conditions produce little or no air movement with cold air temperature, secondary particulate levels (largely ammonium nitrate) are elevated in the entire SJVAB and reach levels above the air quality standard in several urban areas.

The October and November episodes that have occurred in the last several years were low wind speed events. High wind PM10 events are not typical within the SJVAB, but they have occurred and have contributed to high PM10 concentrations in the past. The October-November low wind speed events tend to be localized

stagnation events with wind speeds that are insufficient to disperse high PM10 concentrations. These episodes affect only a few urban areas in the SJVAB. Air quality field programs identified the highest concentrations of PM10 in urban areas. In these episodes, anthropogenic (human) activities entrain PM10 in fugitive geological dust, adding to emissions dispersing from surrounding agricultural operations. The emissions inventory for the SJVAB indicates that most of the directly emitted PM10 is due to open area fugitive geological dust sources. Anthropogenic sources (paved and unpaved road dust, farming operations, and construction/demolition) account for most of the fugitive geological PM10 emissions, and wind erosion of exposed surfaces of geological material accounts for the balance as represented in the emissions inventory. However, downwind ambient PM10 concentrations are not proportional to the emission estimates of fugitive geological PM10 emissions. Most of the large geologic particles settle to the ground within a few kilometers of their source when wind velocities are low; therefore, significant contribution to the urban area exceedances involve only the emissions of large PM10 particles that occur in the urban area and within a few kilometers of the urban area. Implementing control measures for fugitive emissions of geological origin is especially valuable during these months when the contributions from geological sources are highest.

The second elevated PM10 period of the year begins mid-November to mid-December, and it extends through February. This season is characterized by extended periods of stagnant air interspersed with cold, damp, foggy conditions conducive to the formation of particulate nitrate in amounts that are frequently the dominant component of PM10 (often 70 percent or more of the material found on a filter). During the last several years episodes dominated by increased levels of nitrate particulates and primary and secondary carbon occurred in December and January. These episodes occurred during long stagnation periods in cold weather and affected one or more urban areas. The District prohibited agricultural burning (no-burn status) during these events based on meteorology with poor dispersion to limit emissions. Residential wood combustion, particles formed from exhaust gases and poor dispersion of emissions contribute to PM10 buildup in these events.

Both seasonal periods with PM10 exceedances commonly experience stagnant conditions. During a stagnant period, primary geologic or secondary particulates accumulate, resulting in concentrations that eventually exceed the PM10 standard.

Design Values

A design value is the representative value for an air quality standard at an ambient air monitoring site. Design values are established by EPA rules for evaluating monitoring measurements for each monitoring site and for each air quality standard. When the design value is not in compliance with the NAAQS for a pollutant, the design value is used to establish the amount of air quality improvement that is needed to achieve compliance with the standard.

Data recorded at each monitoring site is used to determine the design value for each of the two PM10 standards, (a) the annual average PM10, and (b) the 24-hour PM10. The annual design value is intended to represent the average value of the last three years of complete, quality assured data. Each quarter of a year is averaged as a group so that extra or missing measurements do not unduly influence the design value average. All of the valid 24-hour samples collected at each site over the same period are used to establish the 24-hour PM10 design value. This value represents the peak, valid value observed at each site.

The design value is used as the baseline ambient concentration in modeling efforts to determine whether projected emissions reductions will be sufficient to reduce PM10 concentrations to levels that meet the federal standards.

PM10 concentrations in the SJVAB vary between sites and seasons with regard to sample speciation and contributions from specific source types. For this reason, use of a single design value for the entire SJVAB is not appropriate, and a design value was calculated for each site. The PM10 annual and 24-hour NAAQS require two separate design concentrations, one for each standard per site. The annual design concentration is the expected annual arithmetic mean. The uncertainty in the design concentration estimate is reduced to the extent that sufficient, representative meteorological and monitoring data are available. At least three years of representative air quality measurements are considered in determining 24-hour design concentrations. For a thorough discussion of how design values were determined, please see Appendix K, Modeling Protocol.

Only eight of the 15 sites had complete data sets for establishing the annual design value. These sites are: Bakersfield-California Ave., Clovis, Corcoran, Fresno-First, Modesto-14th Street, Oildale, Stockton-Hazelton, and Visalia. Special calculation procedures directed by federal guidance are used to establish design values for the sites with incomplete data.

