A STUDY OF AIR QUALITY CONDITIONS INCLUDING EMISSIONS INVENTORY, OZONE FORMATION, PM_{10} GENERATION, AND MITIGATION MEASURES FOR MENDOCINO COUNTY, CALIFORNIA

FINAL REPORT

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Prepared for:
Mendocino County Air Quality Management District
Ukiah, CA

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November 16, 1998

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EXECUTIVE SUMMARY

Mendocino County has generally good air quality. However, on a few occasions each year, air quality monitoring locations in the county measure 24-hr average particulate matter (PM_{10}) concentrations at levels which exceed the State of California's air quality standard. In addition, in recent years (1997 being the exception) Mendocino County has experienced increasing ozone levels, with peak ozone concentrations in Ukiah approaching the California State Ozone Standard. Since the population of Mendocino County is expected to grow about 50% over the next 25 years, the Mendocino County Air Quality Management District (MCAQMD) sponsored this study to provide a better understanding of the ozone and PM_{10} sources impacting the county.

Ozone Formation

There are two types of ozone that the public hears about in the news: (1) ground-level ozone (i.e., tropospheric ozone) and (2) stratospheric ozone (i.e., the "ozone layer"). Ground-level ozone is of concern to human health and plant-life due to direct exposure, while the stratospheric ozone layer provides protection to the earth from the sun's ultraviolet radiation. This study is only concerned with ground-level ozone. Ozone is a secondary pollutant formed by the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOC). The precursors to ozone (i.e., NO_x and VOCs) have both anthropogenic (man-made) and biogenic (natural) origins.

Particulate Matter

Particulate matter (PM) can be categorized by size and the type of physical process that produces the PM. Particles less than 2.5 μm diameter (fine particles) are principally due to atmospheric reactions, combustion processes (e.g., residential fuel combustion, and internal combustion vehicles), and some industrial processes. Fine particles produced by atmospheric processes from gaseous emissions are referred to as secondary particles. Coarser particles (less than 10 μm and greater than 2.5 μm) are usually associated with mechanical processes, including wind blown dust, re-entrained road dust, crushing and grinding, and tire wear. All particulate matter smaller than 10 μm (PM_{10}) is considered to be a potential threat to public health.

In most communities, ozone and particulate matter problems are a function of two broad factors: (1) local pollutant emissions from area, stationary, and mobile sources; and (2) transported pollutant emissions from an upwind area. In more rural areas, mobile sources (e.g., road dust for PM, and VOC and NO_x for ozone) tend to dominate in importance, unless there is significant pollutant transport, or there is a particular plant or factory that contributes directly emitted PM or ozone precursors. In the wintertime in these areas, wood-burning stoves and fireplaces are significant contributors to PM_{10} problems, since road dust is reduced on both paved and unpaved roads due to the increased moisture.

ES.1 STUDY OBJECTIVES

To determine the influences on Mendocino County's ozone and PM air quality and to propose ways in which the county can mitigate the impacts of growth on air quality, this project took a three-pronged approach:

(1) a study of past, present, and future ozone formation (and transport) in the county was conducted,

(2) an evaluation of the current emission inventory and projections to future years was prepared, and

(3) identification of potential mitigation measures appropriate to Mendocino County for ozone and PM_{10}.

The study of air quality conditions included the characterization of the meteorological conditions conducive to high ozone concentrations in the Ukiah-Little Lake Air Basin (e.g., Willits and Ukiah) and PM concentrations in Fort Bragg as well as the Ukiah-Little Lake Air Basin. The evaluation of the current county-wide emission inventory for PM and ozone precursors (e.g., VOC and NO_x) included separate assessments of the representativeness of emission factors and associated information used by the California Air Resources Board (ARB) to estimate emissions in Mendocino County. Emission estimates for on-road motor vehicles were given special attention, with detailed estimates prepared for sub-sections of the county. Special attention was also taken to prepare seasonally adjusted emission estimates for summer and winter regimes. To identify appropriate potential mitigation measure options for the county for ozone and PM, existing control plans in a variety of communities were examined. The examination provided a range of potential control measures available to County officials.

ES.2 RESULTS

ES.2.1 Ozone

Key Findings:

- Ozone concentrations in the Ukiah Valley have been measured at or near the level of the State Ozone Standard. Though the frequency of peak concentration events has been decreasing, the number of hours of ozone above natural background levels are showing a distinct trend upwards.
- To limit the contribution of local emissions to the increasing ozone levels, controls on ozone precursors (e.g., NO_x and VOC) must be considered.

- Analyses of local ozone precursor emissions in Mendocino County show that biogenic emissions are by far the single largest VOC source county-wide, and biogenic VOC emissions are substantial when compared to man-made VOC emissions in the Ukiah Valley. Man-made NO_x emissions dominate natural sources. Currently, the largest source of NO_x emissions is on-road mobile sources.
- Using future year projected emissions, ozone levels from local emissions are expected to decline or remain the same, if regulatory control programs remain in effect.

Other findings are summarized below.

- **Comprehensive ozone precursor data are non-existent.**

Air quality stations established to monitor compliance with air quality standards do not provide sufficient data to fully understand the causes of ozone formation and transport. For example, the ozone precursors, hydrocarbons and NO_x, are not adequately measured in Mendocino County. Currently, as in all but the most highest populated urban areas of the State, no hydrocarbon samples are collected in Mendocino County.

- **Ozone concentrations measured in Ukiah may not represent the highest concentrations in the Ukiah Valley.**

The ozone data collected at the E. Gobbi site in Ukiah appear to be somewhat titrated by fresh emissions of NO. Although the ozone measured at the E. Gobbi site are probably representative of the Ukiah urban core, they are probably not representative of the highest ozone values for the Ukiah Valley. Since a large percentage (i.e., 69 percent of the County total according to the 1996 U.S. Census Bureau) of Mendocino County's population lives outside of the urbanized areas of Ukiah, Fort Bragg, and Willits, ozone levels measured at downtown sites are probably under-representing the region's population exposure to ozone.

- **Ozone concentrations at the borders of the Ukiah Valley are not known.**

The air quality assessment in this report showed that transport of ozone and ozone precursors into the Ukiah Valley may be a significant contributor to ozone levels in the Valley. However, with monitors only in downtown Ukiah and Willits, the contribution of upwind ozone to the Valley cannot be quantified. One of the likely paths for transported ozone and precursors into the Ukiah Valley is via aloft transport.

ES.2.2 PM_{10}

Although no sites have exceeded the State standard for the annual geometric mean of 30 $\mu g/m^3$, there have been exceedances of the State 24-hr PM_{10} standard of 50 $\mu g/m^3$ in every year between 1993-1997. However, the median values show no declining trend. The median is consistently in the 10 to 20 $\mu g/m^3$ range for Ukiah and Willits, and between 10 and 30 $\mu g/m^3$ in Fort Bragg.

- **Rural population exposure to PM should be measured.**

PM measurements at Fort Bragg, Ukiah, and Willits may be under-estimating the regional PM_{10} air quality. All three sites are located adjacent to paved roads. However, as discussed above, nearly 70 percent of Mendocino County's population lives outside of the urbanized areas of Ukiah, Fort Bragg, and Willits and many of the rural Mendocino County roadways are unpaved. Thus, the concentration of particulate matter may be under-represented, since the monitoring sites are not impacted by as much fugitive road dust as is common outside of the urbanized areas.

- **Speciation of the PM mass is not available.**

As is typical of most rural Districts in the State, little or no speciated PM data is routinely available. Only under special circumstances, such as a special regional air quality field study, are such data available for all but the most highly populated urban areas of the State. Contributors to PM exceedances in Mendocino county include: unusual emissions events, fire activity (e.g., wildfires, control burns, urban fires, etc.) in and outside of Mendocino County, residential wood combustion for fuel and space heating, sea-salt spray (Fort Bragg), mobile source-related emissions, fugitive dust, and point sources. However, due to the lack of chemical speciation of the PM_{10} samples, source contributions cannot be quantitatively assessed.

ES.3 RECOMMENDATIONS

Recommendations for improved monitoring to address the key issues discussed above are described next for ozone and PM separately.

ES.3.1 Ozone Air Quality

We recommend that Mendocino County consider the following actions to provide better data with which to characterize and assess ozone conditions:

- Add an ozone monitor at the southern boarder of Mendocino County to assess concentrations entering the County when winds are from the south.
- Add an ozone monitor at a more rural location (i.e., away from fresh NO_x sources) in the Ukiah Valley in order to better assess the exposure of the predominantly rural population to ozone.
- Collect a few fully speciated ambient VOC samples during the summer at the Ukiah site, collocated with the NO/NO_x monitor and an enhanced sensitivity CO monitor (i.e., concentrations reported in ppb, rather than ppm).
- Enhance the surface meteorological measurement network in the Ukiah Valley to better assess ozone transport and recirculation.

- Add aloft meteorological measurements at the upwind boundary of the Valley in order to better assess the possibility of transport and recirculation.

ES.3.2 PM Air Quality

We recommend that Mendocino County consider the following actions to provide better data with which to characterize and assess PM conditions:

- Chemically speciate PM samples from historical episodes, if available, or from current samples above the standard.
- Add a PM monitor at a more rural location (i.e., near unpaved roads) in Mendocino County in order to better assess the concentrations in predominantly rural areas.
- Co-locate meteorological stations with sampling locations at Willits and Ft. Bragg to improve probability of pin-pointing any point source contributors.

ES.4 EMISSION INVENTORY ISSUES AND RECOMMENDATIONS

The current emission inventory and future-year projections are matters of great uncertainty. Much of the emission inventory is based on highly uncertain emission factors, statewide or regional averages, and extrapolated or interpolated estimates. Future projections are based on fundamental underlying assumptions regarding future socio-economic growth patterns in Mendocino County, which are highly uncertain by their nature. Furthermore, the assumptions are built on state-wide averages, whereas Mendocino County will likely be quite different than the state-wide average for many growth factors.

ES.4.1 Recommendations for Improving Emission Estimates

- Emission factors and activity data indicators used by the ARB to estimate area sources of ozone precursor emissions for commercial landscape equipment and cutback asphalt appear to be inaccurate for Mendocino County and should be updated.
- The ARB on-road motor vehicle emissions model should be re-run, accounting for the much higher than normal unregistered vehicle fleet in Mendocino County.
- If, in the future, speciated PM filter samples identify road dust as a significant contributor to PM exceedances, PM emissions from unpaved road dust should be re-calculated using revised estimates of unpaved roadway mileage.

Lastly, to more fully understand the uncertainties in Mendocino County's emission inventory, a detailed bottom-up inventory assessment should be performed. The bottom-up approach examines in detail the number, type, size, and activity of various emission sources within a county.

1. INTRODUCTION

Mendocino County has generally good air quality. However, on a few occasions each year, air quality monitoring locations in the county measure 24-hr average PM_{10} concentrations at levels which exceed the State of California's air quality standard. In addition, in recent years (1997 being the exception) Mendocino County has experienced increasing ozone levels, with peak ozone concentrations in Ukiah approaching the California State Ozone Standard. Since the population of Mendocino County is expected to grow about 50% over the next 25 years, the MCAQMD sponsored this study to provide:

- a better understanding of the ozone and PM_{10} sources impacting the county, and
- suggestions for what Mendocino County can do to accommodate growth without sacrificing air quality

1.1 OZONE FORMATION

There are two types of ozone that the public hears about in the news: (1) ground-level ozone (i.e., tropospheric ozone) and (2) stratospheric ozone (i.e., the "ozone layer"). Ground-level ozone is of concern to human health and plant-life due to direct exposure, while the stratospheric ozone layer provides protection to the earth from the sun's ultraviolet radiation. This study is only concerned with ground-level ozone. Thus, when aloft ozone is discussed in this report, it is referring to ozone occurring up to a few thousand meters above the ground.

Ozone (O_3) is a secondary pollutant formed by the reaction of nitrogen oxides and hydrocarbons. In the presence of oxygen (O_2), and with the stimulus of solar radiation, NO_x react in the atmosphere to form ozone and nitric oxide (NO) through the reactions given in Equations 1-1 and 1-2.

$$NO_2 + \text{Sunlight} \rightarrow NO + O \qquad \textbf{(1-1)}$$

$$O + O_2 \rightarrow O_3 \qquad \textbf{(1-2)}$$

Resultant ozone, however, can be quickly reacted away to form nitrogen dioxide (NO_2) by the process given in Equation 1-3.

$$O_3 + NO \rightarrow NO_2 \qquad \textbf{(1-3)}$$

However, the presence of VOCs removes the NO as shown in Equation 1-4. Thus, NO is not available to re-combine with ozone to form NO_2, and therefore, ozone can accumulate.

$$VOC + NO \rightarrow NO_2 + \text{other products} \qquad \textbf{(1-4)}$$

The precursors to ozone (i.e., nitrogen oxides and VOCs) have both anthropogenic and biogenic origins.

1.2 PARTICULATE MATTER

PM can be categorized by size and the type of physical process that produces the PM. Particles less than 2.5 μm diameter (fine particles) are principally due to (in order of importance) atmospheric reactions, combustion processes (e.g., residential fuel combustion, internal combustion vehicles, and fossil-fueled power plants), and some industrial processes. Fine particles produced by atmospheric processes from gaseous emissions are referred to as secondary particles. Coarse particles (less than 10 μm and greater than 2.5 μm) are usually associated with mechanical processes, including wind blown dust, re-entrained road dust, crushing and grinding, and tire wear.

In most communities, ozone and PM problems are a function of two broad factors: (1) local pollutant emissions from area, stationary, and mobile sources; and (2) transported pollutant emissions from an upwind area. In more rural areas, mobile sources (e.g., road dust for PM and VOC and NO_x for ozone) tend to dominate in importance, unless there is significant pollutant transport, or there is a particular plant or factory that contributes directly emitted PM or ozone precursor emissions. In the wintertime in these areas, wood-burning stoves and fireplaces can also be significant contributors to PM_{10} problems, since road dust is reduced on both paved and unpaved roads due to the increased moisture. For example, in the Kent, Washington area (a relatively rural community near Seattle), wood smoke contributes about 40 percent of the PM_{10} during the fall/winter months (Main et al., 1995).

1.3 STATE AND FEDERAL STANDARDS FOR OZONE AND PM

The State of California has adopted a standard for ozone, which defines an exceedance as a day where a single hourly concentration exceeds 0.09 parts per million (ppm). This standard, the primary standard, is designed to be protective of human health. Recently, a new national 8-hr ambient air quality standard for ozone was promulgated. This standard is 0.08 ppm daily maximum 8-hr average. The 8-hr primary and secondary ozone ambient air quality standards are met when the average of the annual fourth-highest daily maximum 8-hr average ozone concentration is less than or equal to 0.08 ppm. Mendocino County has not yet experienced a State exceedance of the 1-hr ozone standard nor a Federal exceedance of the 8-hr standard.

For PM_{10}, the state standards are 30 $\mu g/m^3$ for the annual geometric mean and 50 $\mu g/m^3$ for 24 hours. The 24-hr standards protect the public from the effects of short-term exposure to ambient PM_{10} concentrations and the annual standards protect the public and the environment from the effects of long-term exposure. The State 24-hr standard is exceeded when the 24-hr PM_{10} concentration is $\geq$ 50.5 $\mu g/m^3$. The federal 24-hr PM_{10} standard is exceeded when the 24-hr PM_{10} concentration is $\geq$ 155 $\mu g/m^3$. The State annual standard is exceeded when the annual geometric mean of all 24-hr concentrations at a site is $\geq$ 30.5 $\mu g/m^3$. In 1997, the U.S. Environmental Protection Agency (EPA) set new standards; they retained the annual PM_{10} standard of 50 $\mu g/m^3$ and adjusted the PM_{10} 24-hr standard of 150 $\mu g/m^3$ by changing the form of the standard. The one-expected exceedance form was replaced by the 99th percentile of

24-hr concentrations at each monitor within an area averaged over three years. Mendocino County has experienced several exceedances of the State 24-hr standard for PM_{10} over the past several years.

1.4 STUDY OBJECTIVES

To determine the influences on Mendocino County's ozone and PM air quality and to propose ways in which the county can mitigate the impacts of growth on air quality, this project took a three-pronged approach:

(1) a study of past, present, and future ozone formation (and transport) in the county was conducted,

(2) an evaluation of the current emission inventory and projections to future years was prepared, and

(3) potential mitigation measures appropriate to Mendocino County for ozone and PM_{10} were identified.

The study of air quality conditions included the characterization of the meteorological conditions conducive to high ozone concentrations in Little Lake Air Basin (e.g., Willits and Ukiah) and PM concentrations in Fort Bragg as well as the Little Lake Air Basin (**Figure 1-1**). Specific activities that were carried out were to: acquire, organize, and summarize continuous monitoring data from surface air quality and meteorological monitoring sites; analyze historical ozone and PM air quality and meteorological data; assess ozone and ozone precursor transport; and estimate future ozone levels/recommend mitigation measures.

The evaluation of the current county-wide emission inventory for PM and ozone precursors (e.g., VOC and NO_x) included separate assessments of the representativeness of emission factors and associated information used by the ARB to estimate emissions in Mendocino County. In addition, estimates of future year socio-economic factors were used to prepare emission inventories for the years 2000, 2005, 2010, and 2020. Emission estimates for on-road motor vehicles were given special attention, with detailed estimates prepared for sub-sections of the county. Special attention was also taken to prepare seasonally adjusted emission estimates for summer and winter regimes.

To identify appropriate potential mitigation measure options for the county for ozone and PM, existing control plans in a variety of communities were examined. The examination provided a range of potential control measures available to County officials.

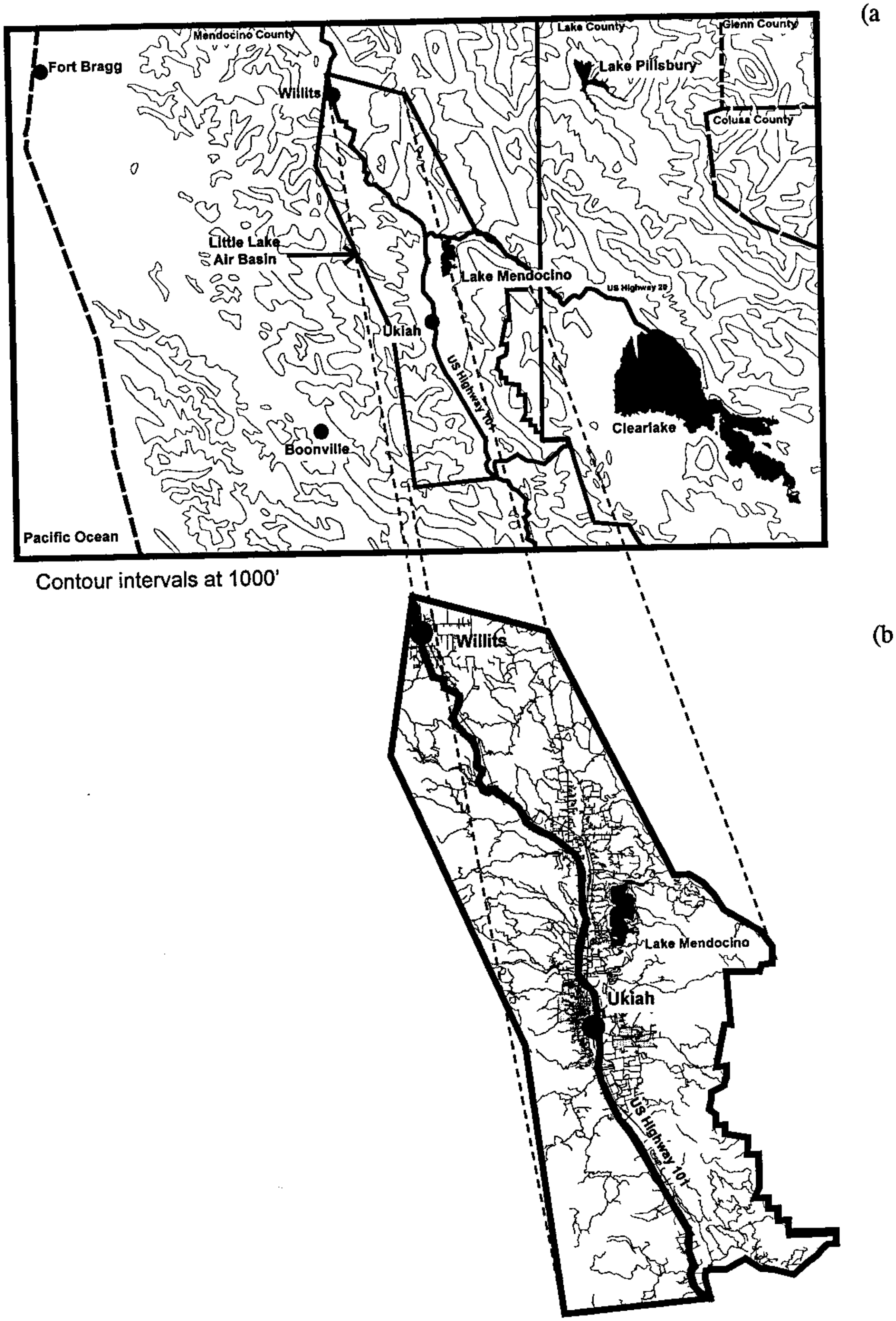


Figure 1-1. Depiction of (a) the region surrounding the Little Lake Air Basin in Mendocino County, and (b) detailed map of the Little Lake Air Basin including metropolitan areas, major roads, and surface streets.

1.5 ORGANIZATION OF THIS REPORT

This report is divided into seven sections, plus an executive summary. Section 1 is this introduction. In Section 2, available ozone, ozone precursor, and meteorological data acquired for the analysis of ozone and PM episodes in Mendocino County is presented. This data-gathering step was extensive and included validation and special processing of the data. Section 3 provides a description (e.g., trends and patterns) of ozone data for Mendocino County (and surrounding areas) from 1993 through 1997 in general and in greater detail for selected days when the ozone concentrations were near the State Ozone Standard and the days leading up to the ozone episode. Ozone data, combined with daily weather charts, wind speed, and wind direction data were examined to determine the known characteristics of the episodes and to allow us to derive conceptual models of general ozone episode patterns in Mendocino County. The number of 24-hr PM exceedances and the times of year for high PM_{10} values were analyzed on a site-by-site basis. Correlations between sites were analyzed to find consistencies and/or variation in the region's PM_{10} concentrations in order to assess possible PM sources. Section 4 presents an analysis of relative source strengths of various emission source categories in Mendocino County on local ozone and PM concentrations, the source (e.g., man-made and biogenic) of VOC, NO_x, and PM within the county were considered. In Section 5 the future-year estimates of air quality are used to prioritize the need for mitigation measures. The results of the ozone/PM air quality issues and the emission inventory evaluation were used to determine which sources contribute most to PM and ozone problems. We then identified a range of potential control measures available to County officials by reviewing relevant literature including air quality management plans for other areas. We also qualitatively ranked the relative importance of these measures to controlling $PM_{2.5}$, PM_{10}, and ozone and prepared a recommended list of control measures that the County could pursue based on technical merit and feedback from a roundtable discussion process. Section 6 presents a summary of the project findings and recommendations for future air quality monitoring and data analysis. A reference list is shown in Section 7.

2. DATA ACQUISITION AND AVAILABILITY

The investigation of air quality in Mendocino County encompassed: (1) an investigation of historical ozone concentrations and the potential contribution of transported ozone and ozone precursors; (2) characterization of the conditions and possible sources of PM_{10} exceedances; and (3) evaluation of the emission inventory for the county. To meet the data needs of the air quality and emission inventory assessments, an extensive effort was undertaken to obtain air quality and meteorological data for Mendocino and the surrounding counties. Data acquisition efforts and a discussion of available data are presented in this section of the report.

2.1 DATA ACQUIRED FOR OZONE EPISODE ANALYSIS

Data for the analysis of Mendocino County's ozone episodes were primarily acquired from the EPA's Aerometric Information Retrieval System (AIRS) and from the MCAQMD. Supplemental air quality data and much of the meteorological data were acquired separately from various organizations. **Table 2-1** summarizes the data included in the study of historical ozone episodes by location, type, and the source from which the data were obtained.

Surface air quality data, including O_3, carbon monoxide (CO), and NO_x, were acquired for a number of sites in and surrounding Mendocino County. Data from sites potentially upwind of Mendocino County, and sites representative of the San Francisco Bay Area outflow were obtained in order to analyze the potential of transport from these regions into Mendocino County. Note that not all pollutants are measured at all sites and no VOC data were available for this entire study region (including the San Francisco Bay Area). The presence of VOC data could have enhanced the project's conclusions by providing additional evidence to understand and document the relative importance of transported pollutants and local sources. Data were used "as is" (i.e., without additional validation).

2.1.1 Surface Meteorology Data

Surface meteorology data (i.e., wind speed, wind direction, and ambient temperature) were used to evaluate the potential for (1) ozone formation from local emissions or, (2) transport of ozone and ozone precursors from upwind areas outside of Mendocino County. Surface meteorology data were obtained from the MCAQMD for Ukiah and Willits. Data for a Geyser site, unit 17, in Sonoma County were obtained from Dr. Sam Altshuler at Pacific Gas and Electric (PG&E). The Geyser 17 surface meteorological monitoring station is located near the top of a ridge at an elevation of about 800 m. These data were treated as pseudo-aloft meteorological data for the Ukiah region.

Table 2-1. Gaseous air quality and meteorology data sources used in this study.

Location	Measurements	Dates	Data Source
306 E. Gobbi St., Ukiah	Ozone, Carbon Monoxide	1993-97	EPA AIRS
889 S. Main St., Willits	Ozone, Nitrogen Oxides, Carbon Monoxide	1993-97	
905 Lakeport Blvd., Lakeport	Ozone	1993-97	
857 5th St., Santa Rosa	Ozone, Nitrogen Oxides, Carbon Monoxide	1993-97	
Healdsburg Airport	Ozone, Surface Meteorology	1993-97	
126 1st St., Sonoma	Ozone	1993-96	
534 4th St., San Rafael	Ozone, Carbon Monoxide	1993-97	
2552 Jefferson St., Napa	Ozone, Carbon Monoxide	1993-97	
1144 13th St., Richmond	Ozone, Nitrogen Oxides, Carbon Monoxide	1993-97	
1001 Allison Dr., Vacaville	Ozone	1995-97	
401 Gregory St., Fairfield	Ozone	1993-97	
40 Sutter St., Woodland	Ozone	1993-97	
University of California at Davis	Ozone, Nitrogen Oxides, Carbon Monoxide, Surface Meteorology	1993-97 (Met: 95-97)	
Anderson Springs Rd., Lakeport	Surface Meteorology	1996-97	
2701 Avalon Dr., Paso Manor	Ozone, Nitrogen Oxides, Carbon Monoxide, Surface Meteorology	1993-97 (Met: 96,97)	
California	Surface Wind Flow Maps	1993-97	ARB
Ukiah Airport	Aircraft Temperature Soundings	1993-97	ARB
Ukiah Airport	Surface Meteorology	1993-1997	MCAQMD
E. Gobbi St., Ukiah	Surface Meteorology	1993-97	MCAQMD
E. Gobbi St., Ukiah	Ozone	1996	MCAQMD
North America	Daily Weather Maps	-	NOAA / NWS
Healdsburg	Surface Meteorology	1993-1997	NSCAQMD
Geyser site	Elevated Surface Meteorology	1993-1997	PG&E

ARB = Air Resources Board
MCAQMD = Mendocino County Air Quality Management District
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
NSCAQMD = Northern Sonoma County Air Quality Management District

Based on prior experience in performing data analyses, we have found it very important to assure the quality of the data prior to analysis. In this way, one can avoid making erroneous conclusions based on invalid data. A number of data validation measures were performed during data processing which resulted in a high quality data set for use in all subsequent analyses.

2.2 DATA ACQUIRED FOR PM_{10} EPISODE ANALYSIS

Data available for the study of historical PM_{10} episodes are listed in **Table 2-2**. Surface meteorological data (NOAA Marine Weather Station) from Fort Bragg were acquired from Ms. Christine Schomer, lab technician, at College of the Redwoods in Fort Bragg, based on an initial contact by the MCAQMD.

Table 2-2. 24-hr PM_{10} data in Mendocino County.

Location	Dates	Data Source
Library, Ukiah	1993-97	EPA AIRS
416 N. Franklin, Fort Bragg	1993-97	
Fire Station, Willits	1993-97	

Speciated particulate mass data were not available for the region (except for a single filter analysis in 1993). As discussed in Section 3, the availability of chemical analysis of PM filter samples could greatly increase the reliability of the data analyses for the PM_{10} episodes in Mendocino County. Lastly, acquisition of day-specific forest fire information was only successful due to the assistance of the MCAQMD.

2.3 DATA ACQUIRED FOR EMISSION INVENTORY EVALUATION

The major objectives of the emission inventory evaluation are to (1) assess and evaluate the current emission inventory for Mendocino County, and (2) project the inventory to future years (e.g., year 2020). The 1995 emission inventory for Mendocino County was obtained from the ARB. The ARB annually reports manmade emissions from stationary, area, and mobile sources for each county in the state of California. Countywide inventories are compiled using data from air pollution control districts and other governmental agencies and are available from the California Emission Inventory Development and Reporting System II (CEIDARS II) at the ARB. Emission estimates of reactive organic gases (ROG), CO, NO_x, sulfur oxides (SO_x), and PM for point and stationary sources are based on data collected by each district. Area source emission estimates for these pollutants are based on data compiled by the districts and ARB staff. On-road motor vehicle emission estimates are made by ARB using the BURDEN7F model which calculates motor vehicle emissions as the product of a use factor and an emission rate. Data inputs for the model are developed by the ARB using

California Department of Transportation (Caltrans) travel estimates, local councils of government travel estimates, and the Department of Motor Vehicles (DMV) registration information. The latest detailed inventory was made for 1995 (California Air Resources Board, 1997a).

In order to project the emission inventory to 2020, county growth and activity data were obtained from the ARB. ARB staff maintains a large and comprehensive emission forecasting system and database containing detailed land-use data and local government planning inputs. The forecasting system combines inputs from a number of different models and is capable of producing historical and projected demographic and socioeconomic trends. The forecasting system incorporates more than 100 growth categories and over 200 control categories for each county in California. Surrogates and growth factors for non-vehicular sources are derived from socioeconomic trends such as employment, population, and industrial activity. Local agencies (i.e., local AQMD) supply the ARB with socioeconomic and demographic growth projections or, in the absence of local data, the ARB uses its forecasting system to generate projections. The ARB staff reportedly surveys districts each year to provide them with an opportunity to review and update the growth data used in the forecasting system (Lerch and Yajima, 1993), however it appears that Mendocino County has not been surveyed in recent years.