Table 5-1
Federal 24-Hour PM10 Design Values

Site Name	Design Value	1999	2000	2001
Bakersfield - California Ave.	**190**	143	140	**190**
Bakersfield - Golden #2	**205**	183	145	**205**
Clovis	**155**	151	114	**155**
Corcoran - Patterson Ave.	**174**	**174**	128	165
Fresno - Drummond	**186**	162	130	**186**
Fresno - First	**193**	154	138	**193**
Hanford - Irwin St	**185**	143	119	**185**
Merced - M Street	134	**134**	104	113
Modesto - 14th Street	**158**	132	112	**158**
Oildale - 3311 Manor St	**158**	156	122	**158**
Stockton - Hazelton-Hd	150	**150**	91	140
Stockton - Wagner-Holt	119	118	104	**119**
Taft - College	128	101	99	**128**
Turlock - 900 Minaret Street	**157**	**157**	104	148
Visalia - Church Street	152	**152**	130	143

Design Value Column – bold indicates value exceeds standard
Year Columns - bold indicates observed value that set the Design Value

Table 5-2
Federal Annual Average PM10 Design Values

Site Name	Calculated by SJVAPCD	Reported in EPA Notice
Bakersfield - California Ave.	48	
Bakersfield - Golden #2	**57**	**55**
Clovis	43	
Corcoran - Patterson Ave.	49	
Fresno - Drummond	50	47-**53**
Fresno - First	42	
Hanford - Irwin St	**53**	**51**
Merced - M Street	40	
Modesto - 14th Street	37	
Oildale - 3311 Manor St	46	
Stockton - Hazelton-HD	35	
Stockton - Wagner-Holt	30	
Taft - College	36	
Turlock - 900 Minaret Street	39	
Visalia - Church Street	**54**	**54**

MODELING METHODOLOGY

Analysis of PM10 concentrations, chemical composition, and meteorology has provided information of the temporal and spatial behavior of PM10 in the SJVAB. The results reveal three different situations that must be addressed:

- Sites with annual average concentrations above the 50 µg/m³ standard;
- Sites with 24-hour levels above 150 µg/m³ in the fall (October to mid-December, sometimes transitioning as early as mid-November), with largest contribution from geologic sources; and
- Sites with 24-hour levels above 150 µg/m³ in the winter (mid-November to mid-December through February), with largest contribution from secondary formation and fine particulate matter sources.

Annual average concentrations above the 50 µg/m³ level, and both types of events with levels above 150 µg/m³, were examined for attainment.

Evaluation is not required at sites with annual design values at or below 50 µg/m³ (rounded to the nearest microgram) and sites with 24-hour design values at or below 150 µg/m³ (rounded to the nearest ten microgram level). However, areas with design values in compliance with the standards do have emissions that contribute to the concentrations observed in locations that do not comply with the standards. Therefore, the contribution to regional levels from sites in compliance were considered for current and projected future years when evaluating the sites with concentrations above the standards.

Emissions Inventory Preparation for Modeling

The District and ARB maintain annual emission inventories of permitted emissions and of estimates of mobile source, area source, and naturally occurring emissions. Emissions inventories were examined and structurally modified for correlation and analysis of observed exceedances. Similar adjustments were made to prepare modeling inventories representative of different seasons. The emissions were grouped as required for CMB analysis and rollback projection. The emission inventories for modeling were also prepared to address the appropriate spatial scale, with an understanding of the appropriate area identified as influencing the ambient concentration at the monitor.

The emissions inventories prepared to correlate with observed design values are called modeling base year inventories. Since these are intended to reflect emissions connected to the design value concentrations, the inventories are not the same as baseline inventories used to establish current District emissions. Projections of future year seasonal emissions without additional controls establish future year projected modeling projections. Projections of future year seasonal emissions

inventories with controls to achieve attainment are referred to as attainment inventories and can be found in Appendix J.

Modeling Protocol

The Protocol outlines the procedures and technical considerations involved in the modeling analysis for the PM10 Plan for submission to the EPA for review and comment. The ARB, District, and Regional Transportation Planning Agencies (TPAs) have jointly prepared data analyses, emissions inventories and modeling analyses to address modeling requirements for the PM10 Plan. Modeling has been conducted with jointly developed input files and mutually accepted modeling assumptions.

Purpose of the Protocol

The goal of the Protocol is to determine an effective program of emission control, establishing the necessary amount and types of emission reduction that must be implemented to achieve compliance with the federal annual and 24-hour PM10 NAAQS.