Our major approach in the emission inventory evaluation was to attempt to obtain consensus among several different sources of emissions-related data and then provide recommendations on improvements that can be made to the inventory. Emissions data and source activity information were obtained from the Mendocino County air district, Caltrans, individual industrial facilities, and the State Franchise Tax Board. It was discovered through conversations with Caltrans staff that Mendocino County has an unusually high percentage of unregistered vehicles. In addition, Franchise Tax data indicate that fuel sales in Mendocino are four times higher than the per capita statewide average. Vehicle miles of travel (VMT) estimates are also higher than statewide averages on a per capita basis. The latest Motor Vehicle Emission Inventory (MVEI) model was used to estimate 1995 mobile source emissions and project emissions to 2020. The 1995 emissions from the MVEI model and projections to 2020, as well as the uncertainties associated with the model based on actual mobile source activity and fleet characteristics in Mendocino County, are further discussed in Section 4.

The 1995 stationary and area source inventories developed by the ARB are based on emission estimates supplied by the districts combined with estimates derived by the ARB. The ARB has assigned the Districts responsibility for periodic updates of major point sources and some area source categories. In the case where the district does not supply the ARB with emission estimates, default values are assigned. The existing defaults have not been systematically updated in several years. During the emission inventory evaluation it was discovered that the default values assigned to some of the stationary and area source categories may be outdated and should be revised. The ARB takes the lead in developing future-year emission estimates throughout California. However, the default growth surrogates used by the ARB to project future-year emissions may not be representative of each District or for some source categories in a specific District. These issues are discussed further in Section 4.

3. OZONE AND PM_{10} IN MENDOCINO COUNTY DURING 1993-1997

In order to understand the ozone and PM_{10} sources impacting Mendocino County, a study of past, present, and future ozone formation (and transport) in the county was conducted. A description of Mendocino County ozone and PM_{10} air quality, and an assessment of the potential contribution from transport of ozone and ozone precursors into the area are presented in this section. It is important to recognize that while the information on air quality in Mendocino County is superior to information available in many similar size counties in the State, it is not sufficient to precisely quantify the contribution of local emissions to observed ozone concentrations. Therefore, in this section, we present "factual" descriptions of ozone and PM_{10} air quality episodes, but can only provide "commentary" on likely or possible relative contributions from local emissions and transported pollutants. Recommendations are provided in Section 6 to address data limitations for future consideration. For ease of presentation, this section is divided into two main sub-sections: (a) ozone air quality and (b) PM_{10} air quality.

3.1 DESCRIPTION OF OZONE AIR QUALITY

Mendocino County's air quality meets national and California ozone standards. However, the Ukiah valley behaves like an ideal photochemical box in which pollutants are confined to a narrow and shallow box, approximately three miles wide and twelve miles in length. On hot, still, summer and fall days, if sufficient ozone precursors are present, the Ukiah valley could experience ozone concentrations above regulated levels. The Willits area, known as the "Little Lake Valley", also has the potential to trap pollutants in the same manner. However, Willits is located at a higher elevation, nearly 500 m compared to Ukiah at around 200 m, and has one third of the population of Ukiah, 5000 people compared to 15,000 (1996 U.S. census). These physical differences between Willits and Ukiah explain in part the stronger winds, less periods of calm, and lower levels of pollutants at Willits than at Ukiah. When elevated ozone levels are observed, the greatest frequency of high ozone values occurs in late summer/early fall (e.g., during the month of September).

Prior to detailed descriptions of individual ozone episodes, we first present a description of the general patterns of ozone air quality for the available sites of Mendocino County (e.g., frequency, magnitude, and time of day of high ozone concentrations). Ozone concentration statistics are presented for selected measures including: (1) distribution of the daily maximum concentrations, (2) frequency of hourly ozone measurements above various levels, and (3) time of day when peak ozone concentrations first occurred. Trends in these statistics can help to clarify changes in ozone levels over time.

In order to assess the variation within data sets, various statistical tests and plots were prepared. One of the plot types used extensively is the box-whisker plot shown in **Figure 3-1.** The box shows the 25th, 50th (median), and 75th percentiles. The whiskers always end on a data point, so when the plots show no data points beyond the end of a whisker, the whisker shows the value of the highest or lowest data point. The whiskers have a maximum length equal to

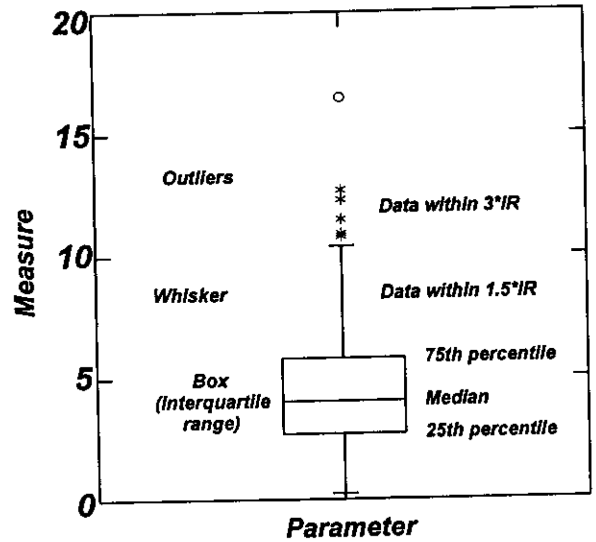


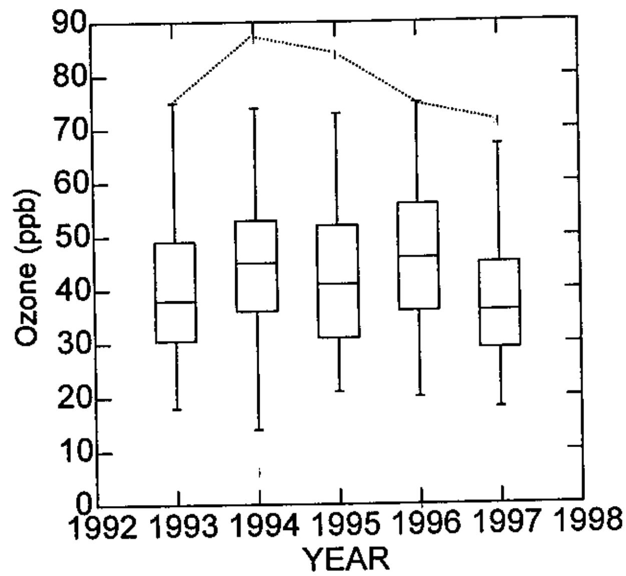
Figure 3-1. Annotated example of box-whisker plot.

1.5 times the length of the box (the interquartile range). Box-whisker plots use 1.5 times the interquartile range to depict the skewness in the data. If there are data outside this range, the points are shown on the plot and the whisker ends on the highest or lowest data point within the range of the whisker. The "outliers" are also further identified with asterisks representing the points that fall within three times the interquartile range from the end of the box and circles represent points beyond this.

Figure 3-2 shows the box-whisker plots of the daily maximum ozone concentrations at Willits and Ukiah by year of occurrence. The dashed line connects the maximum value recorded for that year. Ozone levels at Willits are significantly lower than at Ukiah. The interquartile range for ozone values of all years studied is within 20 to 40 ppb for Willits and 30 to 50 ppb for Ukiah. There was only one day on which ozone concentrations exceeded 70 ppb at Willits: 71 ppb at 1100 PST on July 12, 1994. In contrast, at Ukiah 14 days had ozone concentrations greater than or equal to 70 ppb during the 1993 through 1997 period. Recall that the California ozone standard is violated when ozone reaches 95 ppb. Since Ukiah experiences consistently higher ozone levels than Willits, more detailed examination of Ukiah ozone episodes were conducted.

The Ukiah ozone concentrations were examined to determine the number of hours with ozone above various concentration thresholds (e.g., 40, 50, 60, and 70 ppb). As shown in **Figure 3-3**, the number of hourly measurements exceeding each of the depicted thresholds has increased over the past few years. There is an abrupt decrease in ozone concentrations above all threshold levels during the 1997 ozone season; however, these data may not be representative of a general trend due to the effects of El Nino. Researchers have shown that the cooler-than-normal weather associated with El Nino patterns often result in decreased ozone levels.

a) 906 E. Gobbi Street, Ukiah



b) 889 S. Main Street, Willits

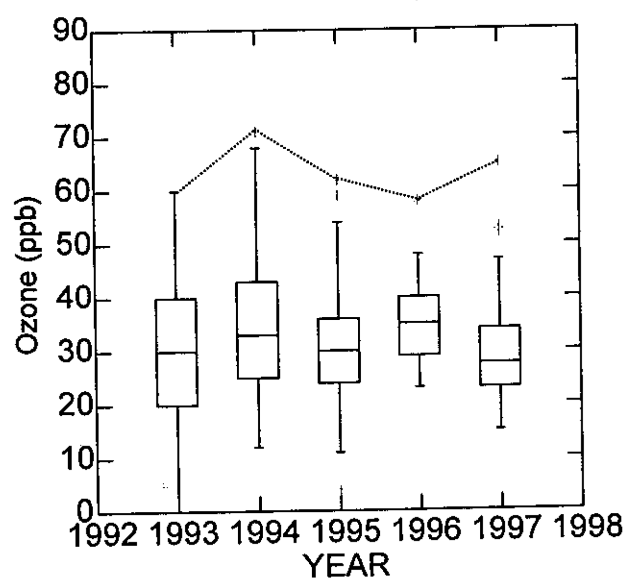


Figure 3-2. Box plots of the daily maximum ozone values by year for the a) Ukiah and b) Willits sites. The dashed line connects annual maximums.

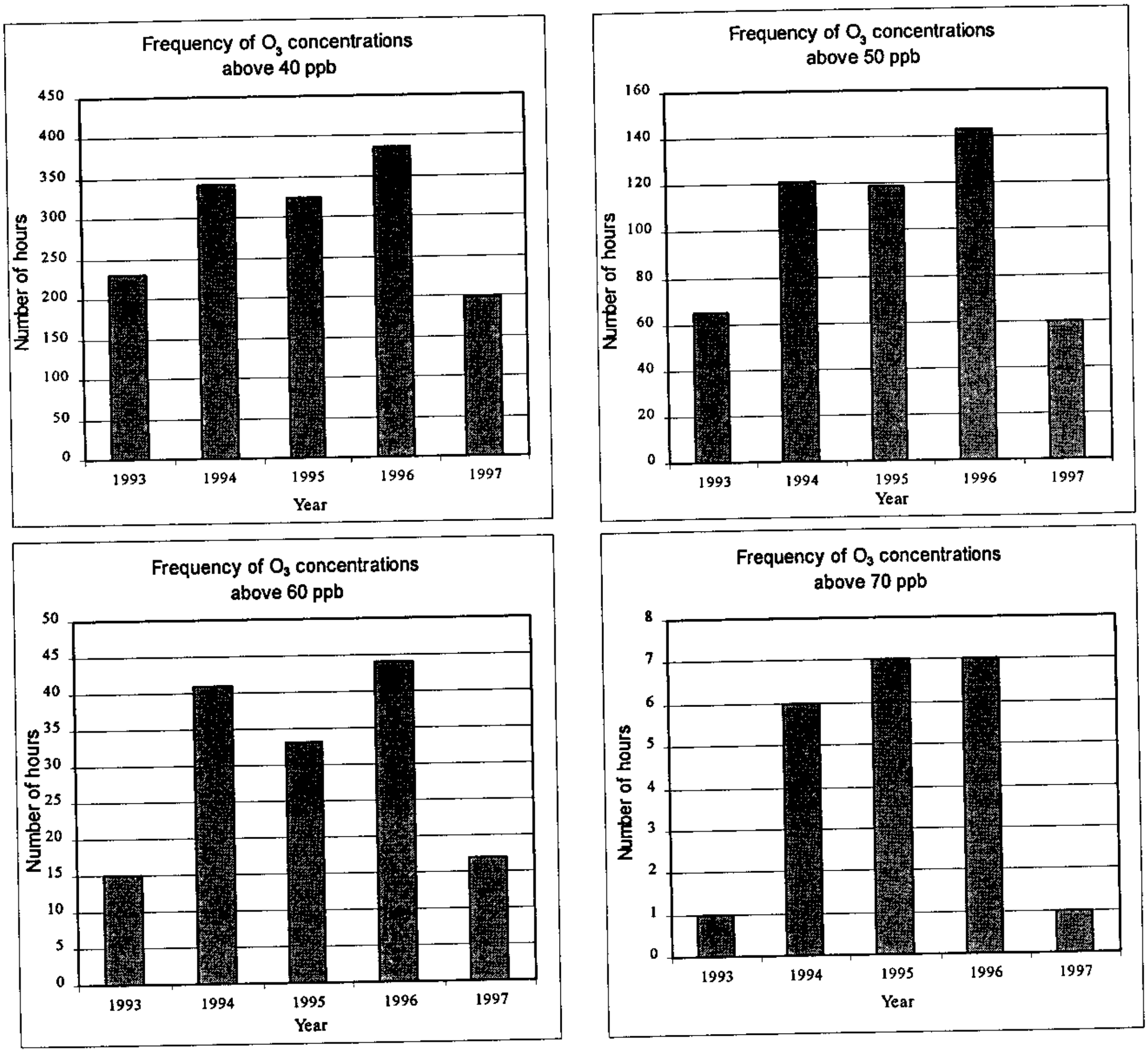


Figure 3-3. Frequency distribution ozone above selected concentration thresholds by year. The data shows an increasing trend in ozone concentrations for all thresholds, except in 1997, which may be attributed to the effects of El Nino.

Figure 3-4 summarizes the frequency of hourly ozone concentrations above the various thresholds versus time of day. The frequency of observed values between 50 ppb and 70 ppb is highest at noon and tails off evenly until 1600 PST. At 1700 PST and 1800 PST there is another increase in frequency of observed high ozone levels, denoting the existence of a double peak in a significant portion of the data set. Values above 70 ppb also peak at noon but show a significant number of occurrences from 1300 PST through 1600 PST indicating that the higher ozone concentrations are just as likely to be observed later in the day.

The time of day that peak ozone concentrations first occur is an indicator of source-receptor relationships. In Ukiah, the hour of the first occurrence of daily peak ozone was most commonly at noon, as seen in **Figure 3-5**. Because of the length of time needed to travel from the nearest possible upwind sources outside of Mendocino County, the presence of midday peaks suggest that ozone is not likely due to same-day transport, but it does not rule out overnight transport on its own, or transport in combination with local sources.

Figure 3-6 shows box-whisker plots of Ukiah ozone levels for 1993 through 1997. The figure shows the midday timing of peak ozone concentrations and the persistent double peak occurring a few hours later. The first peak is probably caused by the photochemical reaction of local VOC and NO_x emissions and/or carryover of ozone and ozone precursors. The second peak could be a function of:

1. A late-arriving polluted air parcel from an upwind region (transported peak);
2. Light, fluctuating winds during the morning emissions period (create "lumpy" ozone cloud);
3. Re-circulation of a polluted air parcel during the peak ozone period (moves ozone cloud around);
4. Non-uniform fresh emissions near the monitoring site (titrate ozone during midday);
5. Re-circulation of a polluted air parcel (fresh NO_x from urban area would make more ozone).

3.1.1 Description of Individual Ozone Episodes

To better understand the meteorological effects on ozone formation and transport in Mendocino County, it is necessary to examine individual ozone episodes in detail. Since there have not been any exceedances of the California state standard for ozone (values > 95 ppb), days with peak concentrations above 70 ppb were identified for further analysis. **Table 3-1** lists the days identified as potential episodes for analysis.

The identified days were then examined and grouped according to their ozone levels, time of ozone peak, wind speed and direction and inversion characteristics. Each of these selection parameters were displayed using a number of descriptive approaches, including: (a) time-series plots of ozone and winds, (b) air parcel trajectories, and (c) maximum inversion heights. Episodes to be analyzed in detail were selected based on the criteria of including episodes with the highest ozone concentrations and representing a variety of episode types (e.g., representing each of the hypothesis described above).

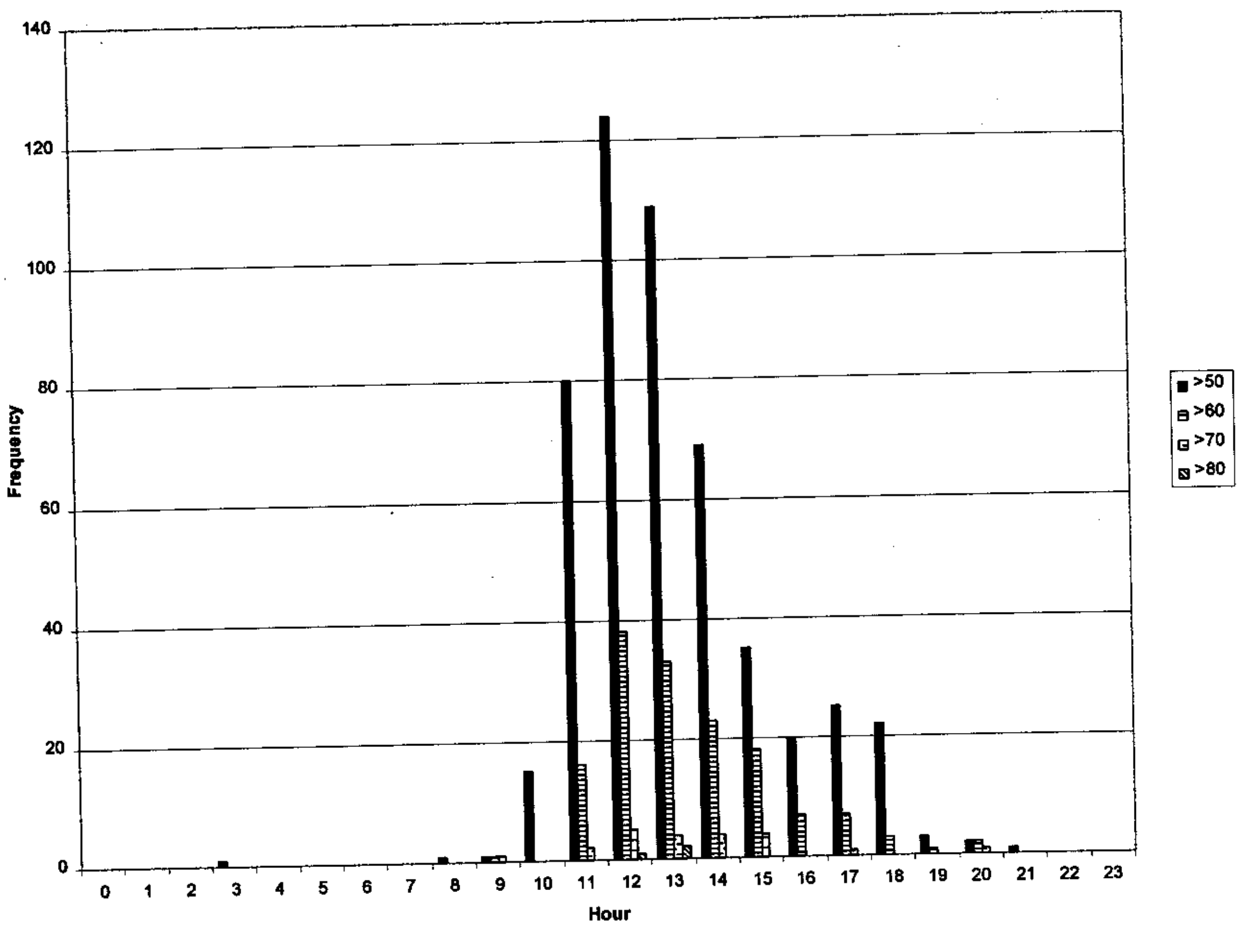


Figure 3-4. Frequency distribution of ozone concentrations (ppb) above selected thresholds verses time of day (PST). Ozone concentrations greater than 50 ppb and 60 ppb are most commonly observed at noon. Concentrations greater than 70 ppb are evenly distributed over the afternoon hours.

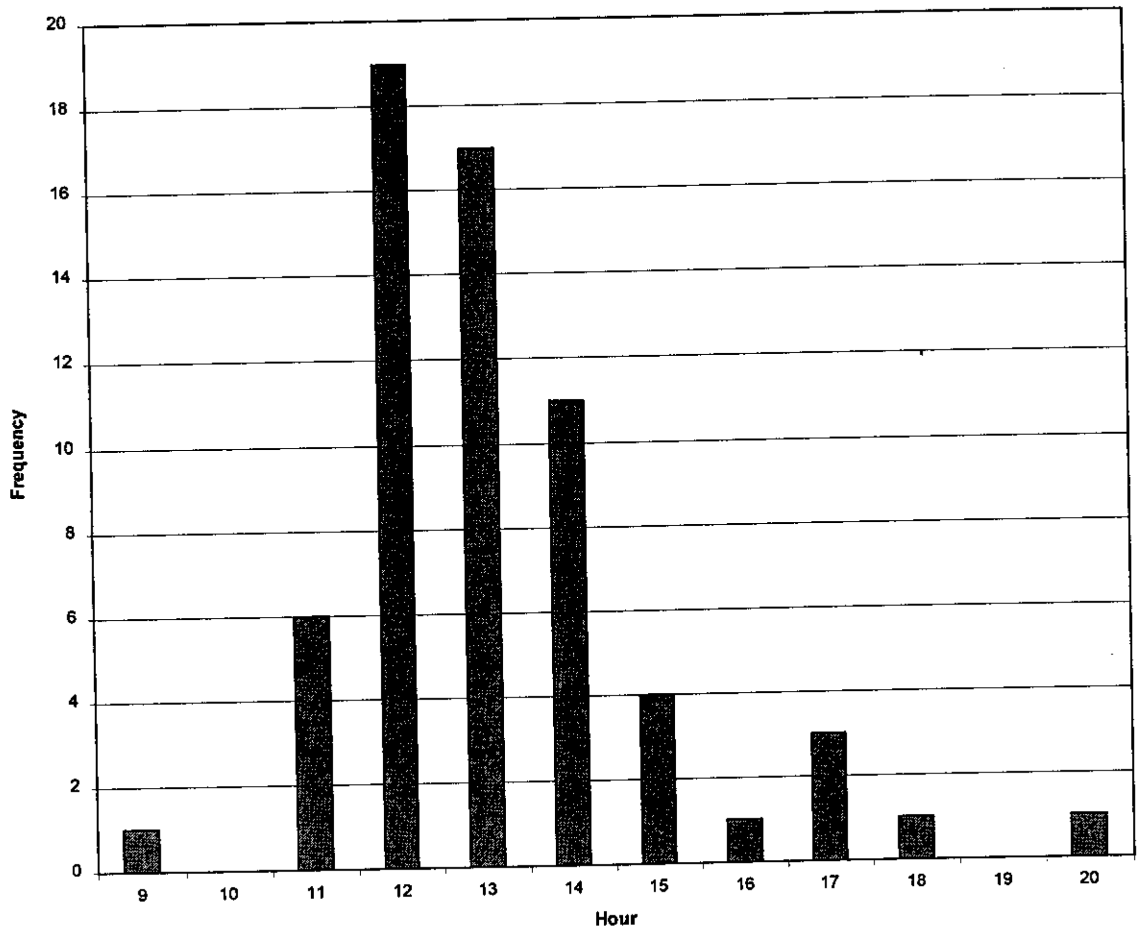


Figure 3-5. Frequency distribution of the hour (PST) of first daily maximum ozone concentration. Only maximums greater than 60 ppb are shown. The most common hour for the first maximum ozone concentration to occur is at 1200 PST.

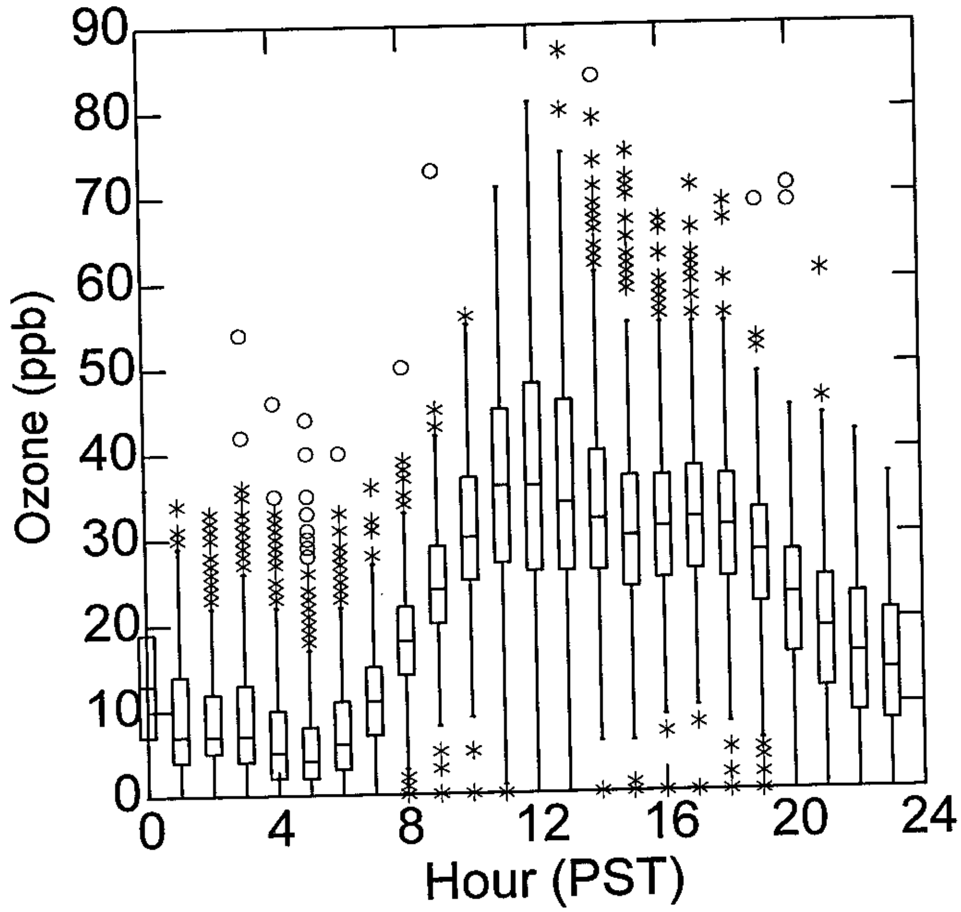


Figure 3-6. Box-whisker plots of ozone concentrations at Ukiah by time of day. Data from all study years (1993-1997) are included.

Table 3-1. Maximum 1-hr ozone concentrations at Ukiah for selected days.

Date	Maximum Ozone (ppb)
9/29/93	75
8/17/94	71
9/6/94	87
9/17/94	74
7/27/95	84
7/28/95	69
9/12/95	73
8/8/96	71
8/16/96	75
9/10/96	75
9/25/96	71
8/6/97	71

Of the twelve identified ozone episodes, four were selected for detailed analysis. **Table 3-2** summarizes the maximum ozone concentrations for the periods selected for further detailed examination. For each episode examined in detail, data were plotted for Ukiah, as well as for nearby potential upwind sites in Healdsburg and Lakeport, and the more distant possible transport indicator sites of Vacaville and Fairfield (representing San Francisco Bay Area "outflow" sites).

Ozone concentrations exceeded 70 ppb during each of the four episodes selected for further analysis. There were three days with ozone concentrations above 70 ppb in Ukiah during 1994 (see Table 3-1). Due to the unique characteristics, September 6 (highest ozone during 1993-1997) and August 17, 1994 (possible regional episode) were selected for detailed analysis. In 1995, of the two days that exceeded the 70 ppb threshold July 27, 1995 6 (second-highest ozone during 1993-1997) was chosen for detailed analysis. Seven days in 1996 had peak concentrations greater than 70 ppb. The September 25, 1996 (double-peak ozone) episode was selected for further analysis due to the unique timing of maximum ozone.

Episode 1: September 6, 1994

The September 6 episode had the highest recorded ozone value in Ukiah during the time period studied (1993-1997), 87 ppb at 1300 PST. **Figure 3-7** depicts the surface air quality in Ukiah and other regional potential upwind sites as a function of time for the episode. These ozone time-series plots of Ukiah, Healdsburg, and Fairfield show that the Bay Area "outflow" sites were at 80 ppb on the afternoon of the day prior to the Ukiah episode (September 5). The upwind and "outflow" sites show a significant decrease in ozone levels on September 6, indicating that the polluted air was cleaned out of these regions on the afternoon of September 5.

Table 3-2. Episodes selected for detailed analysis. Parameters shown are maximum ozone and first hour of occurrence of peak ozone.