The Protocol contains a series of evaluation elements including meteorological evaluation of the factors affecting PM10 concentrations and evaluation using a variety of accepted statistical methods to evaluate the factors related to known and observed episodes and to identify other combinations, patterns and factors not captured by monitoring that are potentially capable of causing PM10 episodes. The analysis also establishes the representativeness of transport and formation of PM10 observed in historical episodes. Modeling of the observed episodes and predicted changes are conducted using receptor modeling with the chemical mass balance model (version CMB 8) for annual and episode conditions at sites that currently do not comply with the federal PM10 NAAQS; regional modeling of secondary particulates by ARB using two regional scale models; and a photochemical box model evaluation to address aerosol chemistry. Episodes evaluated include time periods related to observations that are required to be analyzed for the SIP and episodes observed by additional monitoring during the December 1999 to January 2001 field study monitoring period for the California Regional PM10/PM2.5 Air Quality Study (CRPAQS).

Assumptions

Establishing modeling assumptions and background values requires understanding baseline and projected inventories; air monitoring data; and the properties, sources and behavior of PM10. In addition, the spatial influence of emissions sources and an estimation of background levels must be considered. When assessing secondary PM10, atmospheric reaction processes and rates must also be considered.

Factors essential for modeling analysis include:

- Origin and properties of particles;
- Chemistry and physics of atmospheric particles;
- Atmospheric behavior, transport and fate of airborne particles; and
- Background concentrations to support modeling.

Background Concentrations to Support Modeling

Background concentrations are an input for the specified rollback modeling to identify particulate matter that is not part of the emissions inventory and would not be reduced by local control measures. For modeling purposes, background particulate matter includes particulate matter from natural sources (local, regional, offshore emissions), and the transport of anthropogenic emissions, both particulate matter and precursor emissions of VOCs, NOx, and SOx, into the SJVAB from adjacent air basins and the surrounding region. To prevent overestimation of control effects, emissions from outside of the SJVAB must be treated as background in the modeling process to discriminate the portion of the measured PM10 affected by control strategies. The modeling definition of background is different than would be used for health assessment studies, where background is limited to natural sources and all anthropogenic emissions are evaluated for their cumulative health impact. Background levels of particulate matter vary by geographic location and season and can be higher on an episodic basis. Specific natural events such as wildfires, volcanic eruptions, and dust storms can lead to very high levels of particulate matter. Disregarding such large and unique events, an estimate of background on a daily and episodic basis can be obtained from reviewing multi-year and special field study data.

The natural component of the background contributes to both fine and coarse particles in the atmosphere, and arises from physical processes of the atmosphere that entrain particles of crustal material (PM10 contained in soil, classified as geologic material) as well as from emissions of organic particles and gases from vegetation and natural combustion sources such as wildfires that form secondary particulates. Background natural particulates and particulate precursor emission sources include: wind blown dust from erosion; sea salt; particles formed from the sulfur compounds emitted from oceans and wetlands; NOx from natural forest fires and lightning, and hydrocarbons emitted by vegetation. Living organic matter, including fungal spores, pollen, bacteria, viruses, endotoxins, and non-living organic matter, such as animal and plant debris, also contribute to the PM10 mass. Bacteria and viruses are mainly found attached to aerosol particles and their mass will be attributed to those aerosols. Fungal spores, pollen, and animal and plant debris are found as separate particles. Fungal spores occur mostly in the 2 to 4 mm size range and form the largest and most consistently present component of biological aerosols in ambient air. Levels of fungi and bacteria, which vary seasonally, are generally higher in urban than in rural areas. They are highest near compost and agriculture activities.

The exact magnitude of the natural portion of particulate matter for a given geographic location cannot be precisely determined because the natural emissions are indistinguishable from the long range transport of anthropogenic particles or precursors. Regional annual average natural background levels are estimated as 4 - 8 $\mu g/m^3$ PM10 and 1-4 $\mu g/m^3$ PM2.5 for the western US. Annual average PM10 concentrations in national parks, wilderness areas, and national monuments in the western US range from 5 to 10 $\mu g/m^3$ based on data from Interagency Monitoring of Protected Visual Environments (IMPROVE).

Utilization of Application Assumptions

Particle dynamics, physics, and atmospheric behavior and fate establish background and regional contribution estimates. These estimates are assumptions considered in rollback calculations. If such assumptions were not utilized, the analysis would link all of the observed particulate to local quantified sources. This would overstate the predicted effectiveness of controls. The assumptions for background and regional components are included to ensure that control effectiveness is not overstated (occurring if background levels are set too low), which could potentially lead to a failure to attain, or understated (if background levels are set too high), which would underestimate control effectiveness and require implementation of excessive control measures. For modeling purposes, background particulate matter includes the distribution of particulate matter from natural sources as well as anthropogenic emissions of particulate matter and precursor emissions of VOCs, NOx, and SOx from areas outside of the SJVAB.