Date	Max. Ozone (ppb)	First Hour of max (PST)	Max. Ozone (ppb)	First Hour of max (PST)	Max. Ozone (ppb)	First Hour of max (PST)	Max. Ozone (ppb)	First Hour of max (PST)	Max. Ozone (ppb)	First Hour of max (PST)
	Ukiah		Healdsburg		Lakeport		Vacaville		Fairfield	
8/16/94	--	--	60	1300	50	1100	--	--	73	1600
8/17/94	71	1200	60	1100	70	1300	--	--	73	1300
9/5/94	68	1400	80	1300	50	1100	--	--	79	1500
9/6/94	87	1300	60	1300	70	1300	--	--	56	1400
7/26/95	54	1500	70	1200	50	1600	77	1600	91	1600
7/27/95	84	1400	100	1100	70	1500	105	1600	113	1500
9/24/96	--	--	60	1400	60	1400	53	1600	44	1400
9/25/96	71	1700	50	1300	70	1500	79	1600	55	1400

-- Signifies no data

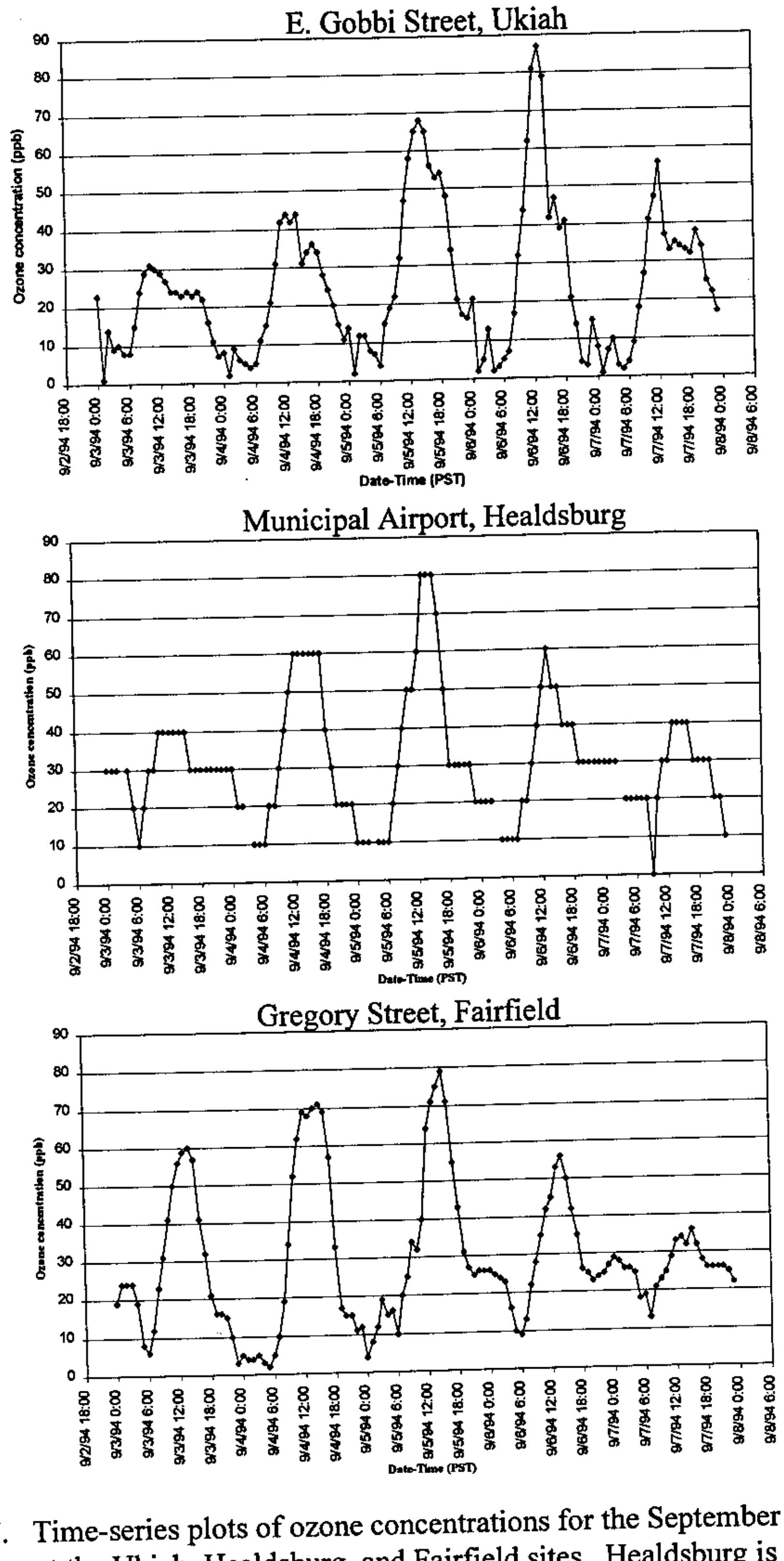


Figure 3-7. Time-series plots of ozone concentrations for the September 6, 1994 episode at the Ukiah, Healdsburg, and Fairfield sites. Healdsburg is shown as the closest upwind monitoring site, Fairfield is shown to represent a Bay Area "outflow" site.

The NWS/NOAA weather maps at the surface and 500 mb levels show that there was no synoptic weather pattern that could dictate the winds in coastal northern California (i.e., no strong pressure gradient dominating California wind patterns). The ARB 500 mb pressure and wind streamline analysis flow charts show that on the morning of September 5 there was an upper-level high located to the south. That afternoon there was strong flow from the south; Santa Rosa reported winds of 7 knots (8 mph) at 150 degrees and Novato had winds of 10 knots (11.5 mph) at 210 degrees at 1600 PST. Early and midmorning winds on September 6 at 0400 PST and 1000 PST were calm at these locations.

Figure 3-8 shows the time-series plots of the wind vectors for two Ukiah valley sites and the pseudo-aloft site at the Geysers. In Ukiah, local surface winds were from the southeast with overnight calm wind. Aloft winds were southerly and steady.

Using the available wind information, back trajectories for this episode were computed. Back trajectories provide an estimate for the path of a hypothetical air parcel over a selected time period. Back trajectories track the movement of an air parcel to illustrate where the air might have come from. The creation of the back trajectories from Ukiah involve the following:

- Starting with the hour before that which corresponds to the time of peak ozone, calculate the distance and direction (i.e., create a wind vector using the average of wind data from the two surface stations) from which an air parcel would travel during that hour.
- Repeat these steps for each hour, working backwards in time, until midnight of the episode day or until the trajectory distance becomes unrealistic due to surrounding topography (for example, ground level back trajectories reach a spatial location that corresponds to an elevation exceeding the mixing depth for that hour).

The Geyser site was used as a pseudo-aloft station in this analysis. Back trajectories were calculated in the same way as described above using the same starting location, overlaid on the surface back trajectory plots. Since this site is being used to represent the aloft meteorological conditions, the local topography does not determine the realistic trajectory distance.

The limited available data do not provide a trajectory that accounts for the topography affecting winds and transport in this region. Furthermore, the aloft wind site used is not located over (or even within the adjacent ridges of) the Ukiah valley; the Geysers wind monitor is located to the south and outside of the Ukiah valley. Because of these limitations, the computed back trajectories can only be used to qualitatively comment on possible source regions. The Ukiah back trajectory for this episode is shown in **Figure 3-9**. The east-west component of the trajectory is likely an over-representation of slope flows in the valley. The relevant features for ozone formation and transport are (a) almost all of the hourly winds result in limited air movement within the topographic constraints of the valley and (b) the strong north-south component of aloft winds indicate the possibility of pollutant transport from the south.

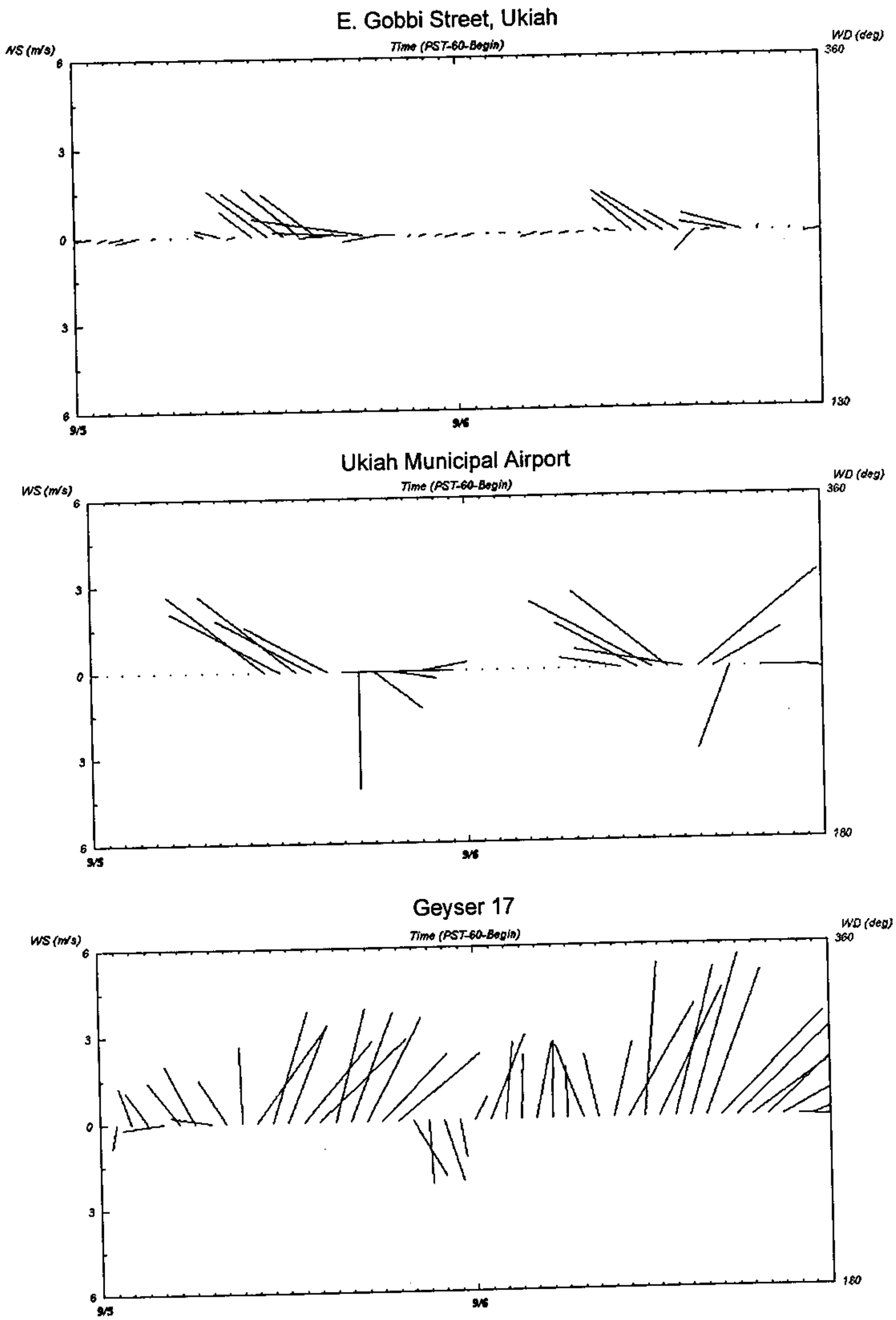


Figure 3-8. Time-series plots of the wind vectors at downtown Ukiah, Ukiah Airport, and the pseudo-aloft site at the Geysers for September 5 and 6, 1994.

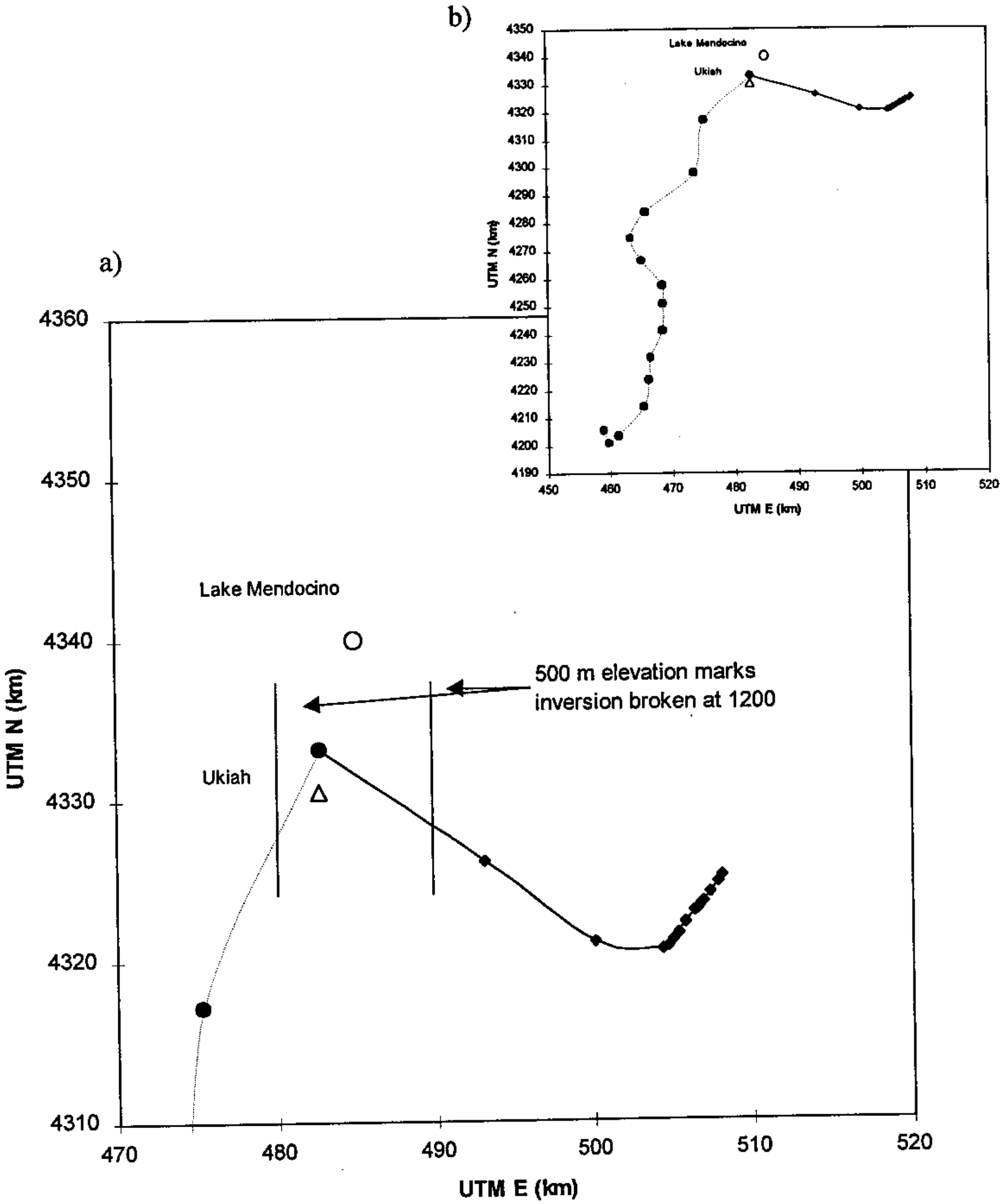


Figure 3-9. Qualitative back trajectories from the Ukiah E. Gobbi Street site for a) surface winds and b) estimated aloft winds, shown on an expanded scale. Trajectories start at the hour of maximum ozone, 1300 PST on September 6, 1994 and end at 0000 PST.

The observed ozone peak occurred at midday (1300 PST). In order for same-day surface transport to have contributed to the observed peak, surface winds would have to be in excess of 20 mph at the upwind and "outflow" sites for Bay Area morning emissions to reach Ukiah by this time, which was not the case as noted above. However, the surface air quality and wind flow patterns do support the hypothesis of overnight transport into the Ukiah valley. Overnight transport is governed by aloft conditions, which remain de-coupled from the surface until the temperature inversion is broken. The hour of peak ozone, 1300 PST, is two to three hours after the inversion height is broken, thus allowing for a polluted aloft air parcel to mix down and significantly contribute to locally generated ozone in Ukiah. Unfortunately, there are only a few locations in the State where ozone air quality data is routinely collected aloft to quantify the presence of the polluted aloft layers. In some instances, special studies using instrumented aircraft are deployed to confirm the presence of aloft ozone concentrations and to quantify their possible transport contribution.

Episode 2: August 17, 1994

On August 17, the maximum ozone concentration in Ukiah was 71 ppb, occurring at 1200 PST. **Figure 3-10** depicts the surface air quality at Ukiah and regional sites during the time period surrounding August 17. Figure 3-10 shows that the upwind and "outflow" sites peaked in the 70 ppb range on the days prior to the Ukiah episode. Lakeport (not shown) ozone concentrations also peaked in the afternoon of the episode day at 70 ppb. Sites much further east of Lakeport in the Sacramento Valley (e.g., Del Paso, Woodland, and U.C. Davis, not shown) peaked midday in the 100 ppb range on the day of the Ukiah episode.

The surface weather maps for August 16 and 17 show a light northeasterly wind pattern in Northern California with a potential convergence zone that could affect coastal northern California. The time-series plots of the wind vectors for the two Ukiah sites and the pseudo-aloft site of the Geysers are shown in **Figure 3-11**. Within the Ukiah valley, surface winds were easterly and steady at the downtown site; the Ukiah Airport winds were northwesterly on the afternoon of August 16 and variable on August 17. Winds measured at the Geysers site were primarily from the north on the afternoon of August 16 but were strong southwesterly on the afternoon of August 17. It is difficult to interpret source and receptor relationships from only a few wind monitors, but both the surface and aloft back trajectories depicted in **Figure 3-12** show that air parcels arriving on August 17 at the Ukiah ozone monitor, may have originated to the northeast.

Since the area to the northeast contains little ozone precursor emissions, no immediate explanation for this ozone episode was apparent and therefore, an investigation for unusual emissions events was conducted. Information from the California Department of Forestry (CDF) & Fire Protection Center for Mendocino County shows that a multi-day wildfire began on the afternoon of August 15 with a reported controlled time on the morning of August 19. The fire, called the Fish Rock Road fire, was reported to have burned approximately 635 acres (personal communication, MCAQMD) and was located to the southwest of Ukiah. Wildfires can have a significant impact on ozone concentrations in the smoke plume itself (up to 50 ppb ozone) and possibly on the region (Roberts and Anderson, 1991). However, as noted in the discussion of the back trajectories for this episode, the winds were primarily from the northeast, which would tend to carry the smoke away from the Ukiah area.

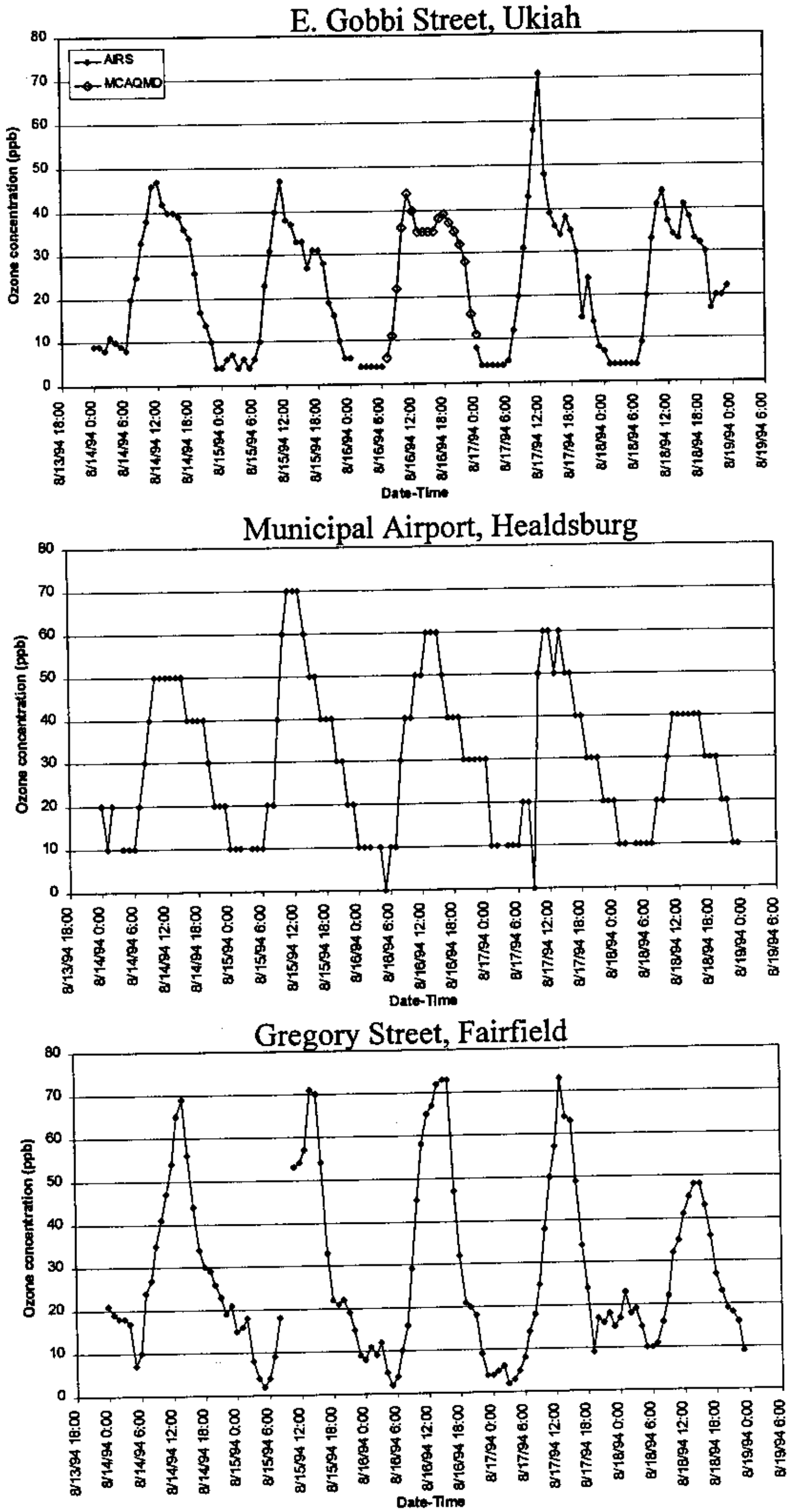


Figure 3-10. Time-series plots of ozone concentrations for the August 17, 1994 episode at the Ukiah, Healdsburg, and Fairfield sites. Healdsburg is shown as the closest upwind monitoring site, Fairfield is shown to represent a Bay Area "outflow" site.

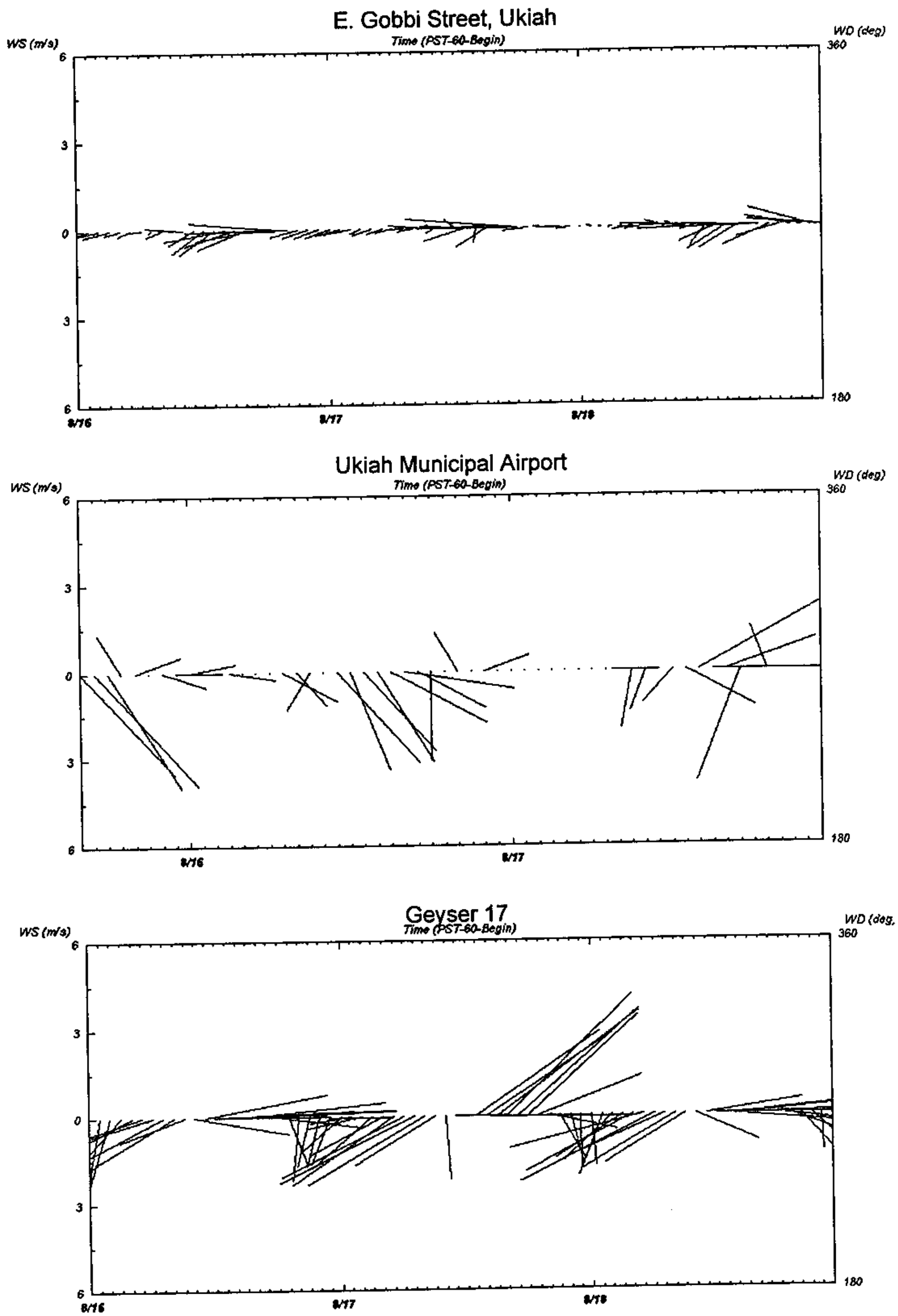


Figure 3-11. Time-series plots of the wind vectors at downtown Ukiah, Ukiah Airport, and the pseudo-aloft site at the Geysers for August 16 and 18, 1994. The time scales vary between plots.

In order to investigate whether any other meteorological characteristic unique to August 17 could cause such a difference in the ozone levels, the local meteorology of that day was looked at in further detail. In an "ideal" box, ozone concentrations are a function of emissions and dispersion (size of the box). The height of the temperature-induced inversion present over the Ukiah valley acts as a lid to Ukiah's ozone "box". The temperature inversion heights were computed from the morning temperature spiral data, collected above the Ukiah Airport, and sponsored by the ARB. The mixing depths were calculated from the intersection between the temperature profile and the observed hourly temperatures projected adiabatically upward (see **Figure 3-13**). Aloft warming and increased stability of the inversion level, in combination with a slower growth rate of the valley's mixing depth on August 17 (compared to surrounding days), are factors that could contribute to elevated ozone levels on this day.

The estimated inversion height, calculated mixing depth, and resulting ozone levels for August 17 and 18 are shown in **Figure 3-14**. These days were similar in surface temperature, wind pattern, and early morning ozone concentrations. However, because Mendocino County is fortunate to have access to aloft temperature data from the ARB (collected daily via aircraft) analysis of differences in aloft meteorology is possible. As shown in Figure 3-14, the mixing depth on August 17 is about 150m less (about 20%) than on August 18 and the inversion appears to have been broken about 2 hours later than on August 18. The lower inversion height and delayed breaking of the inversion layer on August 17 compared to August 18 implies that on August 17 emissions were confined closer to the surface for a longer period of time, thus photochemistry occurred with a higher precursor concentration for an extra 2 hours. The resulting ozone peaks are 71 ppb and 44 ppb for August 17 and August 18, respectively. The hour in which the inversion height is broken corresponds with a dramatic decrease in the ozone concentration (see Figure 3-14). This indicates that locally generated ozone was diluted with cleaner aloft air. For a general discussion on the affect the diurnal evolution of the mixing depth has on ozone formation see Dye et al. (1998).

Episode 3: July 27, 1995

The July 27 episode, the second highest recorded ozone value in the study period, was 84 ppb at 1400 PST. **Figure 3-15** depicts the temporal distribution of the surface air quality in Ukiah and nearby regional sites of Healdsburg and Fairfield. These time-series plots show that the potential "upwind" sites all peaked at the same general time as Ukiah. The peak ozone at Healdsburg occurs from 1100 PST through 1400 PST at 100 ppb, and Fairfield reaches 113 ppb by 1500 PST. Examination of other regional sites showed that Lakeport peaks at 70 ppb from 1500 PST to 1600 PST, and Napa, Santa Rosa, and Vacaville all had maximum ozone concentrations of around 100 ppb. All sites show an ozone build-up on July 26.

The surface weather maps do not show any synoptic weather pattern that could dictate the winds in coastal northern California. The ARB wind streamline analysis flow charts show that there was a rather strong flow from the south on the afternoon of July 26 (1600 PST). Santa Rosa reported winds of 10 knots (11.5 mph) at 180 degrees and Novato had winds of 2 knots (2.3 mph) at 160 degrees. Early morning winds on July 27 at 0400 PST were calm at these locations.

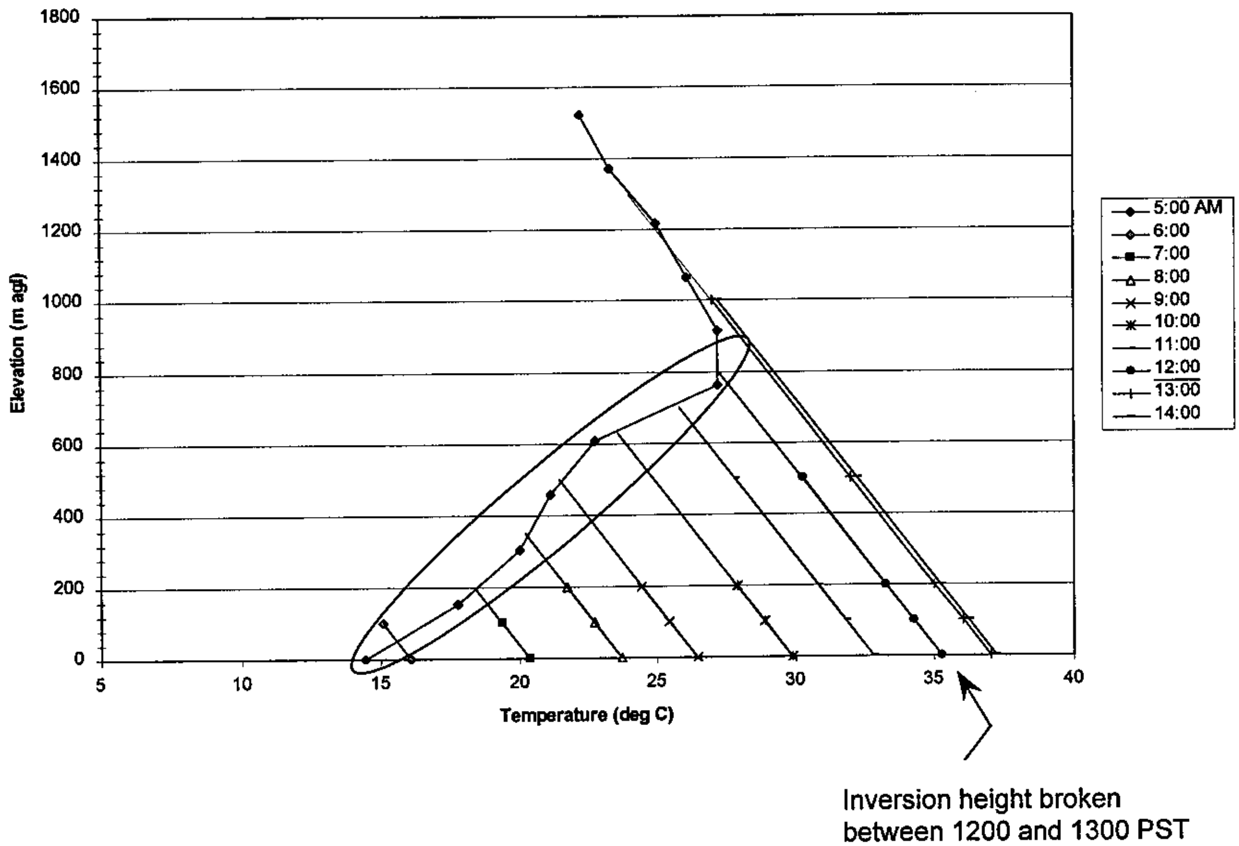


Figure 3-13. Ukiah morning temperature spiral data for August 17, 1994, (estimated inversion height as a function of temperature), and adiabatic projection of observed hourly temperature data. The intersections circled are the hourly estimated mixing depths for the Ukiah Valley.

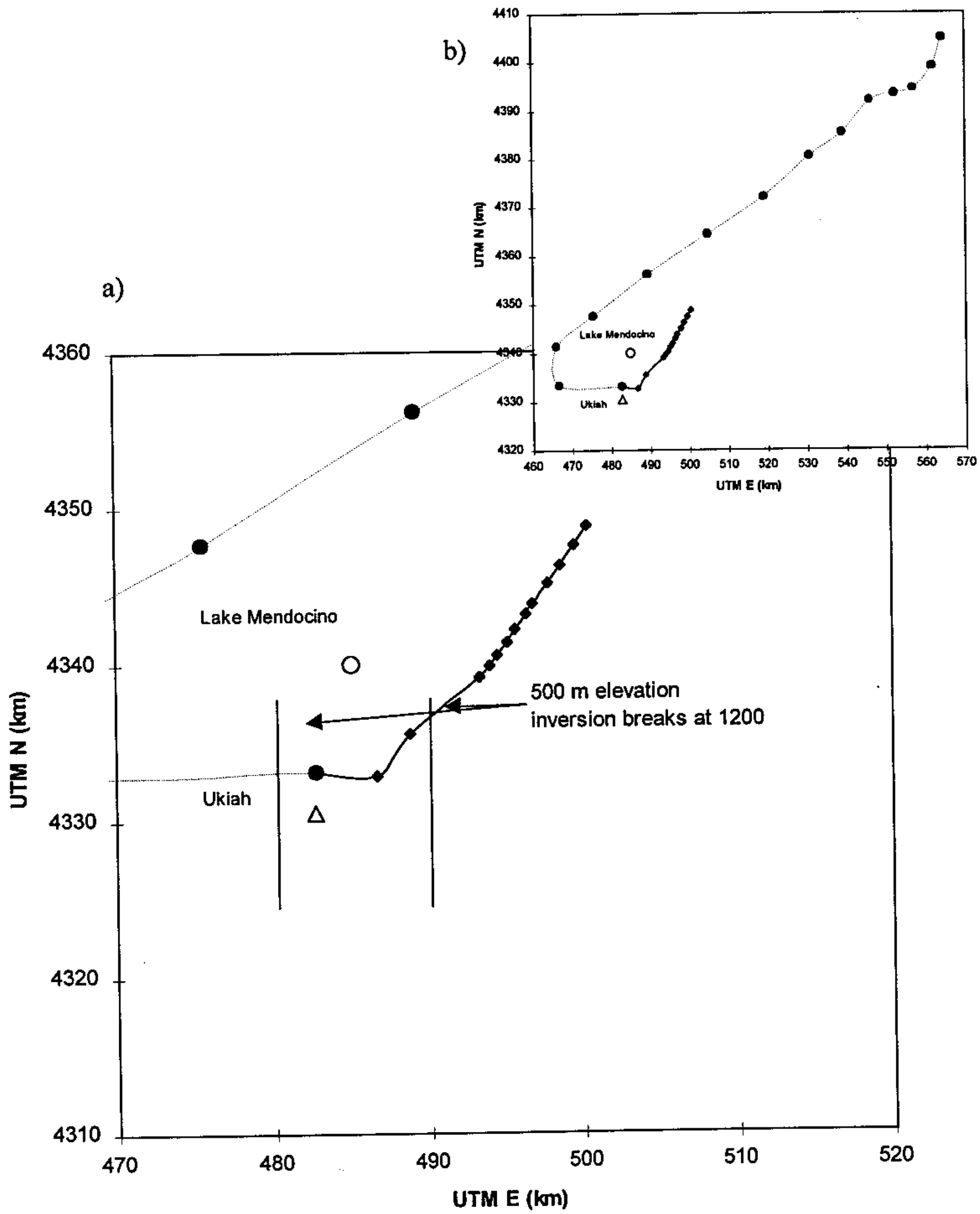


Figure 3-12. Qualitative back trajectories from the Ukiah E. Gobbi Street site for a) surface winds and b) estimated aloft winds, shown on an expanded scale. Trajectories start at the hour of maximum ozone, 1200 PST on August 17, 1994 and end at 0000 PST.

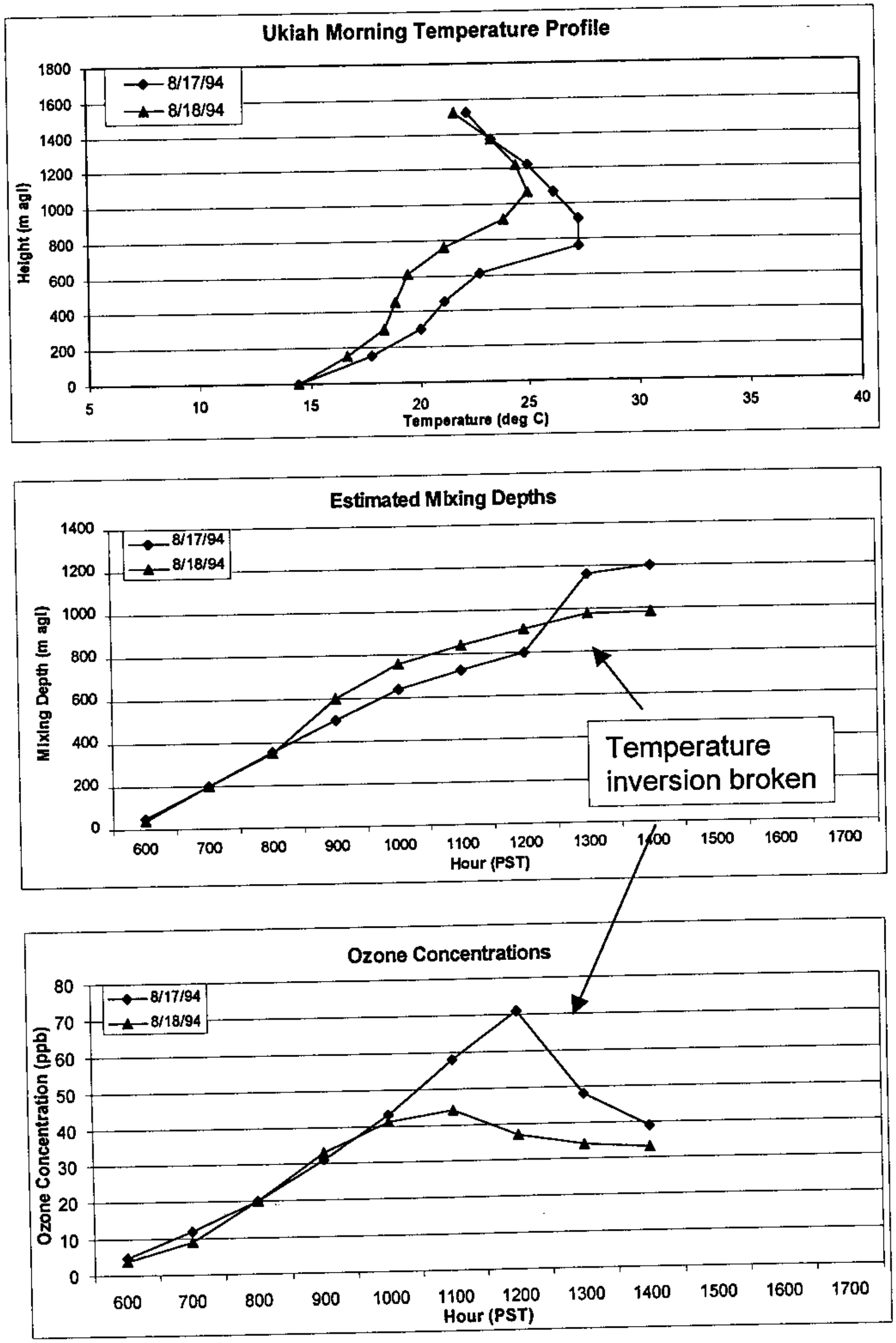


Figure 3-14. Comparison of Ukiah meteorological conditions and resulting ozone concentrations for August 17 and 18, 1994. From top to bottom, morning inversion heights, estimated mixing depth of the Ukiah valley, and observed ozone concentrations.

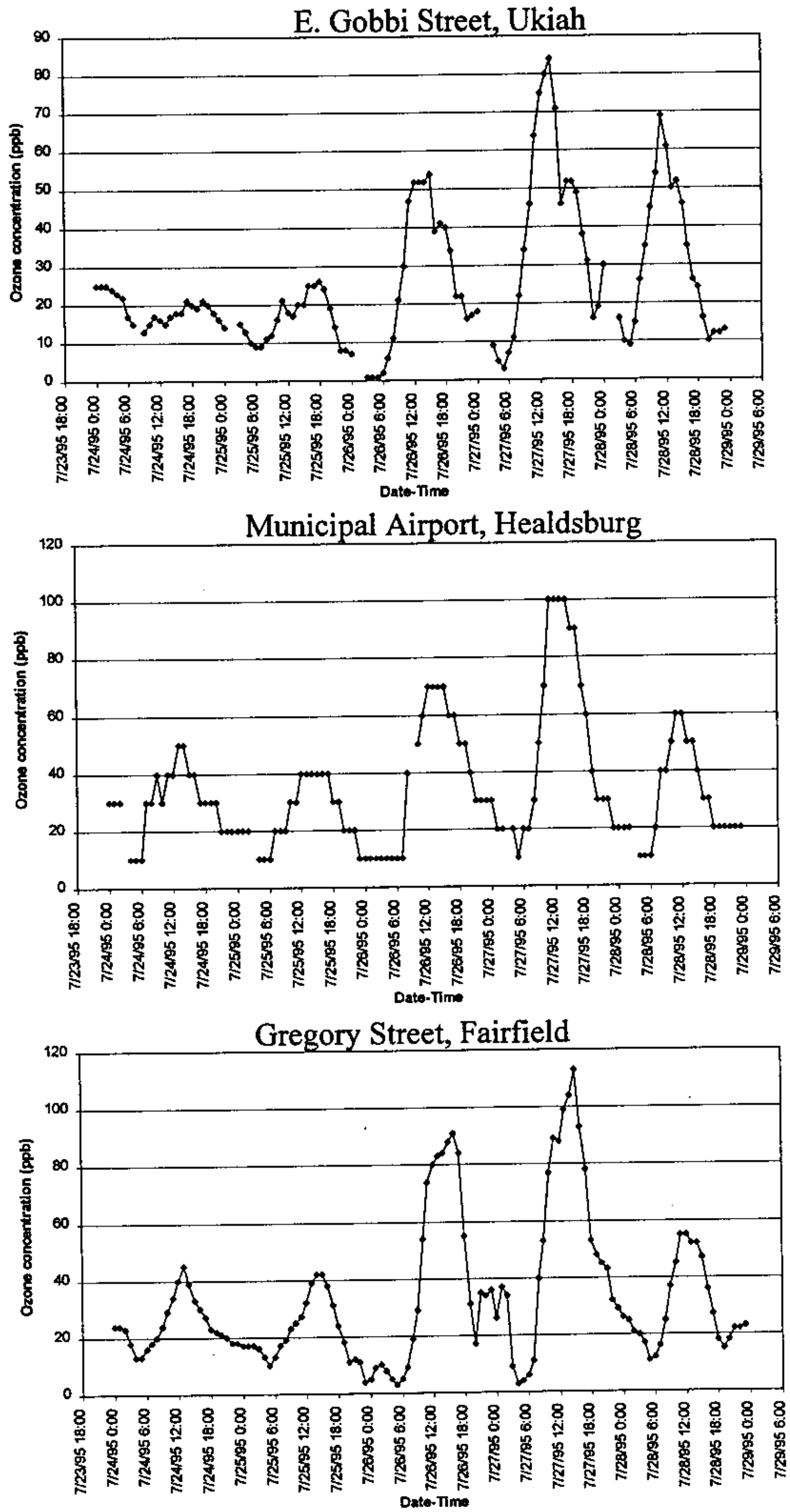


Figure 3-15. Time-series plots of ozone concentrations for the July 27, 1995 episode at the Ukiah, Healdsburg, and Fairfield sites. Healdsburg is shown as the closest upwind monitoring site, Fairfield is shown to represent a Bay Area "outflow" site.

Figure 3-16 shows the wind vector time-series plots for the measurements taken at the E. Gobbi site in Ukiah, the Ukiah Airport, and the Geysers site. E. Gobbi winds were northerly and steady; the Ukiah Airport surface winds show a variable pattern and aloft winds were strong and southerly. The Ukiah back trajectory for this episode is shown in **Figure 3-17**.

During this episode, the timing of the midday peak is too early for same-day surface transport. Ozone concentrations throughout the region show a ramping up on July 26, with a peak occurring on July 27 at most sites. Aloft wind flow patterns support the hypothesis of overnight transport into the Ukiah valley. In Ukiah, the timing of peak ozone, 1400 PST, was three hours after the temperature inversion was broken, between 1000 PST and 1100 PST. The break in inversion corresponds to the hour with the largest increase in ozone, 18 ppb compared to a steady 12 ppb per hour for the hours previous, indicating that a polluted aloft air parcel may have mixed down to contribute to local ozone.

Episode 4: September 25, 1996

On September 25 the maximum ozone concentration was 71 ppb, occurring at 1700 PST. **Figure 3-18** depicts the surface air quality at Ukiah and possible upwind sites for the time period surrounding the episode. Ukiah had a sharp double peak on September 25 with the second peak higher in concentration, 71 ppb at 1700 PST compared to 63 ppb at 1300 PST. Examination of the data for other sites shows that one of the Bay Area outflow sites (Fairfield) has a similar double peak. However, the second peak was much weaker than the first and exhibited much lower concentrations than in Ukiah (e.g., maximum ozone concentrations less than 60 ppb and 40 ppb).

The time-series plots of the wind vectors for Ukiah and the pseudo-aloft site at the Geysers are shown in **Figure 3-19**. Surface winds in Ukiah were northerly with afternoon southeasterly gusts. Winds measured at the Geysers site were northeasterly with periods of southwesterly gusts in the evenings. The Ukiah back trajectory, **Figure 3-20**, indicates a recirculation pattern within the Ukiah valley. The recirculation pattern causes an air parcel path to circle back on itself allowing the parcel to impact a monitoring site more than once.

Examination of the temperature profiles from the ARB aircraft, indicates that the temperature inversion broke between 1200 PST and 1300 PST. This break corresponds with the timing of the first ozone peak. Assuming recirculation occurred, by the time polluted air parcels impacted the monitoring site for the second time, the parcels would have had a longer time to undergo photochemical reactions (free from fresh NO_x emissions). In addition, it is possible that an injection of additional NO_x emissions into a NO_x-limited air parcel as the parcel moves back through the urban area could have resulted in higher ozone levels. While this possibility can only be speculated upon at this time, it is very important because it suggests that ozone production in the Ukiah area may be NO_x-limited. More definitive answers could be obtained by running comprehensive 3-dimensional photochemical models, in the event Mendocino County is required to implement emission reductions to meet the State ozone standard.

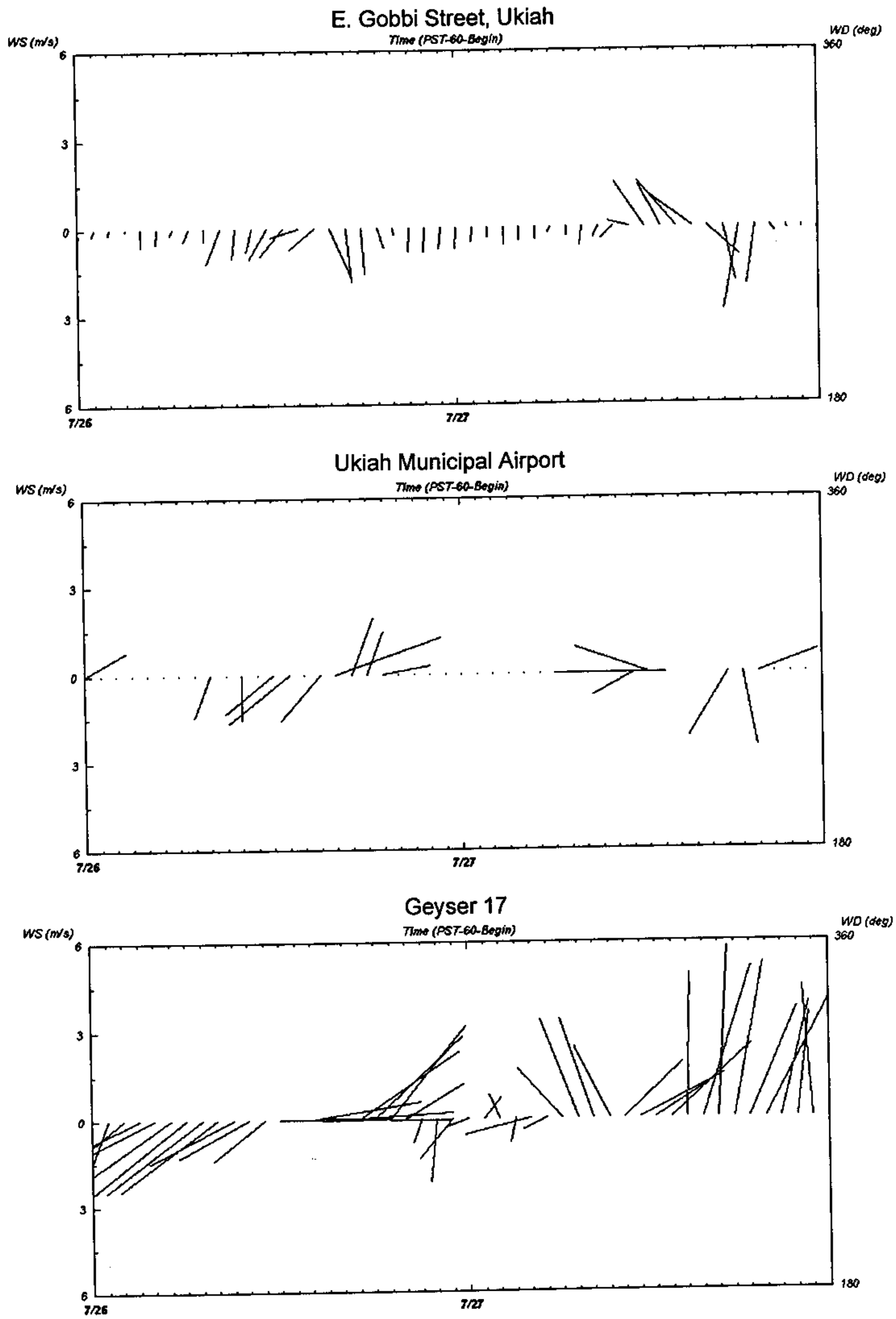


Figure 3-16. Time-series plots of the wind vectors at downtown Ukiah, Ukiah Airport, and the pseudo-aloft site at the Geysers for July 26 and 27, 1995 .

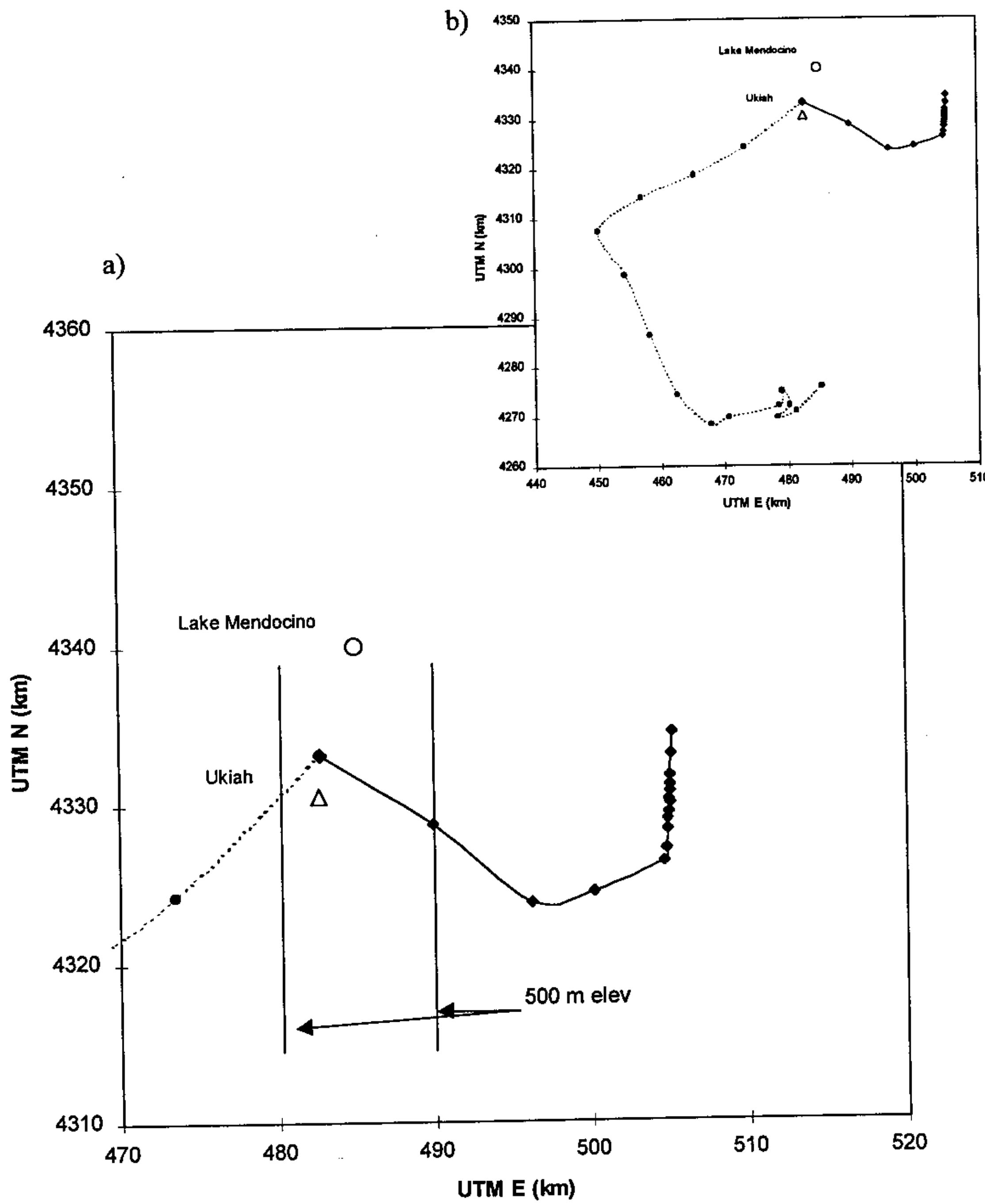


Figure 3-17. Qualitative back trajectories from the Ukiah E. Gobbi Street site for a) surface winds and b) estimated aloft winds, shown on an expanded scale. Trajectories start at the hour of maximum ozone, 1400 PST on July 27, 1995, and end at 0000 PST.

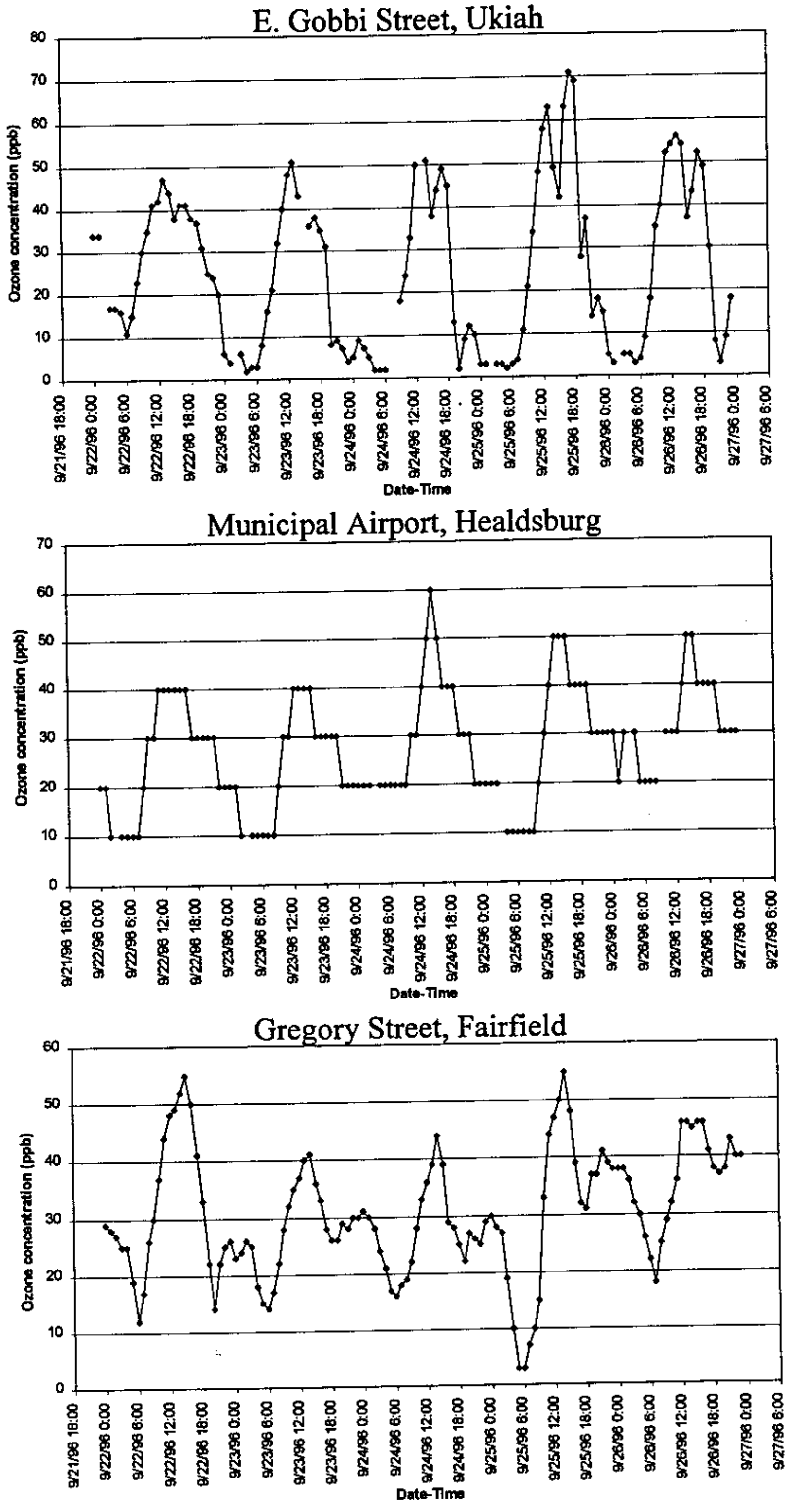


Figure 3-18. Time-series plots of ozone concentrations for the September 25 episode at the Ukiah, Healdsburg, and Fairfield sites. Healdsburg is shown as the closest upwind monitoring site, Fairfield is shown to represent a Bay Area "outflow" site.

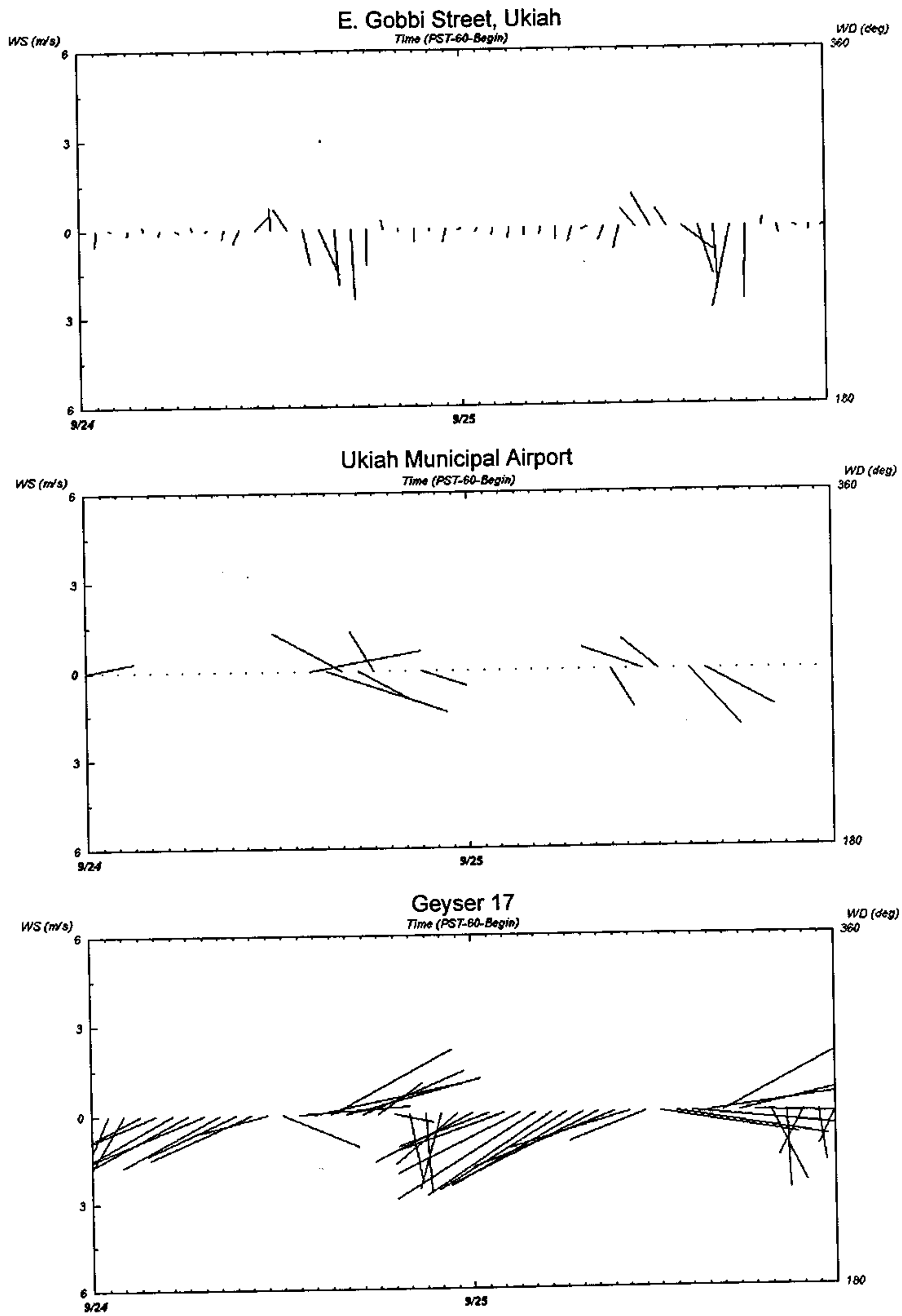


Figure 3-19. Time-series plots of the wind vectors at downtown Ukiah, Ukiah Airport, and the pseudo-aloft site at the Geysers for September 24 and 25, 1996.