Determination of Appropriate Modeling Approach

While several techniques are available to model the direct emission, secondary formation, and dispersion of particulate matter, selecting a methodology that is appropriate for the SJVAB is important. The methodology needs to consider and compensate for the strengths and weaknesses of available approaches. Based upon availability of emission estimates, meteorology, and air quality data in the SJVAB, the use of receptor CMB modeling is proposed, with the support and enhancement of regional aerosol modeling to evaluate secondary formation ratios, and with profile selection for CMB modeling enhanced by assessment of local temporal and spatial emission distribution.

MODELING ANALYSIS COMPONENTS

Meteorological Evaluation

Meteorological data are used to assess the potential for air pollution to accumulate in certain locations. Weather factors that may restrict horizontal and vertical air movement of air masses are important factors in air quality. Vertical movement of air disperses pollutants vertically, while horizontal movement spreads the pollutants

over a wider geographic area. The greater the velocity of wind in the mixing layer, the greater the amount of mixing (dispersion) and transport of pollutants.

Statistical Analysis of Meteorology and Air Quality

Meteorological and statistical analysis was conducted by the District and ARB in order to examine the representativeness of episodes, both historical and present, and to categorize the meteorological regimes and pollution episodes that are being analyzed by CMB analysis as well as to determine seasonal differences in the influence of meteorological variables. Local, regional and mesoscale weather patterns were analyzed by the District to determine key weather features that produced poor dispersion and transport during PM episodes.

Each episode was characterized by a prolonged period (two to three weeks) of limited mixing and light wind flow. During each episode, cold air at the surface and warm air above the mixing layer trap pollutants. Horizontal movement of air was minimal and disorganized reducing dispersion and transport of pollutants. These conditions cause particulates to accumulate throughout the Valley. Under these poor mixing conditions, coarse and fine particulates accumulated and led to high particulate concentrations. Winter exceedances (December and January) were characterized by an increase in fine particles to a level that dominated filter samples. Fall exceedances (October and November) were dominated by coarse particles. To a lesser extent in the fall and a greater extent in the winter, cool damp mornings and restricted vertical air movement contributed to the formation of nitrates and sulfates. Total carbon concentrations from combustion sources remained proportionally the same during the fall and winter exceedances. Due to stagnant weather conditions, the elevated PM10 measurement that resulted in an exceedance of the Federal Standards were caused primarily by local emission sources, rather than background or long-range transport material.

The October 1999 particulate episode was unique and did not follow the general meteorological and chemical pattern observed in other episodes. Concentrations during this event were dominated by geological particles (PM_{10}), with significant contributions from fine particulates of ammonium nitrate and sulfate and total carbon. The abundance of fine particulates in the samples may have been due to abnormalities in atmospheric chemistry reactions. Due to several wildfires to the north and a major tire fire at Westley earlier in October, particulate loading aloft may have decreased solar radiation intensity measurements across the Valley Floor. With reduced solar radiation, the atmospheric chemistry reactions may have changed from the ozone forming regime of mid-October to the secondary particulate regime of late November. As a result, the geological particulates dominated the samples, but the fines exerted a large influence. Due to limited afternoon heating and stagnant weather conditions, local sources contributed to the elevated readings, causing PM_{10} concentrations to exceed the Federal Standards. Please see a separate reference document to this Plan for meteorological analysis details.

Various statistical models were applied, including CART 3.6 analysis by the ARB to determine key predictive and common factors. Both qualitative meteorological analyses and statistical analysis determine whether episodes occur from common or unique factors. The analysis of different meteorological regimes identifies the frequency and extent to which pollutant concentrations are influenced by the local, regional and mesoscale meteorology. This is important to establish representative criteria for SIP development. Also, classification and identification of critical factors with CART analysis assists in the representativeness evaluation and improves parameter identification and weighting for forecasting. Please see Appendix L for a CART Summary Report.

Chemical Mass Balance (CMB) Receptor Modeling

Receptor modeling using the chemical mass balance model (version CMB 8) was conducted for annual and episode conditions at sites that currently do not comply with the federal PM10 air quality standards. This method uses chemical analysis of collected air monitoring samples and information about the chemical composition of contributing sources to evaluate the link between observed conditions and emission sources. The District used the results of the CMB analysis with a modified rollback approach to calculate the effect on design values of predicted aggregate adopted and proposed control measure reductions and other predicted emission trends to establish attainment at sites noncompliant with the NAAQS. This method works well for analysis of directly emitted particles, but it is less certain in predicting the effect of reductions of secondary precursors. The Protocol proposes supplementing the receptor modeling with findings from regional modeling of secondary particulate formation to factor in potential nonlinear secondary particle formation.