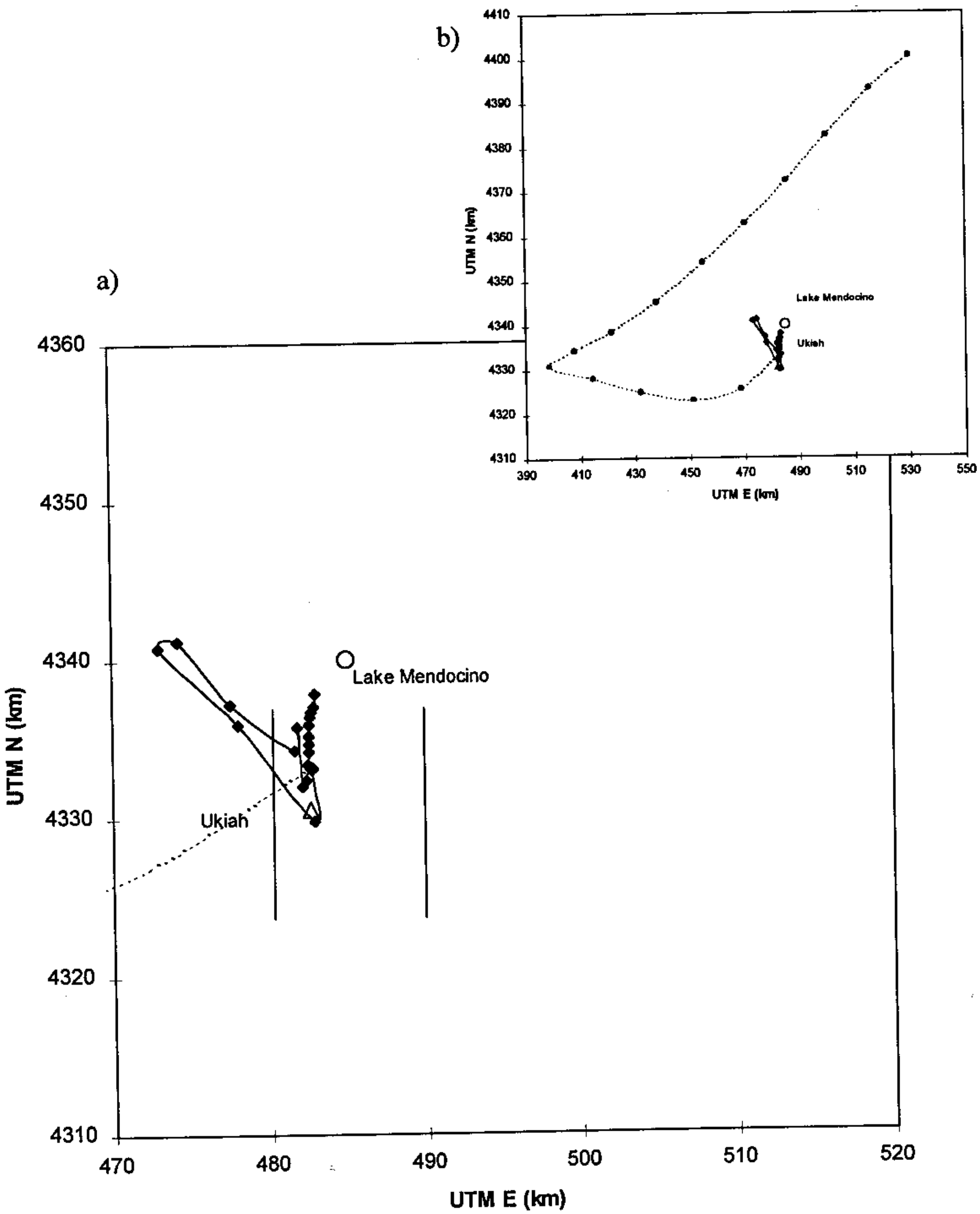


Figure 3-20. Qualitative back trajectories from the Ukiah E. Gobbi Street site for a) surface winds and b) estimated aloft winds, shown on an expanded scale. Trajectories start at the hour of maximum ozone, 1700 PST on September 25, 1996 and end at 0000 PST.

3.1.2 Potential for Ozone Transport

In the previous section, four selected ozone episodes were examined in some detail. The description of individual episodes included: (1) a discussion of the ozone concentrations at Ukiah and potentially upwind sites and sites which act as indicators of Bay Area "outflow", (2) synoptic weather and wind flow patterns, and (3) local Ukiah winds. Each of the episodes displayed unique characteristics, in terms of ozone peak time or relationship to concentrations at other sites in the region. In the description of each episode above, we commented on the likely path of air parcels and possible time of arrival of transported air pollutants. In each case, we ruled out same-day transport because of insufficient wind speeds from likely upwind emission source regions to arrive at the time of the midday ozone peaks observed in Ukiah.

Since no aloft ozone data are available to verify aloft ozone transport, we can only speculate on its possible contribution to observed ozone in Ukiah. Nevertheless, circumstantial evidence is present that can be used to characterize possible transport scenarios. For example, examination of the ozone time-series plots for the first episode (see Figure 3-7) shows that ozone concentrations build up from one day to the next throughout the region. However, on the day of the peak in Ukiah, both of the upwind sites showed a dramatic decrease in ozone levels. We can speculate that local emissions in the Ukiah valley contributed to the 70 ppb level seen on September 5, but that the additional 10-15 ppb of ozone seen on September 6 might be due to overnight transport from the south, since Healdsburg recorded 80 ppb on September 5 and winds aloft were from the south as recorded at the Geysers (located between Healdsburg and Ukiah).

On the second episode, transport of ozone from outside Mendocino County seems unlikely. A more plausible explanation for the observed ozone is that local emissions were confined under strong temperature inversion.

During the third episode, the timing of the midday peak is too early for same-day surface transport. Ozone concentrations throughout the region show a ramping up on July 26, with a peak occurring on July 27 at most sites. Aloft wind flow patterns support the hypothesis of overnight transport into the Ukiah valley. In Ukiah, the timing of peak ozone, 1400 PST, was three hours after the temperature inversion was broken, between 1000 PST and 1100 PST. The break in inversion corresponds to the hour with the largest increase in ozone, 18 ppb compared to a steady 12 ppb per hour for the previous hours, indicating that a polluted aloft air parcel may have mixed down to contribute to local ozone.

On the final episode examined, a sharp double peak was observed. While there is no direct relationship shown on the day of the peak to concentrations in nearby Healdsburg, it is possible that overnight transport may have contributed some ozone and precursors. However, a more plausible explanation is that local emissions were carried in a recirculation pattern over the Ukiah monitoring site resulting in the observed ozone pattern.

3.2 DESCRIPTION OF PM_{10} AIR QUALITY

PM_{10} data from 1993 through 1997 were acquired from the EPA AIRS database for all sites in the County. Although no sites have exceeded the State standard for the annual geometric mean of 30 μg/m³, there have been exceedances of the State 24-hr PM_{10} standard of 50 μg/m³ in every year between 1993-1997. PM_{10} measurements were sorted and ranked site by site to identify which episodes to examine in more detail. Selection criteria included days which exceeded the 24-hr standard or when concentrations were uncommonly high. **Table 3-3** lists the episodes identified for further examination.

Table 3-3. Maximum 24-hr PM_{10} concentrations at Ukiah, Willits, and Fort Bragg for selected episodes. Note exceedances are shown in boldface.

	Maximum PM_{10} (μg/m³)		
Date	Ukiah	Willits	Fort Bragg
11/21/93	**53**	50	
12/29/93	**54**		
1/14/94	49	42	
1/20/94	**52**	42	
2/1/94		**56**	
4/2/94			**53**
4/14/94			**60**
5/26/94			**62**
10/29/94			**54**
6/26/95			**51**
8/7/95			48
8/13/95			**54**
8/19/95			50
4/27/96			**56**
1/7/97		**66**	
3/29/97			**65**

Annual time-series plots of PM_{10} concentrations in Ukiah, Willits, and Fort Bragg were prepared to display the seasonal nature of PM_{10} in Mendocino County and to perform comparisons between sites. **Figures 3-21 a through e** show the annual time-series plots of the 24-hr PM_{10} data for the three sites. The episodes listed in Table 3-3 are circled in the figures. Note that 24-hr PM_{10} is measured on a routine basis, every sixth day. Examination of the figures shows that: (1) PM_{10} concentrations in Willits and Ukiah demonstrate a strong correlation, (2) equally high concentrations are observed at all sites, (3) Fort Bragg has its highest values in the spring and summer months, and (4) Willits and Ukiah have their highest values in the fall and winter months.

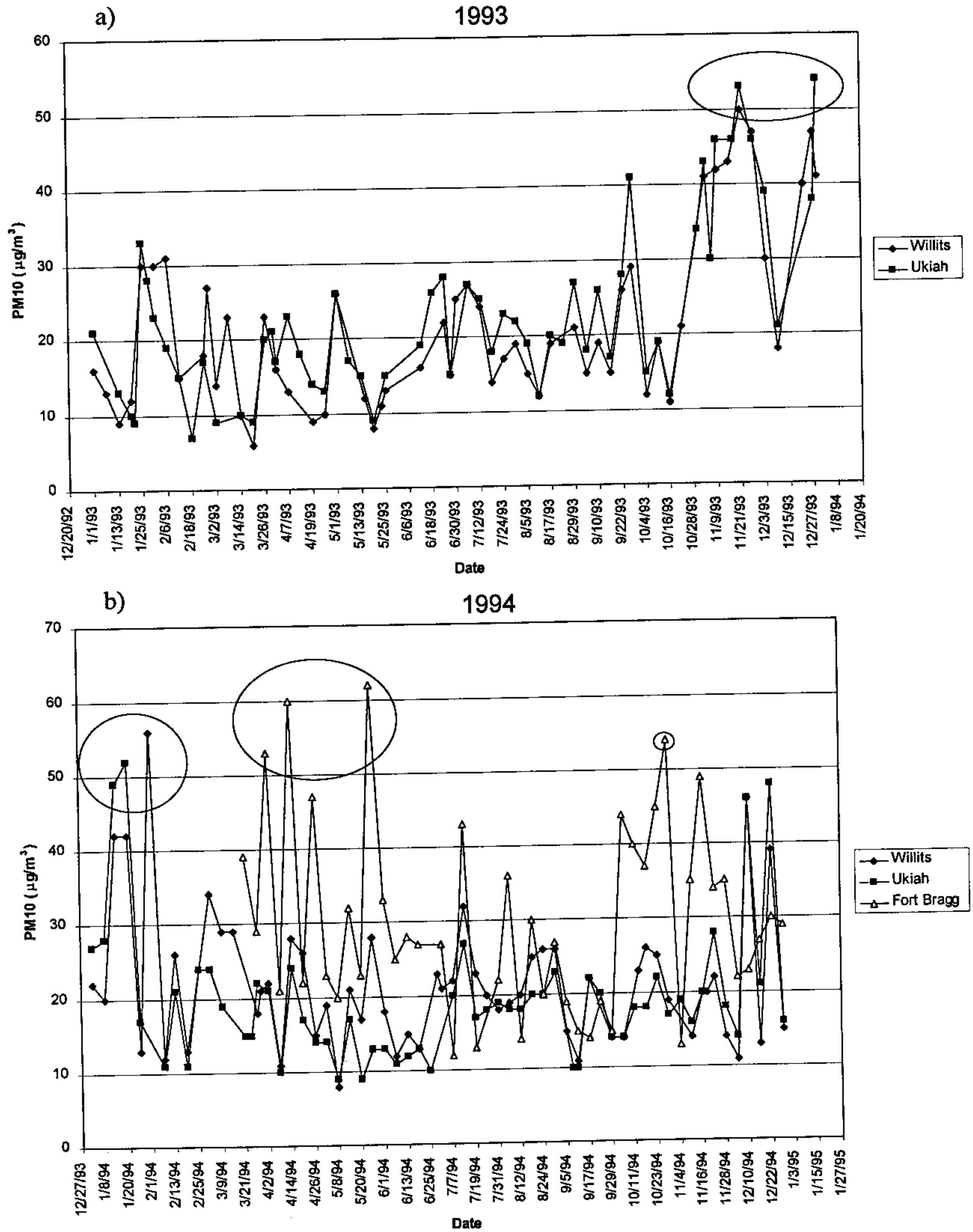


Figure 3-21 a and b. Time-series plots of PM_{10} levels in Willits, Ukiah, and Fort Bragg for 1993 and 1994. Episodes identified are circled.

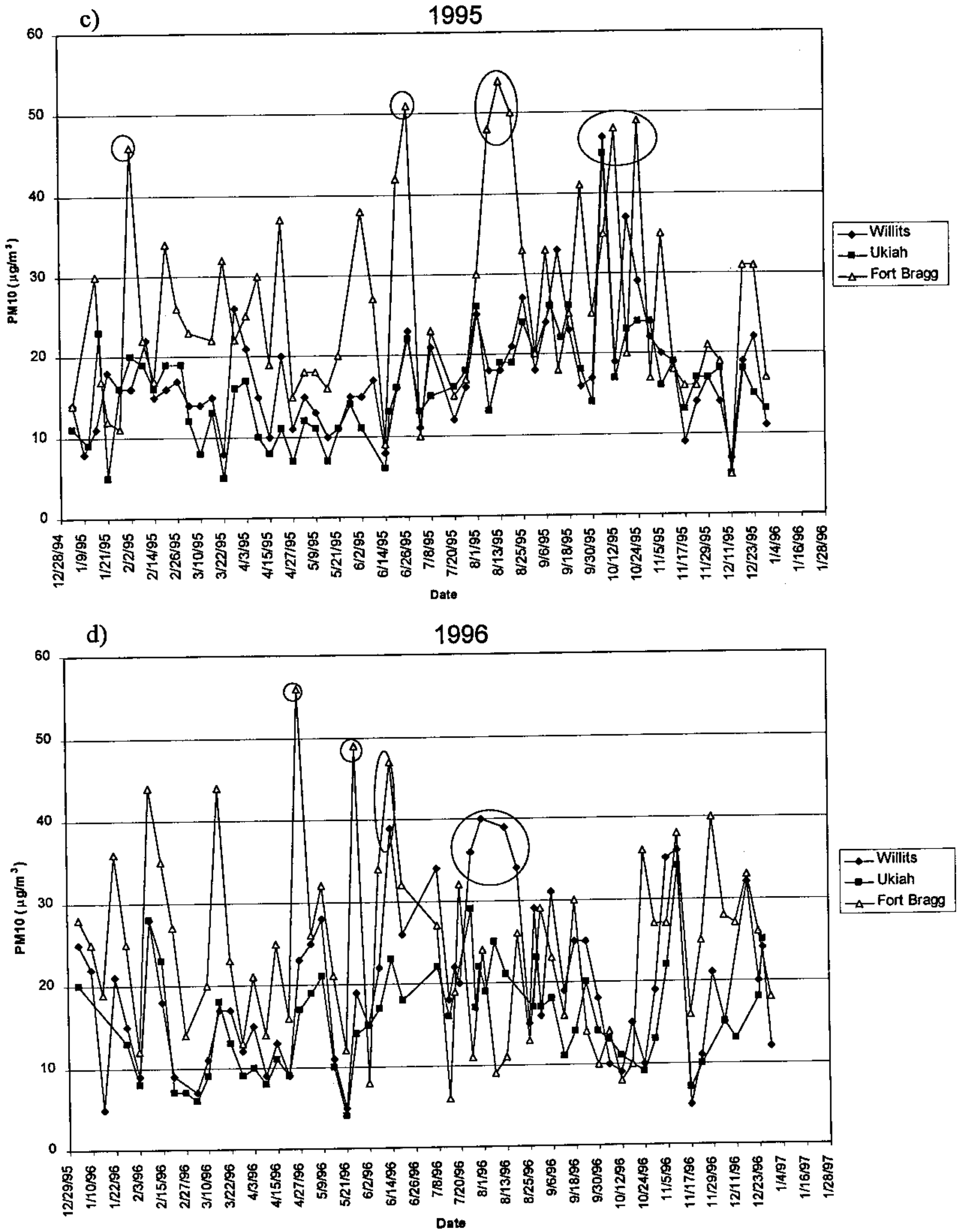


Figure 3-21 c and d. Time-series plots of PM_{10} levels in Willits, Ukiah, and Fort Bragg for 1995 and 1996. Episodes identified are circled.

e)

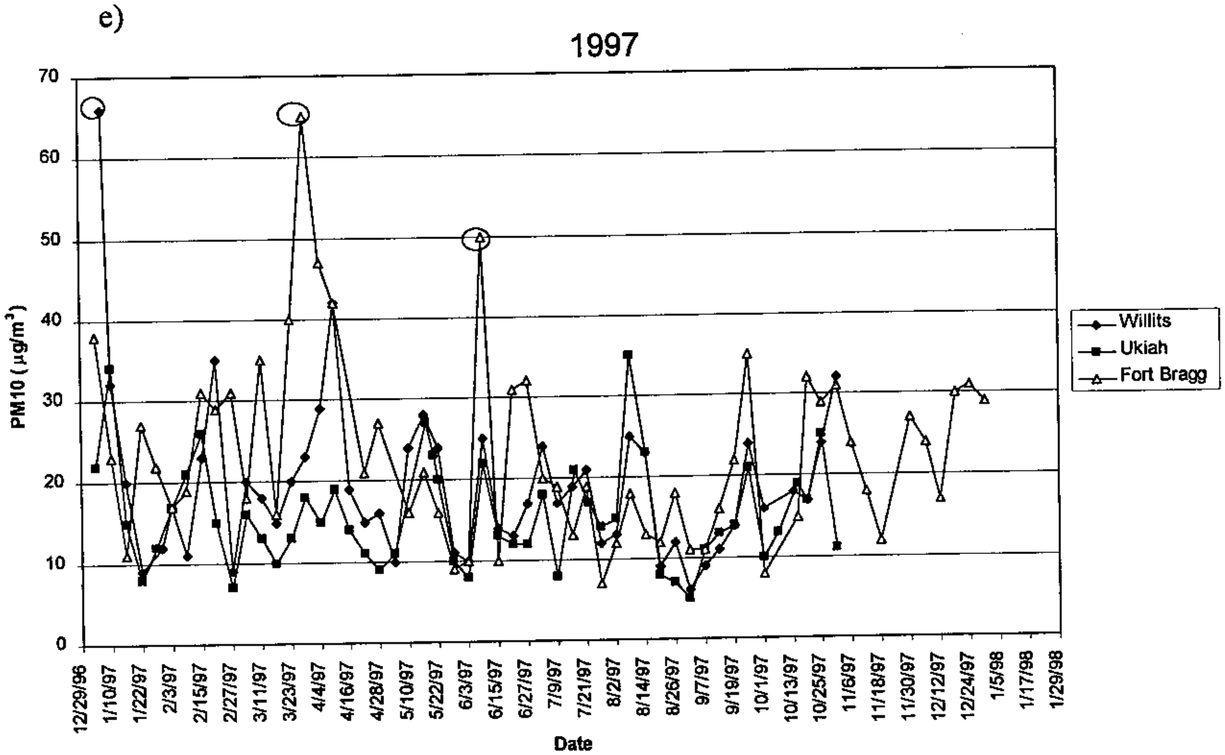


Figure 3-21 e. Time-series plots of PM_{10} levels in Willits, Ukiah, and Fort Bragg for 1997. Identified episodes are circled.

Box-whisker plots of PM_{10} concentrations in Ukiah, Willits, and Fort Bragg versus season during the study years are shown in **Figure 3-22**. Examination of the box plots for Ukiah and Willits shows that 1993 had exceptionally high PM_{10} concentrations. The box plots also show that the maximum values are decreasing during the 1993-1997 time period. However, the median values show no declining trend. The median is consistently in the 10 to 20 $\mu g/m^3$ range for Ukiah and Willits, and between 10 and 30 $\mu g/m^3$ in Fort Bragg.

Figure 3-23 shows a scatter plot of Ukiah and Willits PM_{10} levels during the five-year study period. This plot provides further evidence of the strong correlation between Ukiah and Willits PM_{10} levels at all concentration thresholds. Because the scatter displayed in the diagram is distributed nearly equally at all concentrations and throughout all seasons, the measured particulate mass at the different sites can probably be attributed to similar source activities. **Figure 3-24** shows the scatter plot of Fort Bragg vs. Ukiah PM_{10} levels. PM_{10} levels in Fort Bragg do not correlate well with those of Ukiah or Willits (not shown). This scatter plot also shows that the high Fort Bragg concentrations occur in the spring and when Ukiah has much lower PM_{10} levels.

Peak PM_{10} levels in Ukiah, Willits, and Fort Bragg by time of year over the five-year period is shown in **Figure 3-25**. This plot and Figure 3-22 show the peak PM_{10} levels for Ukiah and Willits to be in the winter and fall. Note that maximum mixing depths within which pollutants may disperse are much shallower during the fall and winter. Thus, pollutants from all local point, area, and mobile sources are confined nearer to the surface than in the warmer seasons of spring and summer. However, recall that Fort Bragg experiences its highest levels in the spring and summer.

A number of possible explanations for this observed pattern (e.g., high levels for Ukiah and Willits during colder months, while Fort Bragg is higher in the spring and summer) can be postulated, including: (a) unusual emissions events, (b) structure fires, (c) residential wood combustion for fuel and space heating, and (d) differences in the size and strength of the mixed layer between coastal Fort Bragg and more inland areas.

Like most filter samples collected in California, PM_{10} samples collected in Mendocino County are not routinely chemically analyzed, however, one filter sample for Fort Bragg was chemically analyzed for May 5, 1993. The total sample mass was 55 $\mu g/m^3$; of this, 19.5 $\mu g/m^3$ was found to be chloride. Assuming that all of the chloride was present as sodium chloride (salt), the total sodium chloride weight would be approximately 32 $\mu g/m^3$, representing 58 percent of the total filter mass. This result is not unreasonable since Fort Bragg's monitoring site is impacted by salt-water spray. Predominant seasonal wind patterns (Hayes et al., 1984) show that on-shore winds are strongest in the spring at Fort Bragg.

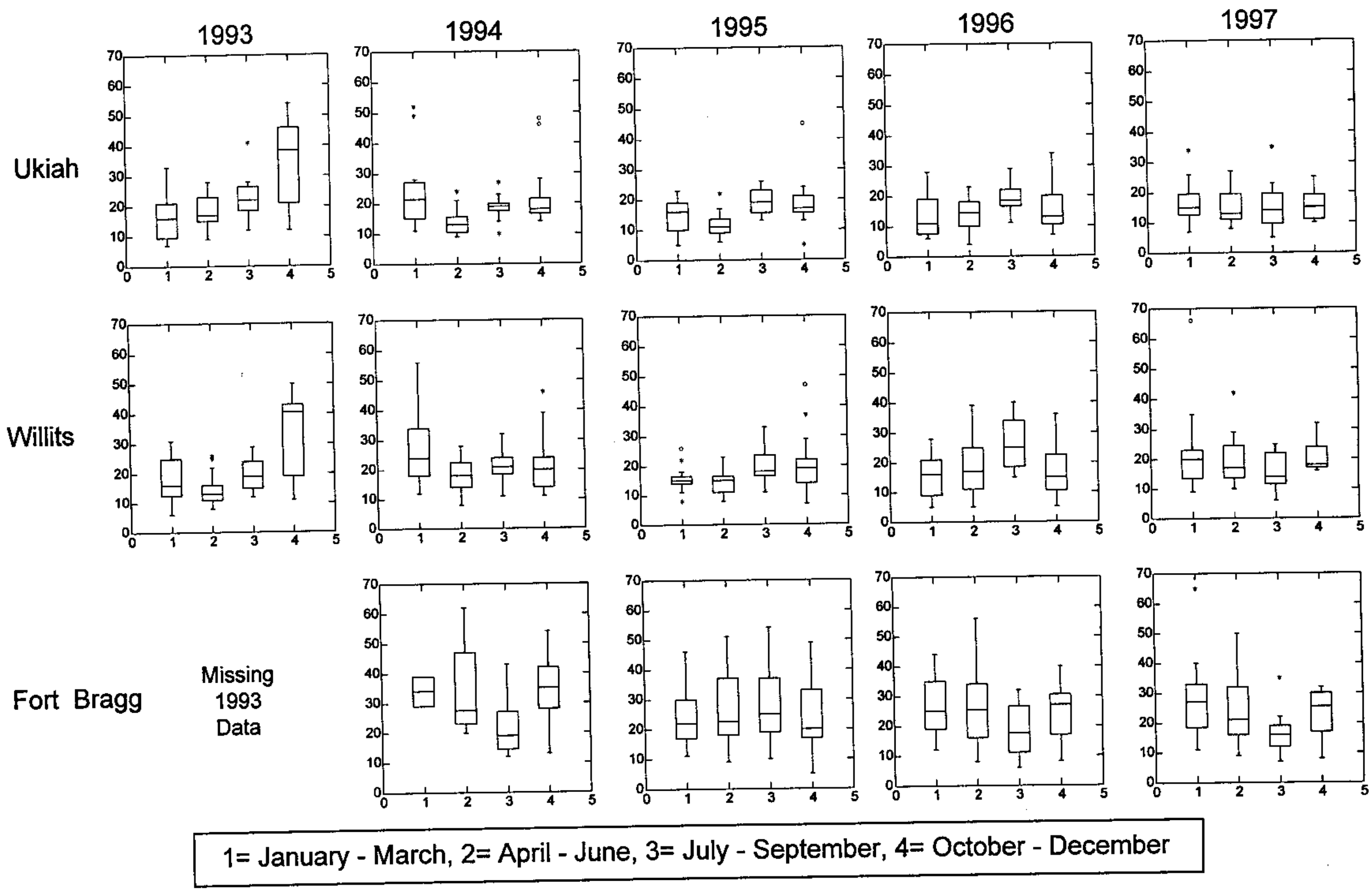


Figure 3-22. Box-whisker plots of PM_{10} levels (µg/m³) over time of year for the Ukiah, Willits, and Fort Bragg sites. Seasons are numbered 1 through 4 representing winter, spring, summer, and fall. The Ukiah and Willits sites show many similarities in the general trends and seasonal profiles. Fort Bragg shows a unique seasonal profile.

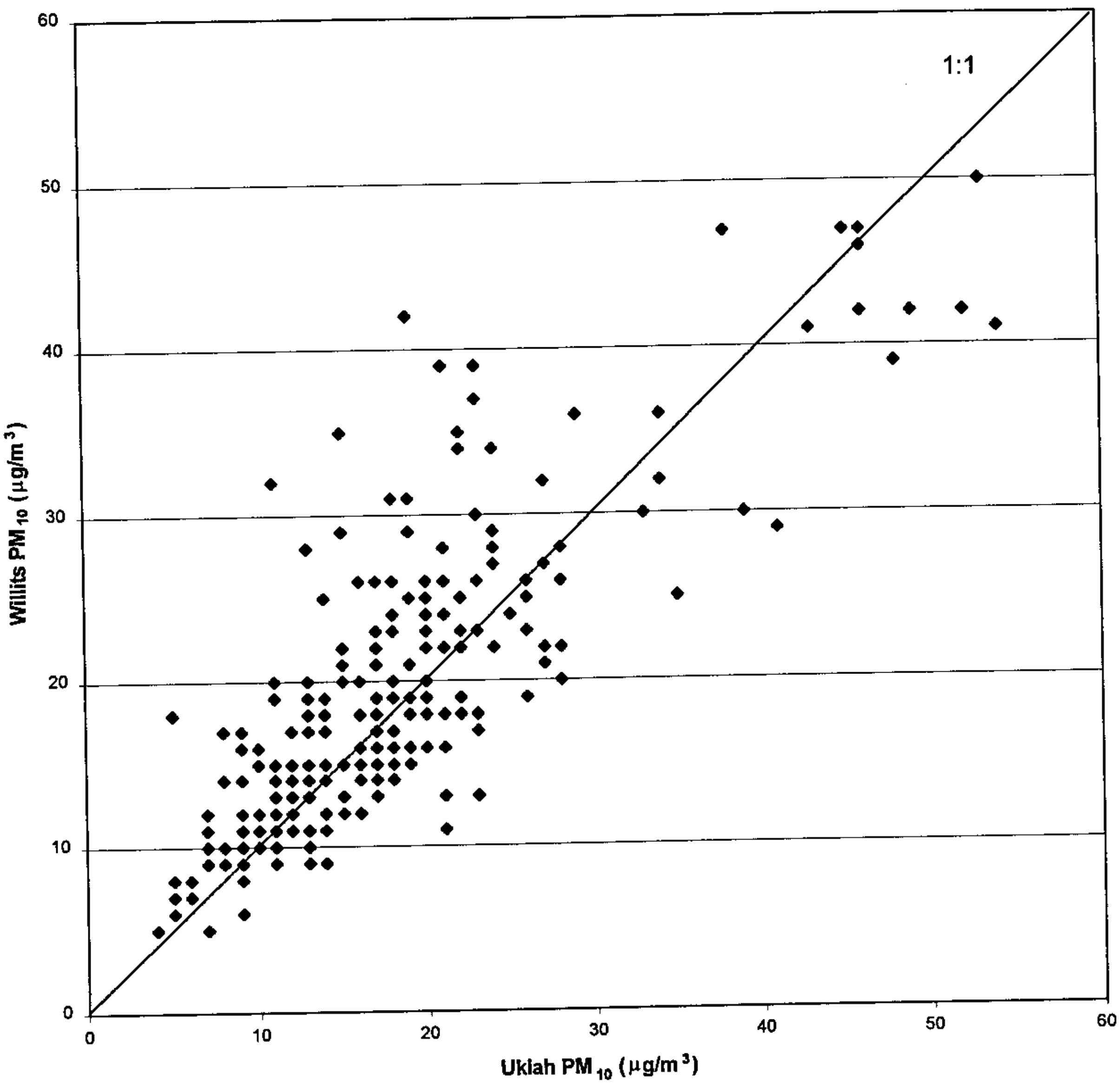


Figure 3-23. Scatter plot of Willits PM_{10} levels versus Ukiah PM_{10} levels. A one-to-one line is shown for comparison.

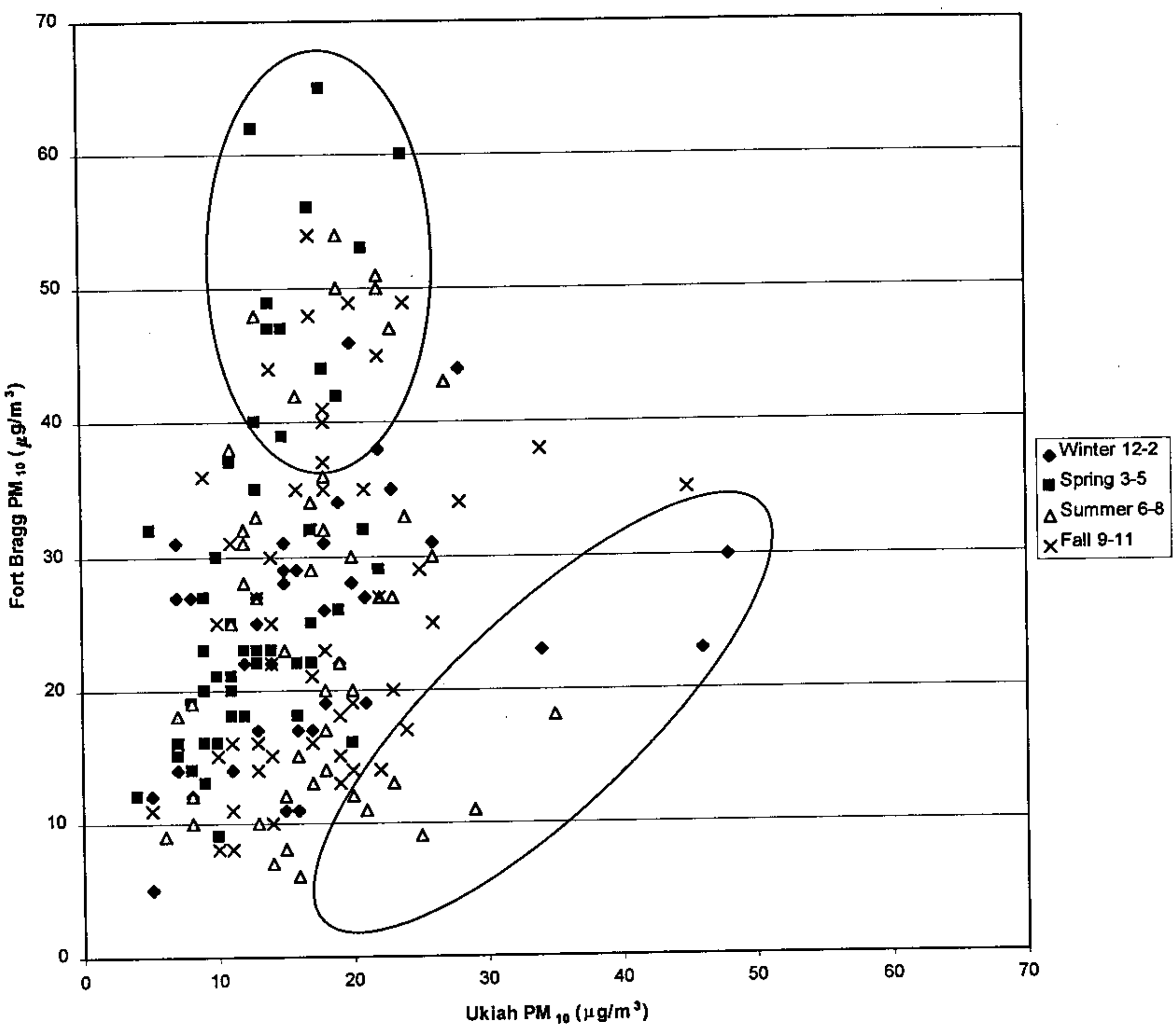


Figure 3-24. Scatter plot of Fort Bragg PM_{10} levels versus Ukiah PM_{10} levels. PM_{10} concentrations are grouped by season. The comparatively high values for Fort Bragg and Ukiah are circled.

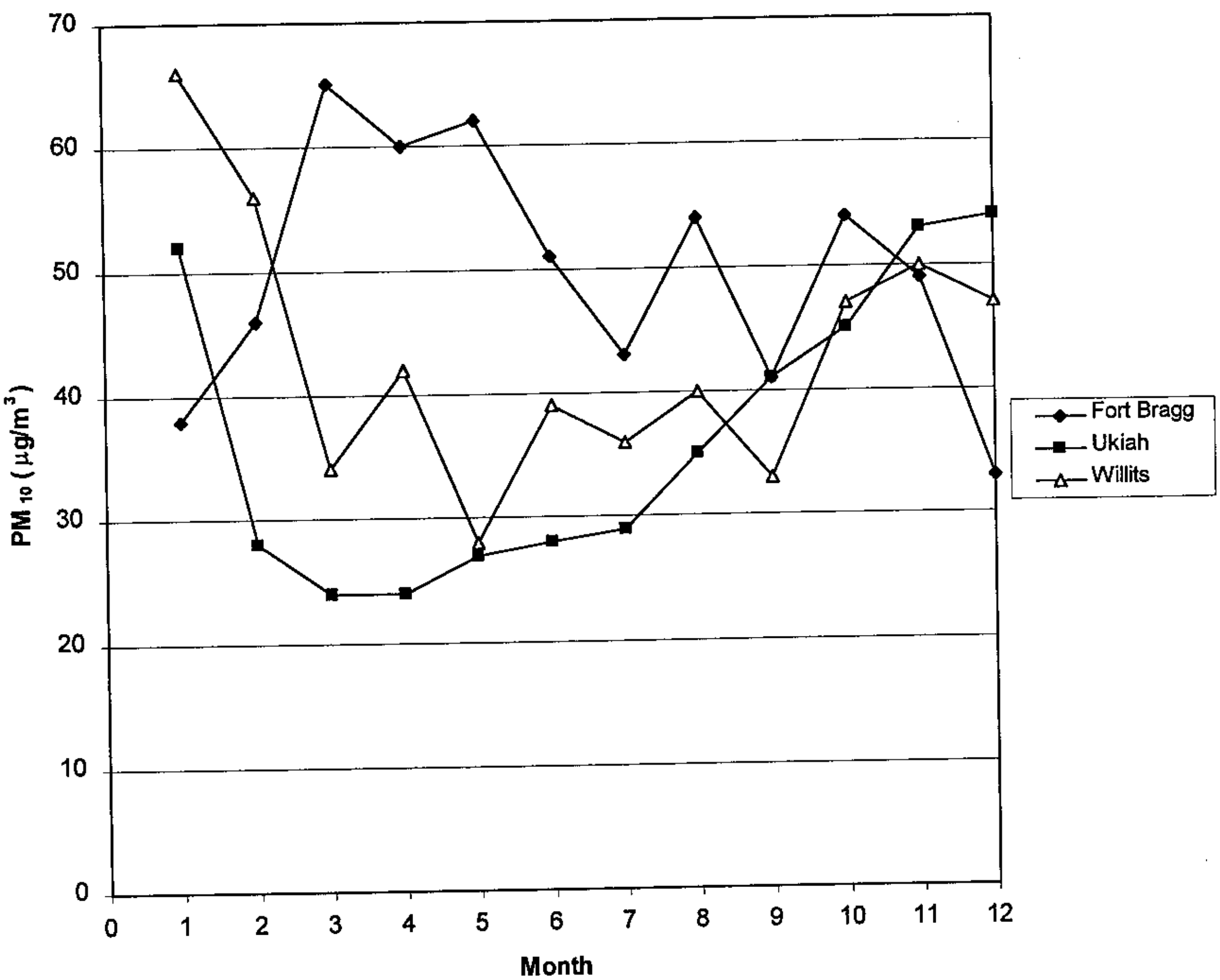


Figure 3-25. Maximum PM_{10} values by month of occurrence (where 1 = January, etc.) The apparent seasonal trend of Ukiah and Willits is opposed by that of Fort Bragg.

It is also of importance to note that the Fort Bragg monitoring site is located a half-mile to the northeast of the Georgia Pacific sawmill plant. This plant has three boiler stacks (fueled by wood scraps) which may contribute to the particulate mass measured in Fort Bragg. On three of the Fort Bragg exceedances, surface winds were southwesterly for a good portion of the day. When the wind direction is southwesterly, Georgia Pacific particulate emissions may impact the monitoring site. **Table 3-4** shows these three days' PM_{10} concentrations and the observed surface wind directions during each day.

Table 3-4. Maximum 24-hr PM_{10} concentrations and surface winds at Fort Bragg for exceedances that may have been affected by a local point source.

Date	PM_{10} ($\mu g/m^3$)	Hour (PDT)	Surface wind direction	Surface wind speed (knots)
6/26/95	51	800	SW	6
		1100	SW	12
		1400	SW	12
		1700	WSW	6
		2000	WSW	6
8/13/95	54	800	SW	3
		1100	NNW	6
		1400	NNW	7
		1700	N	5
		2000	--	--
3/29/97	65	700	E	9
		1000	W	3
		1300	SW	10
		1600	SW	9
		1900	SW	5

Examination of PM_{10} concentrations throughout Mendocino County shows that PM_{10} levels violate the State 24-hr standard at least at one site during each of the study years and that the high concentrations vary by season between sites. Fort Bragg PM_{10} air quality is apparently not correlated with Ukiah or Willits, which are strongly correlated with each other. To provide a more quantitative understanding of source contributions to the PM_{10} samples, a study of the compositions on the PM filter samples at each location as a function of month and wind patterns is needed. The chemical analyses of the filter samples could confirm the hypothesis that the high PM in the Ukiah Valley and at Willits are due to residential wood combustion and the high PM values at Fort Bragg are due to sea salt.

4. EMISSION INVENTORY ASSESSMENT

4.1 INTRODUCTION

The principal emission precursors to ozone formation are oxides of NO_x and VOC. Note that in California, the ARB has refined this category of emissions to include only ROG. Anthropogenic (man-made) ROG emissions come from a broad range of sources such as evaporation of solvents and gasoline, dry-cleaning, and auto-repair shops, while biogenic (natural) ROG emissions are released by trees and plants. NO_x emissions are primarily emitted by anthropogenic sources involving fossil fuel combustion (i.e., motor vehicle exhaust and natural gas combustion). NO_x can also occur naturally (in small quantities) from microbial actions in soils following the application of fertilizer. The emission inventory reported for Mendocino County by the ARB indicates that PM results from a combination of natural processes including windblown dust, mechanically suspended dirt particles (e.g., paved and unpaved-road dust or agricultural activities), wildfires and from man-made combustion sources.

The Clean Air Act Amendments of 1990 require state and local air quality agencies to compile complete and accurate emission inventories as part of their air quality management responsibilities. Emission inventories are used to evaluate air quality, track emission increases or reductions, and for setting permit requirements. The current emission inventory for Mendocino County, available from the ARB California Emission Inventory Development and Reporting System II (CEIDARS II) has not been systematically updated in several years. The objective of this emission inventory assessment is to evaluate the current point, area, and mobile source emission inventories for Mendocino County and then to estimate emissions for about 20 years in the future (e.g., year 2020).

For discussion purposes, we have divided Mendocino County into three sections shown in **Figure 4-1**: (a) the entire County, (b) the area defined as the Little Lake Air Basin, and (c) the urban Ukiah valley which is a sub-section of the Little Lake Air Basin. Mendocino County is a relatively large and heavily forested County with approximately 83,000 inhabitants. The three major cities in the County are Ukiah, Willits, and Fort Bragg. The County is unique in that it contains many features that attract tourism within the County as well as passthrough traffic to nearby tourist attractions; Clearlake, a major recreational area for boating and camping, is located approximately 14 miles east of Ukiah off of Highway 20 in Lake County. Lake Mendocino, a smaller recreation area, is located about 4 miles north of Ukiah. Highway 1, located along the California coast, is a popular tourist route and carries traffic into and through the County, as does Highway 101 which extends through the Ukiah valley.

This section provides a general overview and discussion of emissions in Mendocino County including the relative contribution of man-made and natural sources of ROG, NO_x, and PM. In addition, possible implications of emission inventory inaccuracies in current and future-year emissions in Mendocino County are presented.

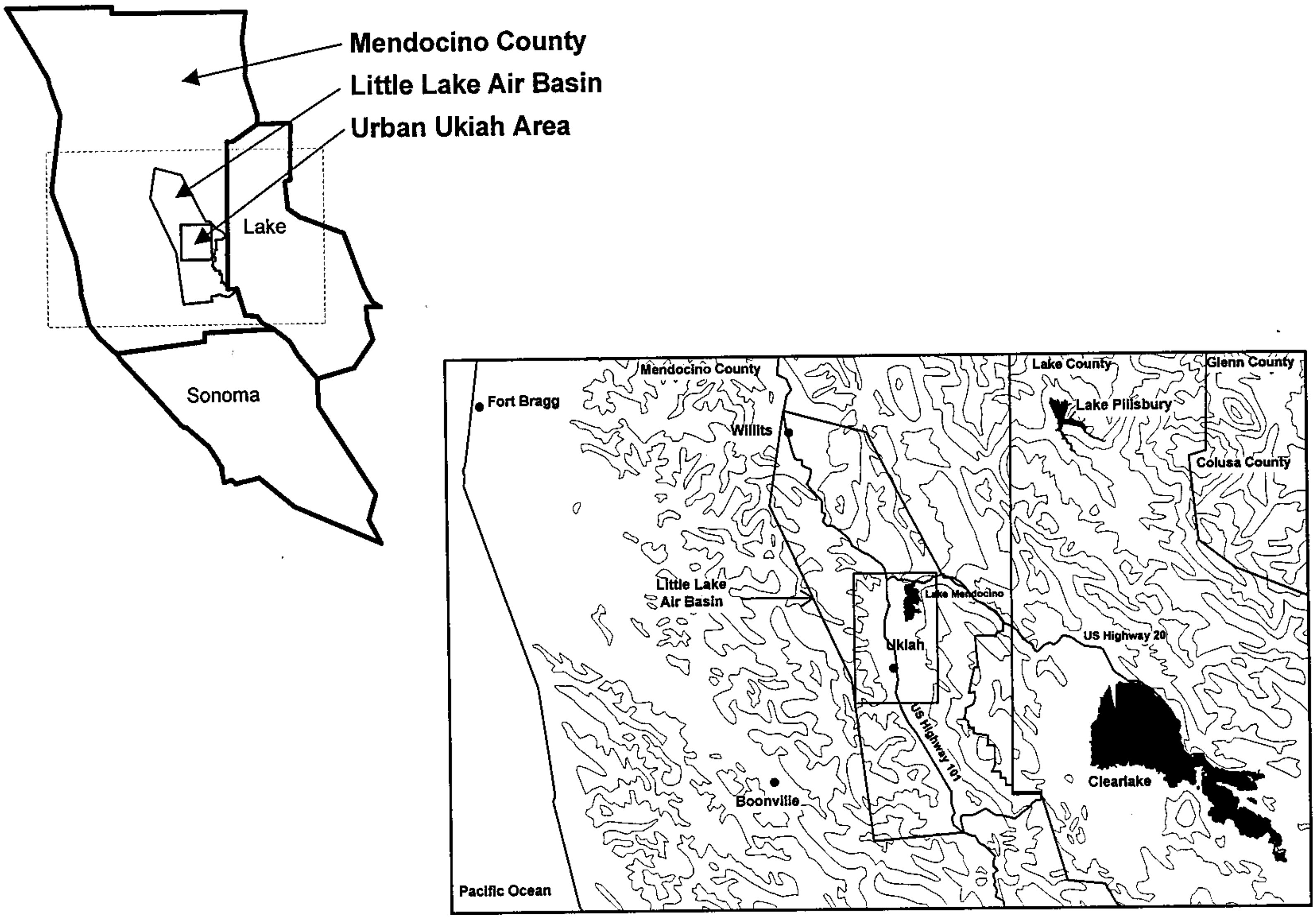


Figure 4-1. Depiction of Mendocino County, the area designated as the Little Lake Air Basin, and the urban Ukiah valley including major highways, lakes, and topography. Note that contour intervals correspond to 1000 feet.

4.2 MENDOCINO COUNTY EMISSIONS: AN OVERVIEW

Mendocino County is a very large County with expansive, rural forested areas as well as agricultural cropland areas and a few major cities (e.g., Ukiah, Willits, and Fort Bragg). From land use data for Mendocino County, obtained from the U.S. Geological Services (USGS) Land Cover Database, it was determined that approximately 50 percent of the total county area is forested, 30 percent is agricultural crop land, 15 percent is urban, and the remaining 5 percent is range land and other. For ease of presentation, emissions are often categorized into several major types: (a) stationary sources, (b) area sources, (c) on-road mobile sources, (d) other mobile sources, and (e) natural sources. A detailed listing of emissions by individual source types is shown in **Exhibit 4-1**. As listed in Exhibit 4-1, examples of stationary sources include industrial facilities; area sources are comprised of wide-spread sources such as residential wood combustion; on-road mobile sources refers to cars and trucks; and other mobile refers to boats, planes, and trains for example. Man-made emission source contributions to 1995 total ROG, NO_x, and PM_{10} emissions are shown in **Figure 4-2**. As shown, on-road and other mobile sources are responsible for more than half of the total ROG and approximately 90 percent of total inventory NO_x emissions. PM emissions mostly come from area sources such as unpaved roads and other sources of dust. In 1995, ROG emissions were 6329 tons/year (about 17 tons/day), and NO_x emissions were 6066 tons/year (also about 17 tons/day). In 1995, mobile sources accounted for the majority of man-made ozone precursor emissions in Mendocino County.

A comparison of total man-made emissions for Mendocino County, the North Coast Air Basin, and the San Francisco Bay Area is shown in **Figure 4-3**. Note that emissions in Mendocino County are responsible for about one-third of the total ROG and NO_x emissions in the North Coast Air Basin, and are relatively small compared to the Bay Area.

4.2.1 Biogenic Emissions

In this study, biogenic emissions were determined using PCBEIS-2, the newest biogenic emission estimation model released by the EPA. PCBEIS-2 is designed to calculate emissions for an entire county, however, adjustments can be made to the input files to account for land use to estimate emissions in sub-county areas. PCBEIS-2 uses the following land use categories: 1) forest, 2) urban forest, 3) agriculture, and 4) other. Examination of topographical maps and satellite imagery, confirm that most of the forested area in Mendocino County is outside of the Little Lake Air Basin, and that the other three land use categories primarily apply in the urbanized area and in the Ukiah valley (below about 1000 feet). Biogenic ROG emissions as estimated by the EPA model are quite large. In fact, in a predominately forested area such as Menodcino County, biogenic ROG emissions can be much greater than man-made ROG emissions.

Category Name	1995 Emissions (tons/year)			
	ROG	CO	NO_x	PM_{10}
Stationary Sources				
Fuel Combustion				
Manufacturing/Industrial		3.7	11.0	
Food/Agriculture	21.9	32.9		29.2
Service/Commercial		3.7	25.6	
Waste Disposal				
Landfills	40.2			
Cleaning and Surface Coating				
Dry cleaning (perchloroethylene)	36.5			
Manufacturing Degreasing	43.8			
Commercial Degreasing (halogenated organics)				
Commercial Degreasing (petroleum based)	69.4			
Auto Refinishing	58.4			
Wood/Furniture/Fabricated Products	25.6			
Thinning/Clean-up	47.5			
Other coatings	14.6			
Cleaning and Surface Coating (Adhesives/Sealants-organic based)	11.0			
Cleaning and Surface Coating (Adhesives/Sealants-water based)	3.7			
Petroleum Production and Marketing				
Petroleum Marketing				
Fuel Dispensing Tanks - Working Losses	167.9			
Fuel Dispensing Tanks - Breathing Losses	18.3			
Vehicle Refueling - Vapor Displacement	105.9			
Vehicle Refueling - Spillage	14.6			
Bulk Plants/Storage - Breathing Losses	7.3			
Bulk Plants/Storage - Working Losses	47.5			
Tank Cars and Trucks - Working Losses	54.8			
Industrial Processes				
Food/Agriculture				
Wine Fermentation	11.0			
Wine Aging	3.7			
Sand Aggregate			0.3	14.6
Parnum Paving	0.1	0.9	3.7	2.9
Georgia Pacific	66.4	799.4	169.0	119.4
Baxman Gravel Co.			0.1	1.7
Wood/Paper				25.6
Masonite Hardboard	123.1	390.3	144.8	194.5
Total Stationary Sources	**992.6**	**1230.8**	**354.4**	**387.9**

Exhibit 4-1. Mendocino County detailed emission inventory. Page 1 of 4

	1995 Emissions (tons/year)			
Category Name	ROG	CO	NO_x	PM_{10}
Area-Wide Sources				
Solvent Evaporation				
Consumer Products				
Aerosol Paint Propellants	10.95			
Aerosol Paint Solvents	18.25			
Aerosol Product Propellants	25.55			
Aerosol Product Solvents	76.65			
Non-Aerosol Solvents	113.15			
Architectural Coatings				
Arch. Coatings Oil Based	91.25			
Arch. Coating Water Based	43.8			
Thinning and Cleanup Solvents	25.55			
Pesticides/Fertilizer				
Agri. pesticides (Methyl Bromide)	25.55			
Agri. pesticides (non-Methyl Bromide)	138.7			
Aerosol Resid. Pesticides	14.6			
Asphalt Paving				
Cutback Asphalt	273.75			
Hot-Mix Asphalt	3.65			
Emulsified Asphalt	18.25			
Miscellaneous Processes				
Residential Fuel Combustion				
Wood Combustion - Stoves	321.2	4661.05	65.7	719.05
Wood Combustion - Fireplace	25.55	511	3.65	65.7
Fuel Combustion - Sp. Heating (Gas)		7.3	18.25	3.65
Fuel Combustion - Sp. Heating (Dist.Oil)	3.65	7.3	29.2	3.65
Fuel Combustion - Water Heating		3.65	10.95	
Other -Liquified Petroleum Gas		3.65	14.6	
Farming Operations				
Tilling Dust				29.2
Construction and Demolition				
Building Construction Dust-Res				94.9
Building Construction Dust-Com				10.95
Building Construction Dust-Indust				7.3
Building Construction Dust-Instit				25.55
Road Construction Dust				248.2
Paved Road Dust				
Paved Rd Travel Dust-Major Streets				266.45
Paved Rd Travel Dust-Collector Streets				91.25
Paved Rd Travel Dust-Local Streets				288.35
Unpaved Road Dust				
Unpaved Rd Dust Trav.-City and County Roads				1168
Unpaved Rd Dust Trav.-U.S. Forest and Park Roads				518.3
Unpaved Rd Dust Trav.-B.L.M. Roads				2482
Unpaved Rd Dust Trav.-Farm Roads				80.3
Fugutive Windblown Dust				
Ag. Lands				3.65
Unpaved Roads				62.05
Fires				
Structural Fires		25.55		
Waste Burning and Disposal				
Ag. Burning - Prunings	3.65	32.85		3.65
Range Improvement	3.65	32.85		3.65
Forest Mangement	21.9	759.2		40.15
Weed Abatement		7.3		
Non-Ag. Open Burning	40.15	281.05	18.25	51.1
Utility Equipment				
Lawn and Garden - Residential	69.35	295.65		
Lawn and Garden - Commercial	803	3084.25	7.3	18.25
Commercial Charbroiling	3.65			14.6
Total Area-Wide Sources	**2175**	**9713**	**168**	**6300**

Exhibit 4-1. Mendocino County detailed emission inventory. Page 2 of 4

Category Name	1995 Emissions (tons/year) ROG	CO	NO_x	PM_{10}
Mobile Sources				
On-Road Motor Vehicles				
Light Duty Passenger				
Non-catalyst starts	87.6	386.9	7.3	
Non-catalyst hot stabilized	138.7	985.5	76.65	
Non-catalyst evap running losses	3.65			
Non-catalyst evap resting losses	3.65			
Non-catalyst hot soak	29.2			
Non-catalyst diurnal	3.65			
Catalyst starts	485.45	6763.45	237.25	
Catalyst hot stabilized	361.35	8289.15	952.65	3.65
Catalyst evap running losses	36.5			
Catalyst evap resting losses	32.85			
Catalyst hot soak	62.05			
Catalyst diurnal	21.9			
Catalyst tire wear				3.65
Catalyst brake wear				7.3
Diesel starts		7.3		
Diesel hot stabilized		3.65	7.3	
Light Duty Trucks				
Non-catalyst starts	62.05	200.75	3.65	
Non-catalyst hot stabilized	73	525.6	40.15	
Non-catalyst evap running losses	3.65			
Non-catalyst evap resting losses	3.65			
Non-catalyst hot soak	18.25			
Non-catalyst diurnal	3.65			
Catalyst starts	416.1	5832.7	244.55	
Catalyst hot stabilized	321.2	6602.85	1043.9	3.65
Catalyst evap running losses	18.25			
Catalyst evap resting losses	21.9			
Catalyst hot soak	47.45			
Catalyst diurnal	18.25			
Catalyst tire wear				3.65
Catalyst brake wear				3.65
Diesel starts		3.65		
Diesel hot stabilized		3.65	7.3	
Medium Duty Trucks				
Non-catalyst starts	3.65	10.95		
Non-catalyst hot stabilized	3.65	25.55	3.65	
Catalyst starts	58.4	730	36.5	
Catalyst hot stabilized	51.1	762.85	153.3	
Catalyst evap running losses	3.65			
Catalyst evap resting losses	3.65			
Catalyst hot soak	3.65			
Catalyst diurnal	3.65			
Light Heavy Duty Gas Trucks				
Non-catalyst hot stabilized	10.95	350.4	40.15	
Catalyst hot stabilized	10.95	193.45	91.25	
Catalyst evap running losses				
Medium Heavy Duty Gas Trucks				
Non-catalyst hot stabilized	7.3	259.15	25.55	
Catalyst hot stabilized		36.5	18.25	
Light Heavy Duty Diesel Trucks				
Diesel hot stabilized	7.3	32.85	47.45	3.65
Medium Heavy Duty Diesel Trucks				
Diesel hot stabilized	14.6	65.7	102.2	10.95
Heavy Heavy Duty Diesel Trucks				
Diesel hot stabilized	40.15	189.8	357.7	29.2
Diesel tire wear				
Motorcycles				
Non-catalyst starts	3.65	18.25		
Non-catalyst hot stabilized	10.95	47.45	7.3	
Heavy Duty Diesel Urban Buses				
Diesel hot stabilized			7.3	
Total On-Road Mobile	2511.20	32328.05	3511.30	69.35

Exhibit 4-1. Mendocino County detailed emission inventory. Page 3 of 4

Category Name	1995 Emissions (tons/year) ROG	CO	NO_x	PM_{10}
Other Mobile Sources				
Aircraft				
Military		14.60		
Commercial		14.60		
Civil	3.65	109.50		
Trains				
Locomotive Load Hauling	7.3	21.90	175.20	10.95
Ships and Commercial Boats				
Commercial gasoline	3.65	29.20		
Commercial diesel	47.45	105.85	259.15	25.55
Recreational Boats				
Recreational Boats gasoline	310.25	1361.45	18.25	10.95
Recreational Boats diesel	3.65	3.65	10.95	
Off-Road Recreational Vehicles				
Off-Road Motorcycles	25.55	138.70	3.65	
All Terrain Vehicles	18.25	98.55		
Four Wheel Drive Vehicles	7.3	91.25	7.30	
Commercial/Industrial Mobile Equip.				
Light Duty Equipment - four stroke (LPG)	14.6	452.60	14.60	
Light Duty Equipment - four stroke (gas)	25.55	730.00	10.95	
Light Duty Equipment - four stroke (diesel)	14.6	91.25	186.15	10.95
Heavy Duty Equipment (gasoline)	3.65	116.80	3.65	
Heavy Duty Equipment (diesel)	25.55	138.70	438.00	18.25
Transport Refrigeration (diesel)	3.65	14.60	18.25	
Farm Equipment				
Heavy Duty Gasoline	62.05	1846.90	36.50	
Heavy Duty Diesel	73	277.40	850.45	51.10
Total Other Mobile	649.70	5657.50	2033.05	127.75