CMB Analysis with Linear Rollback

CMB analysis with linear rollback can be applied to short and long term data. However, the lack of treatment of meteorology in the model affects seasonal and annual average modeling less than it affects modeling of a 24-hour episode. In the rollback projection, ambient pollutant concentrations are linked to CMB receptor analysis of source contributions. The output of the CMB receptor model was used with linear rollback to combine the most accurate source identification available with a reliable technique for assessing control programs.

Urban Airshed Modeling (UAM)

Regional modeling of secondary particulates was conducted by ARB with a version of the Urban Airshed Model modified to address aerosol chemistry (UAM-Aero). This model was used to learn as much as possible from the IMS-95 dataset (an early component of CRPAQS) by evaluating a monitored event of nitrate particulate formation. Additional analysis of the dataset with modeling techniques under development for CRPAQS was used for comparison to the UAM-Aero results. Results improve understanding and provide useful secondary particle formation rates and precursor ratios, particularly for nitrate particulates, and can be viewed in

Appendix M. Results are used in conjunction with receptor modeling to enhance the accuracy and reliability of predicted effects of emission trends and adopted and proposed control measure reductions of secondary precursors.

MODELING RESULTS

Combining the results of the meteorological and statistical analysis allows evaluation of whether the monitoring data and design value represent the likely worst case value, which would be a more stringent design value than is required, or whether the monitoring data may represent something less than the fourth highest likely value, which may not be sufficiently protective. Receptor and regional modeling allow evaluation of future NAAQS compliance by rollback analysis.

Simulation of Observed Particulate Concentrations

CMB receptor modeling is an analysis method used to link observed levels of particulates to the sources of emissions grouped into source categories. The CMB model links the speciated chemical composition of the filter sample at the site to emissions inventories that represent the emissions at the time of the 24-hour observation, or represent seasonal or annual average values as appropriate. Where emission information is lacking for a particular component (e.g., seasonally resolved mineral dust emissions), rollback can still be applied to other components.

Annual: Evaluation of annual concentrations by receptor modeling to determine probable source contributions must include appropriate consideration of, and adjustments for, seasonal differences in sources and seasonal differences in atmospheric conditions that affect particle origin, formation and atmospheric residence time. In addition to CMB modeling of episode days, monthly averages for required sites have been modeled to develop annual average contribution estimates.

Table 5-3
Federal Annual PM10 Design Values For Analysis

Site Name	Calculated by SJVAPCD	Reported in EPA Notice
Bakersfield-Golden #2	**57**	**55**
Fresno-Drummond	50	47-**53**
Hanford, Irwin St	**53**	**51**
Visalia, Church Street	**54**	**54**

24-Hour Episodes: Exceedances were characterized and grouped by chemical speciation and source attribution based on conceptual models, data evaluation and modeling analyses. This information has been used to help identify the contributing sources. For 24-hour exceedances where ammonium and nitrate ions are a significant fraction of the total particulate mass, particle speciation, gaseous

concentration, meteorological, and emissions data have been analyzed to attempt to determine the limiting precursor.

Table 5-4
Federal 24-Hour PM10 Design Values For Analysis

Site Name	Design Value	1999	2000	2001
Bakersfield, California Ave.	**190**	143	140	**190**
Bakersfield-Golden #2	**205**	183	145	**205**
Clovis	**155**	151	114	**155**
Corcoran, Patterson Ave.	**174**	**174**	128	165
Fresno-Drummond	**186**	162	130	**186**
Fresno-First	**193**	154	138	**193**
Hanford, Irwin St	**185**	143	119	**185**
Modesto, 14th Street	**158**	132	112	**158**
Oildale, 3311 Manor St	**158**	156	122	**158**
Turlock, 900 Minaret Street	**157**	**157**	104	148

Design Value Column – bold indicates value exceeds standard
Year Columns - bold indicates observed value that set the Design Value

Conclusions

The modeling conducted for the 2003 PM10 Plan meets EPA criteria for areas designated as serious nonattainment for PM10. As was indicated throughout this plan, the San Joaquin Valley's PM10 problem is complex. The District and ARB used the best modeling tools available to address this complexity and to provide reasonable assurance that the control strategy will attain the NAAQS.