Exhibit 4-1. Mendocino County detailed emission inventory. Page 4 of 4

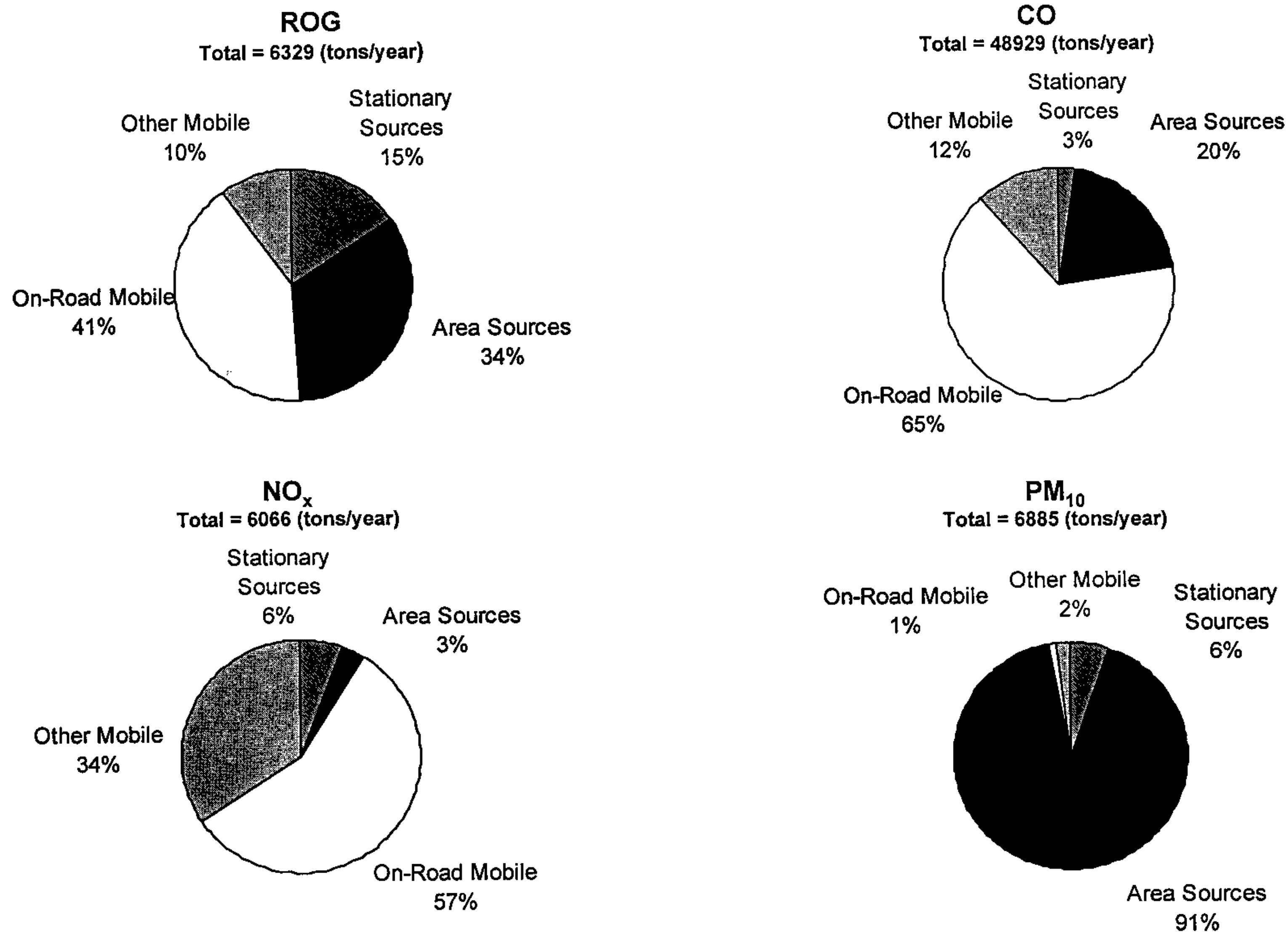
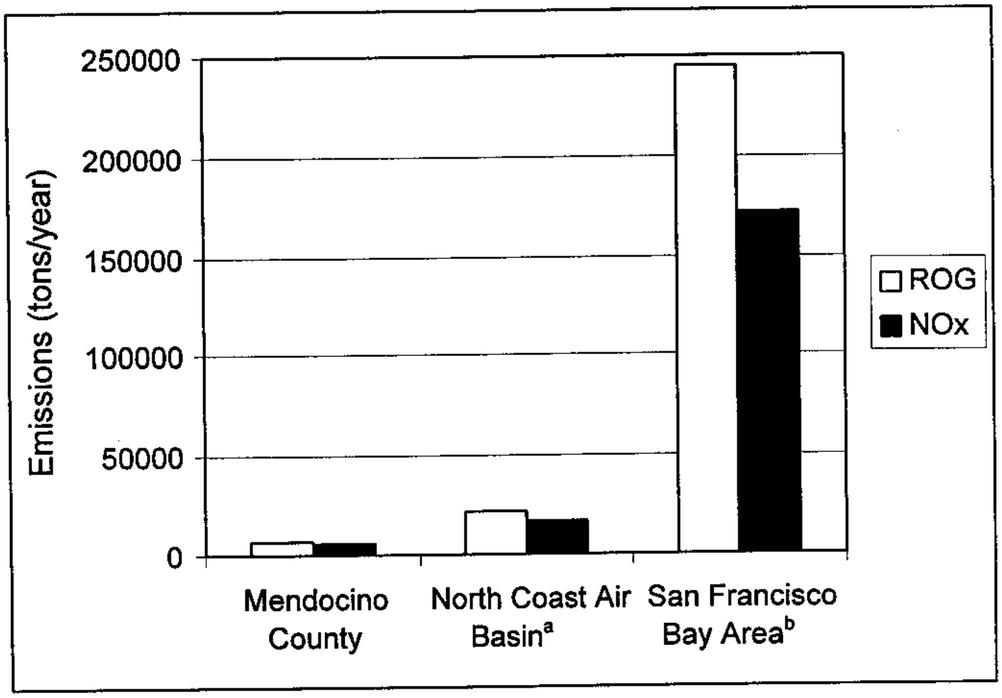


Figure 4-2. Source category contributions to the 1995 ROG, CO, NO_x, and PM_{10} emission inventory in Mendocino County.



a. The North Coast Air Basin includes the following counties: Del Norte, Humboldt, Mendocino, northern Sonoma, and Trinity.
b. The San Francisco Bay Area includes the following counties: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and southern Sonoma.

Figure 4-3. Comparison of 1995 ROG and NO_x emissions in Mendocino County, the North Coast Air Basin, and the San Francisco Bay Area.

Table 4-1a and b summarizes the man-made and biogenic emissions calculated for Mendocino County, the Little Lake Air Basin, and the urban Ukiah valley and compares them to total man-made emissions in Mendocino County. VOC emissions from biogenic sources in Mendocino County and in the Little Lake Air Basin are much greater than ROG emissions from man-made sources. However, in the urban Ukiah valley, where there is less forested land, and a significant amount of urban land use, the biogenic emissions are much less, but are about the same as the man-made ROG emissions.

Table 4-1a. Man-made and biogenic emission estimates for Mendocino County.

Source	ROG (tons/day)	% of Total ROG	NO_x (tons/day)	% of Total NO_x
Biogenic	335	95	0.6	3
Man-made	17.3	5	16.6	97
Total	352		17.2	

Table 4-1b. Biogenic emission estimates for Mendocino County, the Little Lake Air Basin, and the urban Ukiah valley.

Region	Area (km^2)	VOC Emissions (tons/day)	NO_x Emissions (tons/day)
Mendocino County	9253	335	0.55
Little Lake Air Basin	800	31	0.06
Urban Ukiah Valley	130	3	0.01

4.2.2 Man-Made Emissions

Stationary and area-wide sources

The largest stationary sources of ROG are evaporative emissions associated with fuel dispensing tanks (i.e., vapors emitted during gasoline refueling). Evaporative emissions associated with refueling are responsible for about 17 percent of the total stationary source ROG emissions. About 80 to 85 percent of the stationary source NO_x and PM_{10} comes from two point source facilities: Georgia Pacific, located in Fort Bragg and Masonite Hardboard, located in Ukiah. Commercial lawn and garden equipment and residential wood combustion are the two major contributors to area source ROG, while residential fuel combustion is the major source of NO_x. Unpaved road dust is responsible for more than half of the area source PM_{10} emissions and residential wood combustion is responsible for about 10 percent. **Tables 4-2a and b** list the top three stationary and area source contributors to ROG, NO_x and PM_{10} in 1995.

Table 4-2a. Top three contributing source categories to 1995 total stationary source emissions in Mendocino County.

Stationary Source	Emissions (tons/year)	% Total Stationary Source Emissions
ROG		
Fuel Dispensing	168	17
Masonite Hardboard	123	12
Vehicle Refueling	106	11
NO_x		
Georgia Pacific	169	48
Masonite Hardboard	145	41
Service/Commercial Sector	26	7
PM_{10}		
Masonite Hardboard	195	50
Georgia Pacific	119	31
Agricultural Industry	29	8

Table 4-2b. Top three contributing source categories to 1995 total area source emissions in Mendocino County.

Area Source	Emissions (tons/year)	% Total Area Source Emissions
ROG		
Commercial Landscape Equipment	803	37
Residential Wood Combustion	321	15
Cutback Asphalt	274	13
NO_x		
Residential Wood Combustion	66	39
Residential Fuel Combustion (Distillate Oil)	29	17
Residential Fuel Combustion (Gas)	18	11
PM_{10}		
Unpaved Road Dust (BLM Roads)	2482	40
Unpaved Road Dust (City & County)	1168	19
Residential Wood Combustion	719	11

Stationary source ROG emissions from fuel dispensing and vehicle refueling are estimated by ARB using gasoline sales and throughput data from the California State Board of Equalization combined with AP-42 vapor displacement emission factors. The calculated emissions take into account Stage I and Stage II vapor recovery efficiencies. Because emissions from vehicle refueling were so high, fuel consumption data for Mendocino County were reviewed. It was discovered that gasoline sales in Mendocino County account for 1.25 percent of the California statewide total, although other socio-economic statistics such as population, total taxable sales, the number of valid drivers licenses, and the number of unregistered vehicles account for approximately only 0.3 percent of the statewide totals. Based on this information obtained from the California Board of Equalization and Caltrans, it can be inferred that the per capita fuel sales for Mendocino County are about four times higher than the statewide average.

Area source ROG emissions for commercial landscape equipment and cutback asphalt were grown by ARB from District values from 1987 and 1989 respectively (personal communication, MCAQMD). These values appear to be inaccurate and should be revised. Note that because the MCAQMD also believes the growth factors used by ARB are inaccurate, they are in the process of developing new base year inputs for use by ARB for the 1997 emission updates. According to the Mendocino County Transportation Department, fast cure cut-back asphalt has not been used in the county since about 1995 and should be remove from the emission inventory. Residential wood combustion is estimated by ARB using county-wide residential energy demand estimates which are based on temperature and the corresponding heating demand, the number of residential heating units, and woodstove/fireplace emission factors (California Air Resources Board, 1997b).

Mobile source emissions

Because mobile source emissions account for the majority of ozone precursor emissions in Mendocino County, it is of interest to examine the contributions of both on- and off-road mobile sources. **Figure 4-4** shows a detailed breakdown of the vehicle contributions to on-road mobile source ROG and NO_x emissions. Light-duty vehicles (i.e., light-duty cars and trucks) are responsible for the bulk of mobile source ROG and NO_x emissions, while heavy-duty trucks are responsible for about 15 percent of mobile source NO_x. Farm equipment and commercial/industrial equipment account for about 35 percent of the off-road mobile source ROG emissions and about 80 percent of NO_x emissions. Recreational boats also contribute significantly to off-road mobile source ROG (about 50 percent). The recreational boat emissions reported are consistent with emissions published in the Improved Inventory of Emissions from Pleasure Craft in California (California Air Resources Board, 1995). **Figure 4-5** shows a detailed breakdown of the off-road mobile source emission inventory for ROG and NO_x.

Emission estimates for on-road mobile sources were generated using the latest version of the Motor Vehicle Emission Inventory (MVEI7G) model. The MVEI7G incorporates the latest research on motor vehicle emission factors, and includes vehicle miles of travel (VMT) data by vehicle class for most counties in California. The model estimates ROG, CO, NO_x and PM_{10} emissions during the summer ozone season. The 1995 on-road mobile source emission estimates developed using MVEI7G for Mendocino County are shown in **Table 4-3**. On-road mobile source ROG emissions for a typical summer day are about 6.9 tons/day, and the NO_x emissions are 9.6 tons/day.

The MVEI7G model provides a fairly detailed breakdown of emissions by vehicle type. Based on vehicle fleet mix, it can be seen that most of the ROG and NO_x emissions come from light-duty vehicles. Heavy-duty trucks also contribute significantly (about 20 percent) to NO_x emissions. The MVEI7G model uses vehicle registration data by vehicle type. Countywide fleet distribution and VMT are incorporated into the model based on information supplied by the Department of Motor Vehicles and Caltrans. Using this information and vehicle emission factors by type and vintage, the model provides a fairly detailed breakdown of on-road mobile source emissions. The MVEI7G model assumes a certain percentage of unregistered vehicles per county which may not be representative of the high percentage of unregistered vehicles in Mendocino. The statewide average percentage of unregistered vehicles is about 6-8 percent; through discussions with Caltrans it was discovered that about 20 percent of the vehicles in Mendocino County are unregistered. If the MVEI7G model assumes 6-8 percent unregistered vehicles in Mendocino County, then the mobile source emissions are likely underestimated. Furthermore, if the fraction of unregistered vehicles that are higher emitting sport utility and light duty trucks then the emissions are even more likely to be underestimated.

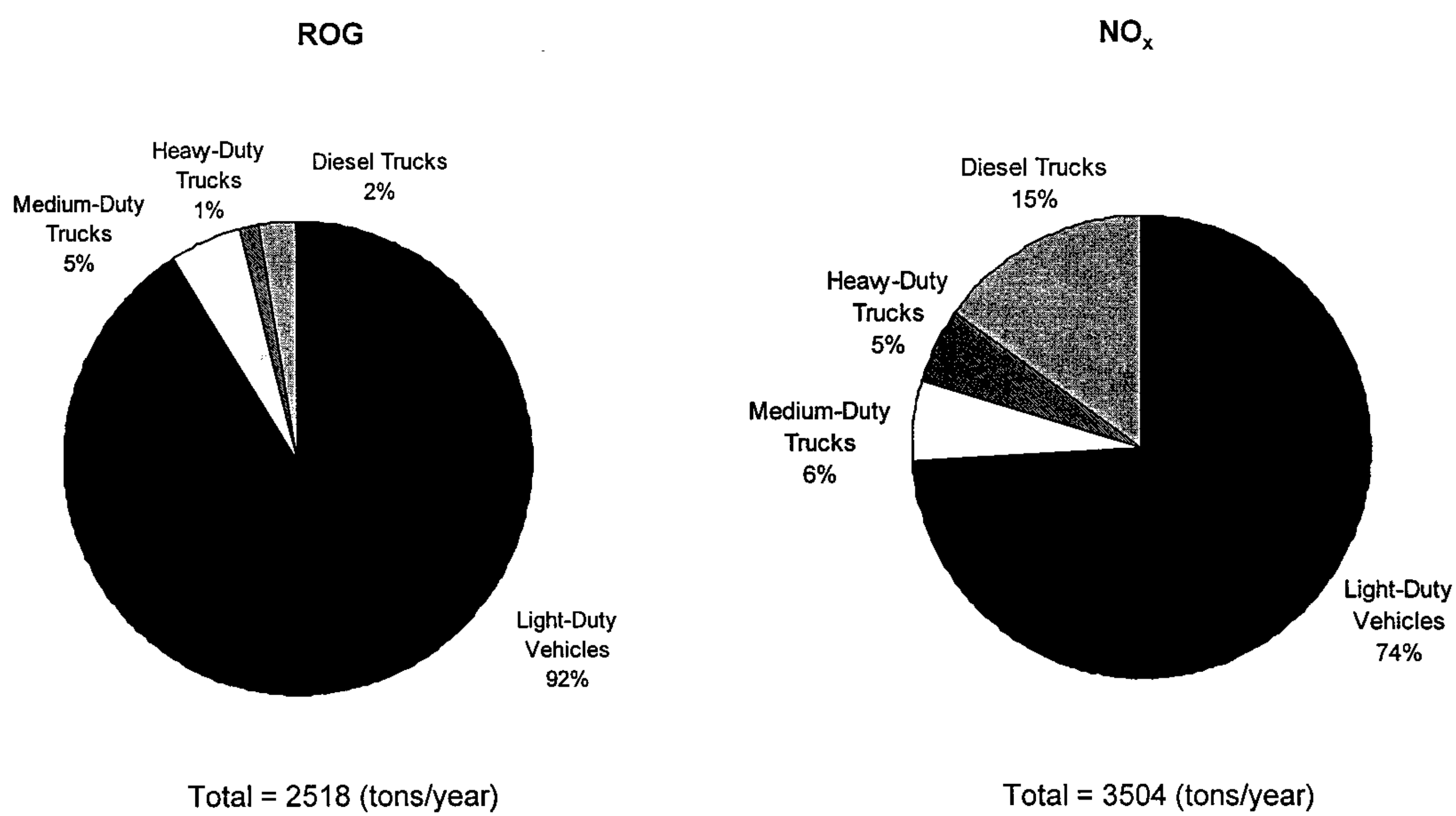


Figure 4-4. Vehicle contribution to 1995 on-road mobile source ROG and NO_x emissions in Mendocino County. Light-duty automobiles and trucks account for most of the mobile source ROG and NO_x emissions.

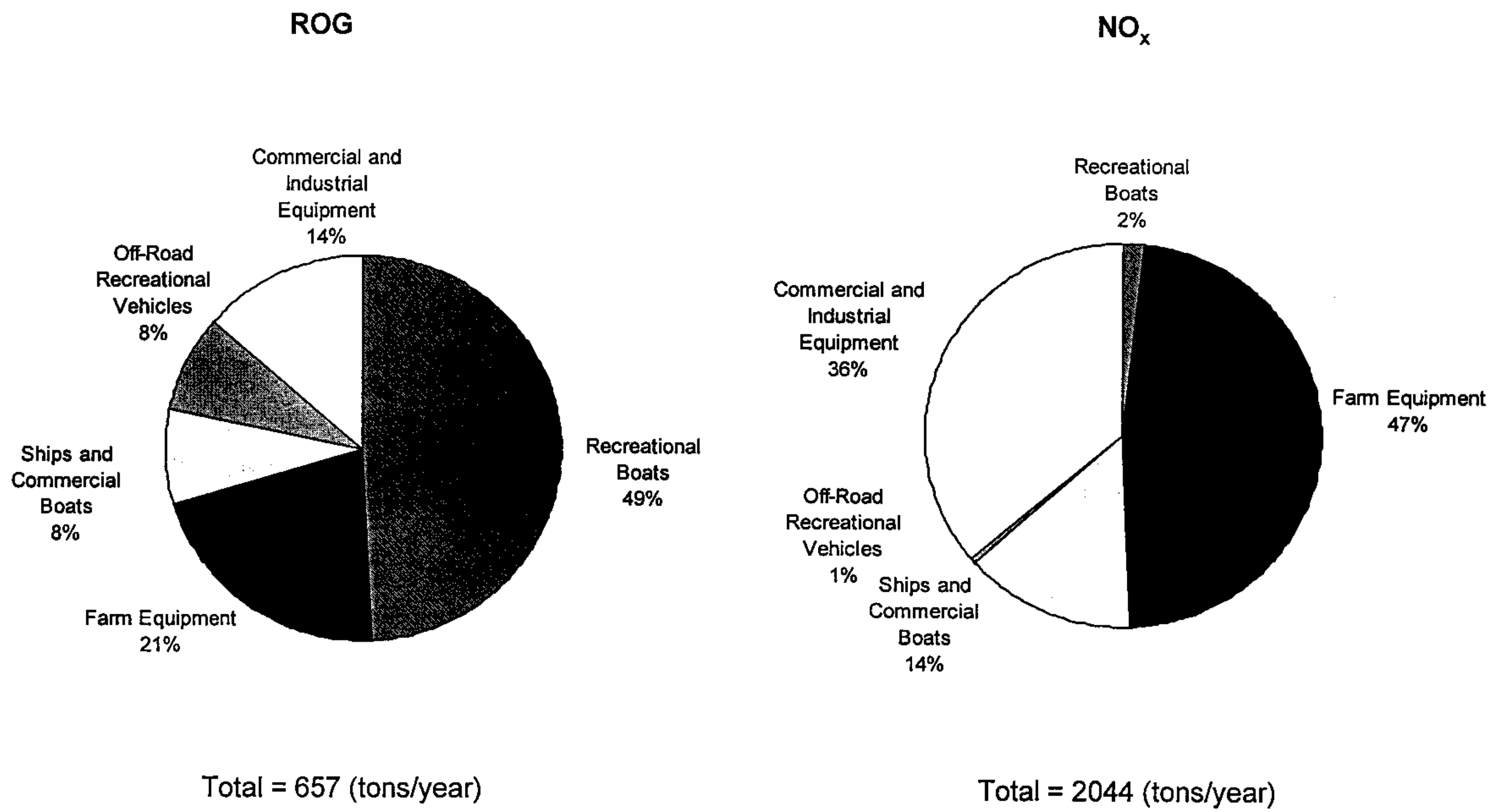


Figure 4-5. Vehicle contribution to 1995 off-road mobile source ROG and NO_x emissions in Mendocino County. Recreational boats account for about half of the off-road mobile source ROG emissions while farm equipment and commercial and industrial equipment account for more than 80 percent of the off-road mobile source NO_x emissions.

Table 4-3. Summary of 1995 mobile source emissions in Mendocino County. Emissions were estimated using the ARB MVEI7G Model. All emissions are reported in tons per day.

Category		Light-Duty Vehicles	Medium-Duty Trucks	Heavy-Duty Trucks	Diesel Buses	Motorcycles	Total
Number of In-Use Vehicles		72790	3652	3772	8	2709	82931
Daily VMT (thousands)		2336	116	165	0	14	2631
Number of Daily Starts		465032	23331	14597	0	1463	504423
Emissions (tons/day)	ROG	6.3	0.34	0.27	0	0.04	6.9
	NO_x	7.2	0.53	1.9	0.02	0.02	9.6

The emissions in Table 4-3 encompass all on-road mobile sources in Mendocino County, including major freeways, highways, and surface streets. A number of issues make on-road motor vehicle emissions in Mendocino County unique. First, since Highway 101 is a major artery that spans the length of California, and because Mendocino County is a popular tourist destination, a significant portion of the traffic on Highway 101 may be from vehicles that are not native to, or registered in Mendocino County, but merely passing through. Examination of per capita VMT for selected counties in California showed that counties containing popular tourist attractions, or significant pass-through traffic, have about a 1.5 times higher per capita VMT ratio than counties that do not attract tourism. Second, through discussions with Caltrans, it was discovered that Mendocino County has an unusually high percentage of unregistered vehicles (up to 20 percent) a large proportion of unpaved roads (approximately 2100 total miles) and a large number of Mendocino County residents own four-wheel drive vehicles.

A special analysis of detailed vehicle count data was used to estimate the portion of the vehicles (and the emissions associated with those vehicles) that are on Highway 101 (and that are passing through Mendocino County). Caltrans measures vehicle counts along major highways in California (Caltrans, 1996). In Mendocino County, there are 40 markers along Highway 101. At each of these markers, the total daily number of vehicles (both trucks and cars) passing by is tabulated. The truck counts are reported by Caltrans according to the number of axles per truck (2-5 axles). The truck VMTs were determined separately for medium-duty and heavy-duty because of their different emissions characteristics (California Air Resources Board, 1986). The cross-reference used to assign truck axle counts to the ARB truck emission categories is:

- 2 axle = 45 percent light-duty and 55 percent medium-duty
- 3 axle = 70 percent medium-duty and 30 percent heavy-duty
- 4 axle = 33 percent medium-duty and 67 percent heavy-duty
- 5 + axle = 100 percent heavy-duty

A summary of the mobile source emissions by vehicle class along Highway 101 is shown in **Table 4-4**. ROG emissions on Highway 101 in Mendocino County were estimated to be 2.7 tons/day, which accounts for about 40 percent of the County total mobile source ROG emissions and 18 percent of the total man-made ROG emissions. The NO_x emissions on Highway 101 were estimated to be 3.8 tons/day accounting for 26 percent of the total mobile source NO_x emissions and 23 percent of the total man-made NO_x emissions. Approximately 61 and 66 percent of the County total VMT for medium and heavy-duty trucks, respectively, is on Highway 101. It is not surprising that the medium and heavy-duty truck VMT is high on Highway 101 since this vehicle class accounts for transporting goods long distances, thus, they are more likely to be using Highway 101 rather than surface streets.

A significant portion of Highway 101 in Mendocino County runs through rural areas where the emissions do not contribute directly to ozone concentrations in Ukiah. In order to assess mobile source emissions contributions to ozone along the urban portion of Highway 101, mobile source emissions in the area defined as the Little Lake Air Basin as well as the

Table 4-4. Summary of 1995 mobile source emissions along Highway 101 in Mendocino County.

Category		Light-Duty Vehicles	Medium-Duty Trucks	Heavy-Duty Trucks	Total
Daily VMT (thousands) (percent of county total VMT)		851 (36%)	70 (61%)	108 (66%)	1029 (39%)
Emissions (tons/day)	ROG	2.2	0.21	0.18	2.7
	NO_x	2.2	0.32	1.2	3.8

urbanized portion of the County running through Ukiah were calculated. The emission estimates for the stretch of Highway 101 in the Little Lake Air Basin are shown in **Table 4-5**, and the emissions estimates for the stretch of highway running through Ukiah are shown in **Table 4-6**. ROG and NO_x emissions corresponding to the stretch of Highway 101 through the Little Lake Air Basin are 1.8 and 2.5 tons/day, respectively. About 20 percent of the total mobile source ROG emissions (10 percent of the total man-made ROG emissions) and about 17 percent of the total mobile source NO_x emissions (15 percent of total man-made NO_x emissions) come from the stretch of highway running through the Little Lake Air Basin.

Table 4-5. Summary of 1995 mobile source emissions along Highway 101 in the region defined as the Little Lake Air Basin (refer to Figure 4-1).

Category		Light-Duty Vehicles	Medium-Duty Trucks	Heavy-Duty Trucks	Total
Daily VMT (thousands) (percent of county total VMT)		581 (25%)	47 (40%)	66 (40%)	693 (26%)
Emissions (tons/day)	ROG	1.5	0.14	0.11	1.8
	NO_x	1.5	0.21	0.75	2.5

Table 4-6. Summary of 1995 mobile source emissions along Highway 101 in the region defined as the urban Ukiah valley (refer to Figure 4-1).

Category		Light-Duty Vehicles	Medium-Duty Trucks	Heavy-Duty Trucks	Total
Daily VMT (thousands) (percent of county total VMT)		202 (9%)	6 (5%)	4 (3%)	212 (8%)
Emissions (tons/day)	ROG	0.50	0.02	0.01	0.56
	NO_x	0.50	0.03	0.05	0.78

The emission estimates for ROG and NO_x emissions along the urban stretch of Highway 101 running through Ukiah are about 0.6 tons/day and 0.8 tons/day, respectively. The stretch of highway in Ukiah accounts for about 7 percent of total mobile source ROG emissions (3 percent of the total man-made ROG emissions) and about 5 percent of the total mobile source NO_x emissions (5 percent of total man-made NO_x emissions). It is important to note that the traffic on the urbanized portion of Highway 101 is from vehicles traveling within the urban area as well as vehicles passing through the urban area. Determining the number of vehicles that are passing through Mendocino County is not straightforward since the vehicle count data reported by Caltrans does not track specific vehicles. **Table 4-7** summarizes the traffic count data for individual points along Highway 101.

Table 4-7. Summary of traffic count data for segments of Highway 101 through Mendocino County. The traffic volume data was obtained from Caltrans.

Road Segment	Traffic Volume (# of vehicles)
Vehicles entering County at southern border	10,700
Southern end of Ukiah urban area	21,100 (26,000 max in Ukiah urban area)
Northern end of Ukiah urban area	7100
Vehicles leaving County at northern border	5100

An examination of the vehicle count data shows that there are about twice as many vehicles entering Mendocino County from the south on Highway 101 as there are leaving the northern end of the County; this is likely due to several east-west highways leading out of the County, as well as leading to Highway 1 on the coast. In addition, there may be more commuters traveling daily into Mendocino County from the south than from within Mendocino County to the north. Also note that the largest vehicle counts are recorded in the Ukiah area (up to 26,000 vehicles). It is not surprising that the vehicle counts are highest in Ukiah since it is the largest city in Mendocino County in terms of population, and most of the area to the north of Ukiah is rural. The larger vehicle counts near Ukiah are likely the result of local traffic. There are 7100 vehicles leaving the Ukiah urban area (on a net basis, about 3600 less than entered the County). As you travel north along 101, traffic volumes decrease and about 5100 vehicles leave the County. Since more vehicles enter the County from the south than exit from the north, it can be assumed that 5100 vehicles leaving the County on the north end represent, in the net, a measure of passthrough traffic. This approach yields an estimate that about 20 percent of the vehicles traveling on Highway 101 are passing through the County.

It is of interest to examine the traffic volumes in the Ukiah urban area since the mobile source emissions generated in this region contribute directly to ozone levels in the Little Lake

Air Basin. Using the same methodology as discussed above to determine the number of vehicles that are passing through the County, and the traffic volume data in Table 4-7, the passthrough traffic for the Ukiah urban area was determined. About 7 percent of the vehicles traveling from the south end of the County on Highway 101 pass through the Ukiah urban area, but remain in the County; therefore, about 73 percent of the vehicles that travel on Highway 101 are localized in and south of the urban Ukiah area. **Figure 4-6** depicts the proportion of VMT and corresponding emissions (assuming emissions are proportional to VMT) along various segments of Highway 101. **Figure 4-7** shows an estimate of the proportion of traffic that is local and passthrough traffic and the corresponding emissions. Note that different segments are used in the two figures to better distinguish emissions due to passthrough versus local traffic.

4.3 PM_{10} EMISSIONS

As shown in Figure 4-2, area sources such as residential wood combustion and entrained road dust (from both paved and unpaved roads) are the major contributors to PM_{10} emissions. There is typically seasonal variation in PM_{10} emissions. For example, in the wintertime, wood burning stoves and fireplaces are a significant contributor to PM_{10} emissions while road dust is less of a contributor due to increased soil moisture. However, in the summer, when roads are dry and temperatures are high, wood burning stoves and fireplaces would be less of a problem and road dust would dominate. Because of the seasonal variation in PM_{10} emissions sources, is of interest to determine source contributions by season. Since the emission inventory obtained from the ARB is an annual average inventory, seasonal emission estimates of PM_{10} were calculated using an equation that accounts for residential wood combustion activity and rainy conditions (days when road dust is minimal). **Figure 4-8** shows the seasonal source contributions to PM_{10} emissions. Man-made sources of dust (i.e., road dust, construction and demolition dust and agricultural dust) are the major contributors to summertime PM_{10} emissions and residential fuel combustion is more of a contributor in the wintertime, as would be expected.

4.4 EMISSION INVENTORY METHODS ASSESSMENT

The ARB annually reports man-made emissions from stationary, area, and mobile sources for each county in the state of California. Stationary sources include major industrial and manufacturing facilities (point sources) as well as fuel storage facilities and refueling stations. Area sources include locally distributed pollution sources such as residential fuel combustion, road and building construction, and unpaved road travel. Mobile sources include both on-road and off-road mobile sources. The inventories are compiled using data from air pollution control districts and other governmental agencies and are available from CEIDARS II at the ARB (California Air Resources Board, 1997a).

Emission estimates of ROG, NO_x, and PM for point and stationary sources are based on data collected by each district. Area source emission estimates for these pollutants are based

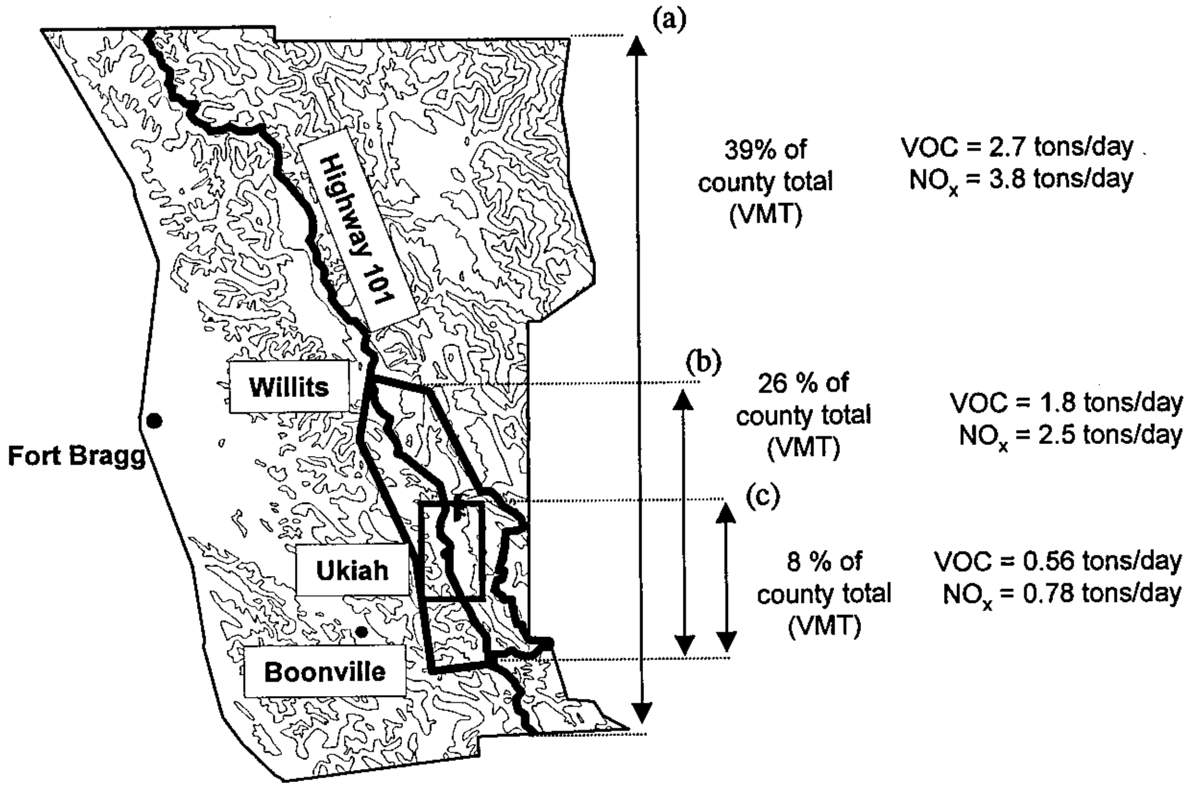


Figure 4-6. Percent of total on-road VOC and NO_x emissions along (a) entire stretch of Highway 101, (b) the Little Lake Air Basin, and (c) the urban Ukiah area.

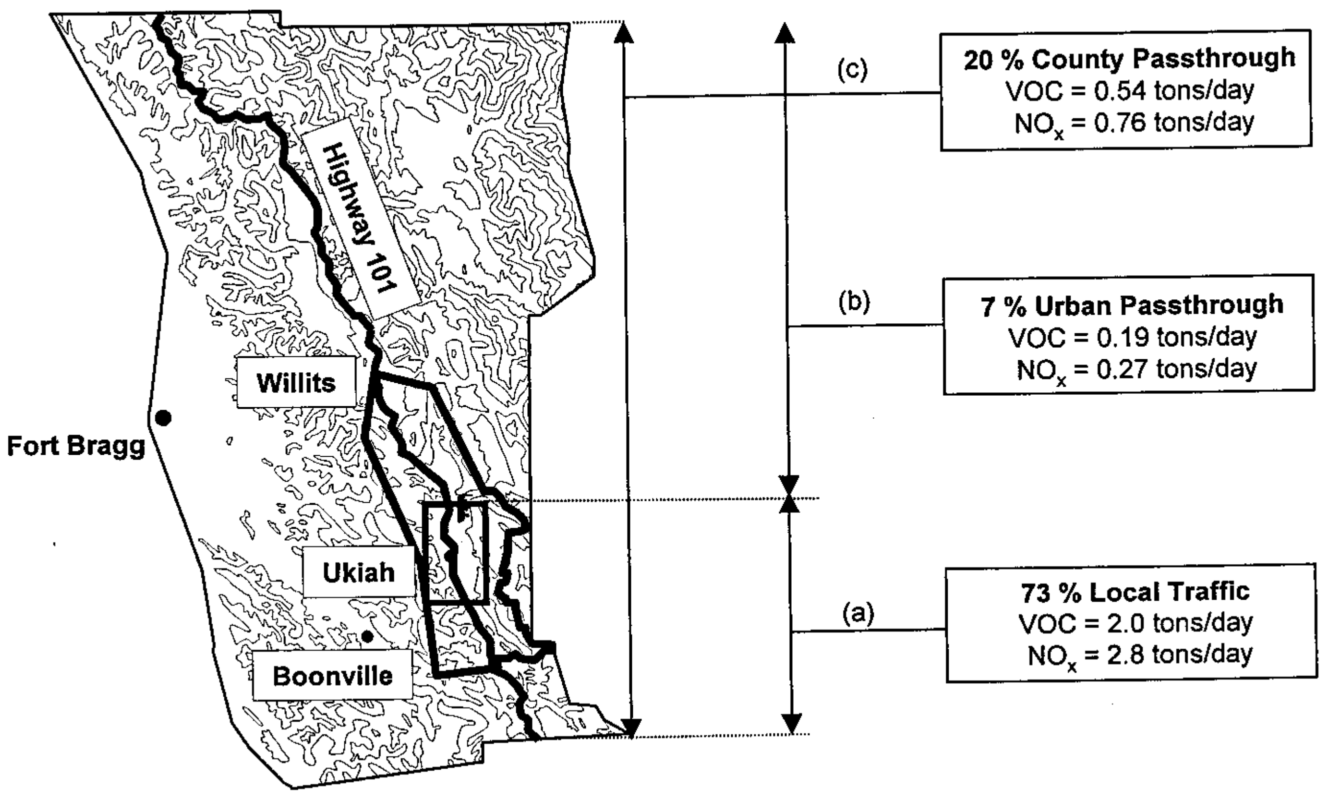
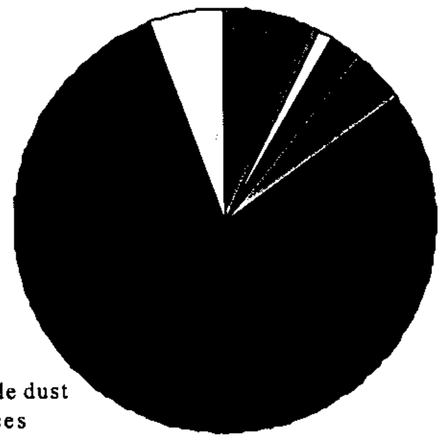


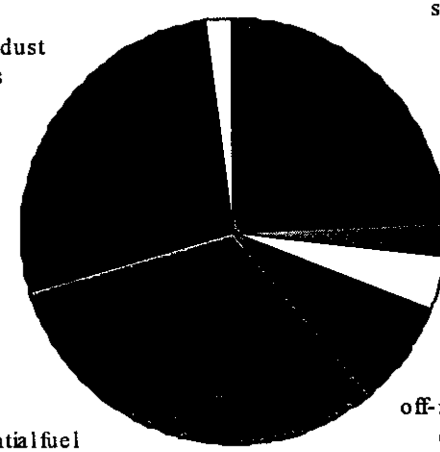
Figure 4-7. Percent of total on-road VOC and NO_x emissions along Highway 101 for (a) local urban traffic, (b) vehicles passing through the urban Ukiah area, and (c) vehicles passing through the county. Note that local traffic is responsible for 73 percent of the emissions along the entire stretch of Highway 101 in Mendocino County.

PM_{10} Summer - 1995



Total = 16 (tons/day)

PM_{10} Winter - 1995



Total = 5 (tons/day)

Note: Man-made dust includes paved and unpaved road dust, construction and demolition, and farming operations.

Figure 4-8. Seasonal source contributions to 1995 PM_{10} emissions.

on data compiled by the districts and ARB staff. There are approximately 260 emission sources that are classified as stationary and area-wide sources. Of the 260 stationary and area sources categories, the ARB is responsible for estimating emissions for 130 categories, and the county or regional air district is responsible for the remaining 130 categories. The local air districts have the choice of using their own methods for the 130 categories or using ARB's methods (California Air Resources Board, 1997b). On-road motor vehicle emission estimates are made by the ARB using the BURDEN7F model that calculates motor vehicle emissions as the product of a use factor and an emission rate. Data inputs for the model have been developed by the ARB using Caltrans travel estimates, local councils of government travel estimates, and the Department of Motor Vehicles registration information. The latest detailed inventory was made for 1995.

Area source ROG emissions for commercial landscape equipment and cutback asphalt are among the 130 emission source categories that are assigned to the districts. Through discussions with ARB staff, it appears as though district input for these two categories has not been supplied to ARB, consequently, default values have been assigned to these categories. It is likely that the default values are outdated and should be revised. Residential wood combustion is estimated by ARB using county-wide residential energy demand estimates which are based on temperature and the corresponding heating demand, the number of residential heating units, and woodstove/fireplace emission factors (California Air Resources Board, 1997b).

The emission inventory for Mendocino County was obtained from ARB and reviewed according to each major source category. A "reality-check" approach was used to verify emissions estimates and to evaluate the sensibility of the inventory. CEIDARS II reports point source emissions by individual facilities. There were five major industrial facilities in Mendocino County listed in CEIDARS II. The individual facility emissions were reviewed and updated facility information was obtained through data provided by Mendocino County. Each of the major source categories was reviewed by comparing the expected emissions associated with a specific emission source to the reported emissions from that source. Comparison of the emission estimates for Mendocino County to emission estimates for other counties with similar source activity were performed, and per capita emissions comparisons were made to verify the consistency of the absolute amount of area source emissions compared to other counties in California.

4.5 FUTURE-YEAR EMISSIONS PROJECTIONS

In order to examine which emission source categories will be important for future-year emissions contributions, emissions projections were made based on the 1995 Mendocino County emission inventory. Forecasting emissions is a complex process involving the understanding and prediction of future economic, socioeconomic, and mobile source activity. Forecasting emission-related activity is difficult because economic recessions and booms can complicate the forecasting process and lead to variable regional economic activity patterns that upset linear forecasting techniques. Although emissions forecasting is challenging, it is of interest to estimate future-year emissions in order to assess which emission sources will be important in the future in an attempt to develop realistic and effective air pollution control strategies.

4.5.1 Discussion and Derivation of Growth Factors

Because future-year emissions forecasts are difficult to project due to the complex economic and socioeconomic variables involved and the limited availability of historical trend data, it is often necessary to develop future-year indicators or surrogates to represent activity in individual industries and/or emissions categories. Surrogates are demographic and socioeconomic figures such as population and employment that have been projected for future years. Surrogates are assigned to each industry based on their representativeness of activity in that industry. For example, future-year activity in the construction industry might be determined based on the predicted future-year population or number of households in an area. Therefore, the surrogate assigned to the construction industry would be population or number of households. It is important that the surrogate assigned to each emission source category is representative of that source. Assigning surrogates to emission sources can be difficult because of limited data and resources.

The ARB staff maintains a large and comprehensive emission forecasting system and database containing detailed land-use data and local-government planning inputs. The forecasting system combines inputs from a number of different models and is capable of producing historical and projected demographic and socioeconomic trends. The forecasting system incorporates more than 100 growth categories and over 200 control categories for each county in California. Surrogates and growth factors for non-vehicular sources are derived from socioeconomic trends. Local agencies (i.e., local AQMD) supply the ARB with socioeconomic and demographic growth projections or, in the absence of local data, the ARB uses its forecasting system to generate projections. The ARB staff surveys districts each year to provide them with an opportunity to review and update the growth data used in the forecasting system (Lerch and Yajima, 1993).

Surrogates and growth factors for Mendocino County were obtained from the ARB. A total of 24 growth surrogates were used to project future-year point and area source emissions in Mendocino County. The ARB assigns growth surrogates to each emission source category according to point and area source Emission Inventory Codes (EIC). Growth factors were calculated for Mendocino County based on the surrogates assigned by ARB. In order to examine projected growth trends in each of the industrial sectors, the average annual percent change for each activity indicator (for each industry) from 1995 to 2020 was calculated in five-year increments. Growth factors were calculated for 1995, 1997, 2000, 2005, 2010, 2015, and 2020 using a base year of 1995, the future-year activity estimates for each industry, and the following equation:

Example growth factor calculation for 1997 and 2000 using a base year of 1995:

1997 growth factor = (activity factor in 1997 / activity factor in 1995)

2000 growth factor = (activity factor in 2000 / activity factor in 1995)

In the case of VMT and population, surrogate activity data was not available for years beyond 2010, so growth factors were generated using linear interpolation based on the available information. **Table 4-8** lists the percent growth for each surrogate over a 25-year time period (1995 to 2020) based on ARB projections. Note that positive percent changes indicate growth, while negative changes indicate decline. Also note that some projection surrogates show no change over time. Emission categories which contribute significantly to ozone formation or PM exceedances should be reviewed more closely than other surrogates. **Figure 4-9** is a graphical representation of the 25-year percent growth data contained in Table 4-8. The right side of the center axis represents growth (or increasing surrogate activity) and the left represents decline in surrogate activity.

Table 4-8. Percent growth in each surrogate from 1995 to 2020 as projected by ARB.

Growth Surrogate	Annual Average Percent Growth	Percent Growth (1995-2020)
Agricultural Product Employment	1.1	27
Construction Employment	1.9	48
Dwelling Units	1.9	48
Gallons of Gasoline Consumed	0.5	12
Fire Stations	0.0	0
Forestry	2.8	70
Food Production	2.5	63
Furniture Manufacturing	4.0	101
Lumber Manufacturing	2.2	55
Misc. Manufacturing Employment	-1.6	-41
Mineral Manufacturing	2.3	59
Total Manufacturing	2.6	66
Population	2.1	53
Services	2.7	68
Total County Employment	1.5	38
Total County VMT	1.1	27
Aircraft Activity	0.0	0
Railroad Activity	1.0	25
Ship Employment	-1.3	-33
Registered Gasoline Recreational Boats	3.4	85
Registered Diesel Recreational Boats	3.8	95
Registered All-Terrain Vehicles	2.1	52
Registered Four-Wheel Drive Vehicles	2.1	52
Agricultural Farming Employment	1.0	25

Forecasted Industrial Growth Factors
1995-2020

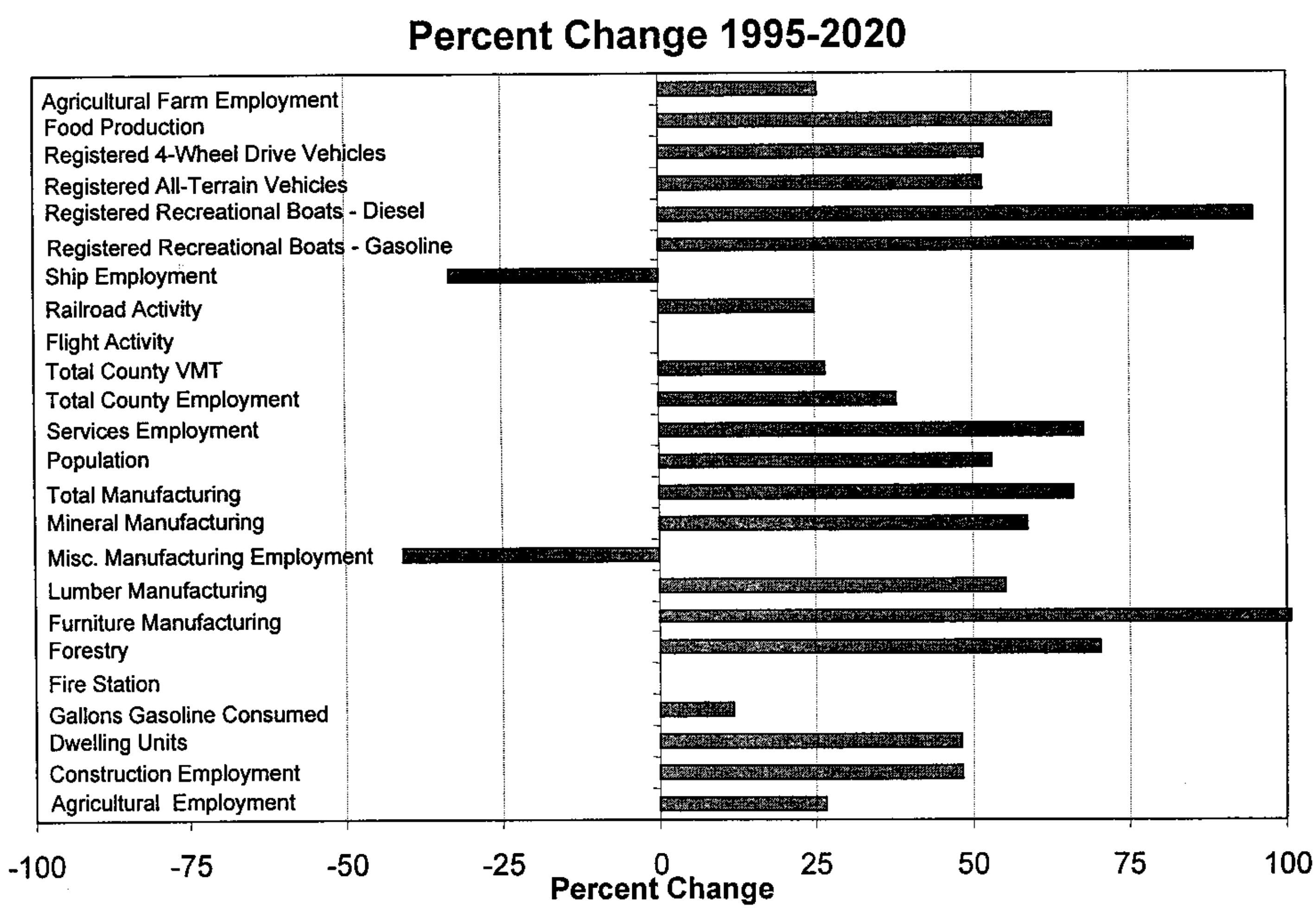


Figure 4-9. Industrial growth factors forecasted by the ARB.

The 25-year projections show growth in all categories with the exception of miscellaneous manufacturing employment and employment in the ship industry which show a 41 and 33 percent decline, respectively. Fire stations and aircraft activity show no growth. The categories showing the largest increases in future-year activity are furniture manufacturing, registered recreational boats (both gasoline and diesel), and the service and manufacturing industries.

The 25-year growth projections shown in Figure 4-9 are useful to examine annual average and overall growth or decline in an industry, but may not be indicative of trends in individual (yearly) growth factors.

4.5.2 Future-Year Emissions Projections

Future-year emissions were projected using the growth factor information generated by the ARB. Source category contributions to future-year emissions were examined to assess the impact of individual source contributions over time based on the methodology used by the ARB. Future-year on-road mobile source emissions were calculated using the MVEI7G model. Parameters accounted for by the MVEI7G model include: type of control technology and fuel usage, distribution of operating speeds, speed and temperature correction factors, and the reduction in emissions resulting from motor vehicle regulatory programs. Point, area, on-road mobile, and other mobile source emissions were calculated for 1995, 1997, 2000, 2005, 2010, 2015, and 2020.

Total man-made ROG emissions are expected to decline by about 11 percent from 1995 to 2020, while NO_x and CO are expected to decline by about 30 percent. Total PM_{10} emissions are expected to increase by about 30 percent. **Table 4-9** shows the percent change in total pollutant emissions from 1995 to 2020 (column 3) and individual source category emissions contributions. In 1995, on-road mobile source emissions were the largest contributor to total emissions in Mendocino County followed by area sources. Although increases in VMT and traffic volume are projected for future-years, on-road mobile source emissions are expected to decline (for all pollutants) and eventually level off as a result of newer, cleaner vehicles and fleet turnover. The dramatic decline in on-road mobile source emissions is predicted by the ARB to occur throughout the State. It is important to note however, that if Mendocino County's fleet turnover is slower than the statewide average, somewhat lower emission reductions can be expected.

Projected increases in population will cause area sources, particularly the service industry, to become the major contributor to future-year emissions for all pollutants (a 30-50 percent increase). Stricter regulations on utilities and industry in conjunction with more efficient industrial pollution reduction and control technology are expected to cause stationary source NO_x, CO, and PM_{10} emissions contributions to decline in future years while stationary source contributions to ROG are expected to increase by about 20 percent. Increases in stationary source ROG are attributable to gas station refueling activity. Increases in other mobile source emissions are expected for all pollutants. CO and ROG emissions from other

Table 4-9. Annual average and total percent change in emissions from 1995-2020 by source category for ROG, NO_x, CO, and PM_{10}.

Pollutant and Source Category	Percent of Man-made Emissions	Annual Average Percent Change in Emissions	Percent Change in Emissions (1995-2020)	Net Change
ROG				
Area Sources	34	1.8	44	-11
Stationary Sources	15	0.8	21	
On-Road Mobile Sources	41	-3.5	-87	
Other Mobile Sources	10	2.2	54	
NO_x				
Area Sources	3	1.9	48	-32
Stationary Sources	6	-1.2	-30	
On-Road Mobile Sources	57	-2.6	-64	
Other Mobile Sources	34	0.9	23	
CO				
Area Sources	20	1.8	46	-30
Stationary Sources	3	-1.6	-39	
On-Road Mobile Sources	65	-2.8	-69	
Other Mobile Sources	12	1.7	43	
PM_{10}				
Area Sources	91	1.2	31	27
Stationary Sources	6	-1.0	-26	
On-Road Mobile Sources	1	-1.5	-37	
Other Mobile Sources	2	0.9	22	

mobile sources are projected to increase by about 45 and 55 percent, respectively, while NO_x and PM_{10} emissions are projected to increase by about 20 percent. **Figures 4-10 through 4-13** show trend plots of ROG, NO_x, CO, and PM_{10} emission projections by source category from 1995 to 2020.

Recent evaluations of mobile source emission inventories have shown that in regions where emissions are dominated by mobile sources, ROG mobile source emission inventory estimates are commonly underestimated by a factor of 1.5 to 2. In Fresno, an area dominated by mobile source emissions, it was determined that ambient CO/NO_x ratios were in reasonable agreement with mobile source emission inventory CO/NO_x ratios. However, ambient ROG/NO_x ratios in Fresno were about 1.5 times higher than emission inventory ratios (Haste et al., 1998a). Similar findings were reported for Galleria, Texas; Bronx, New York; and Lynn, Massachusetts (Korc et al., 1995; Haste et al., 1998b). What this suggests is that the absolute amount of mobile source ROG reported in the 1995 emission inventory for Mendocino County is likely somewhat underestimated. However, this underestimation has little impact on

ROG Emission Trends

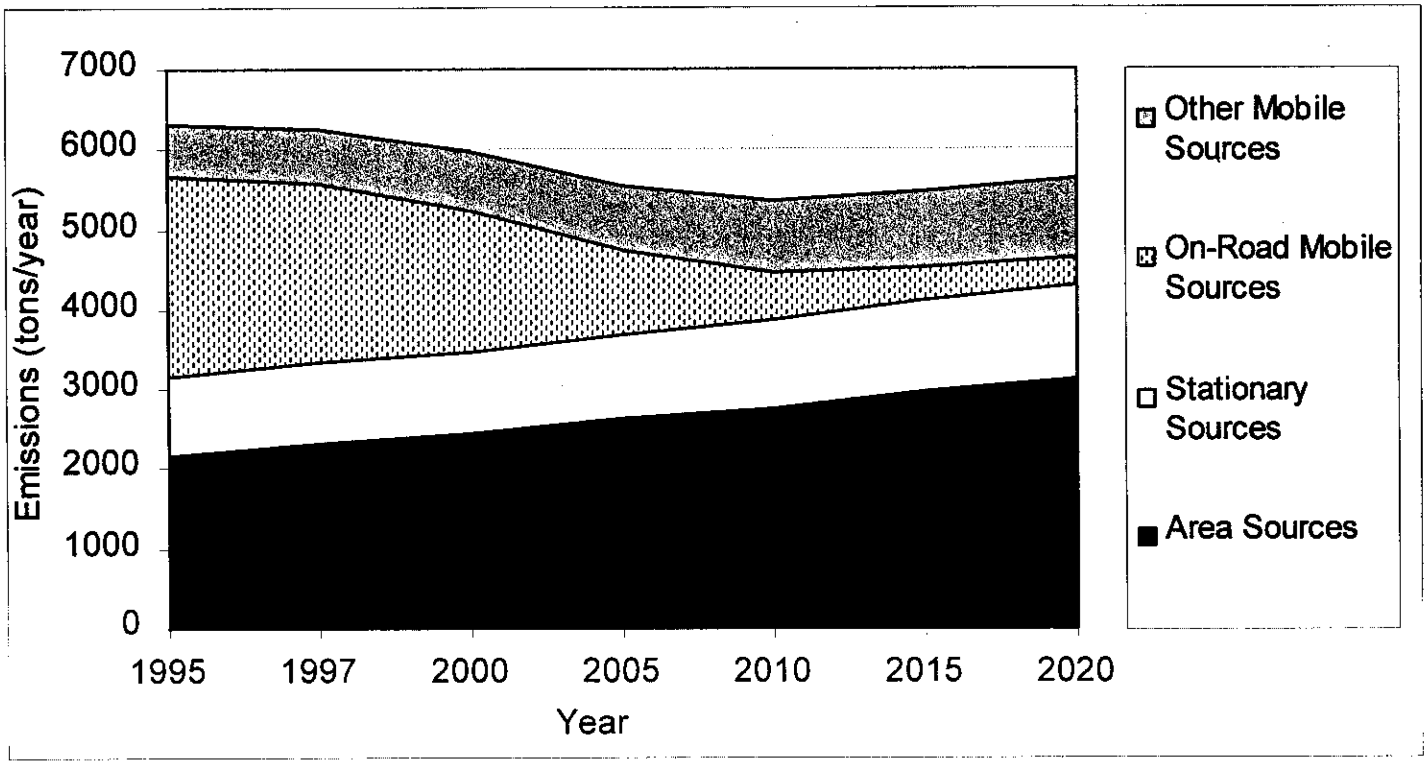


Figure 4-10. Future-year ROG estimates by source category as projected by the ARB.

NO_x Emission Trends

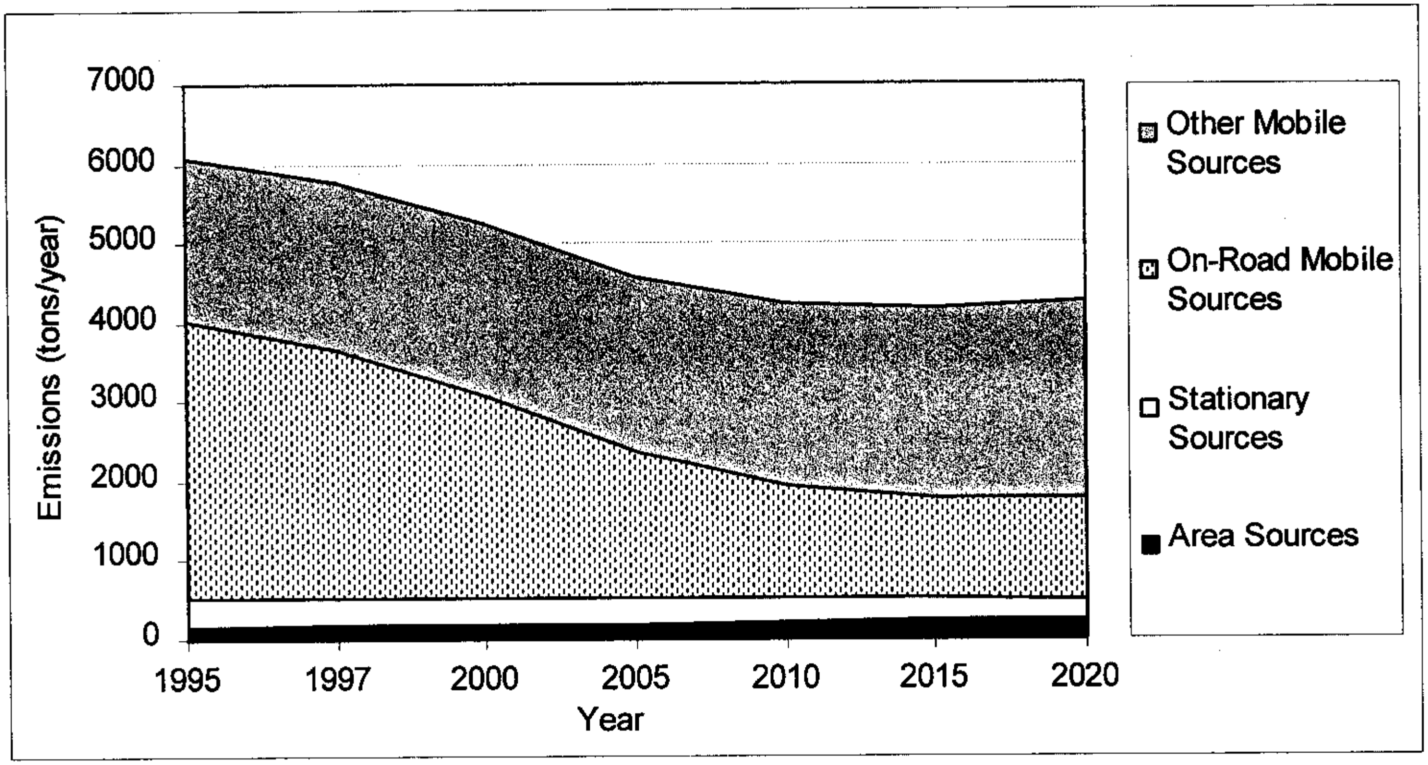


Figure 4-11. Future-year NO_x estimates by source category as projected by the ARB.

CO Emission Trends

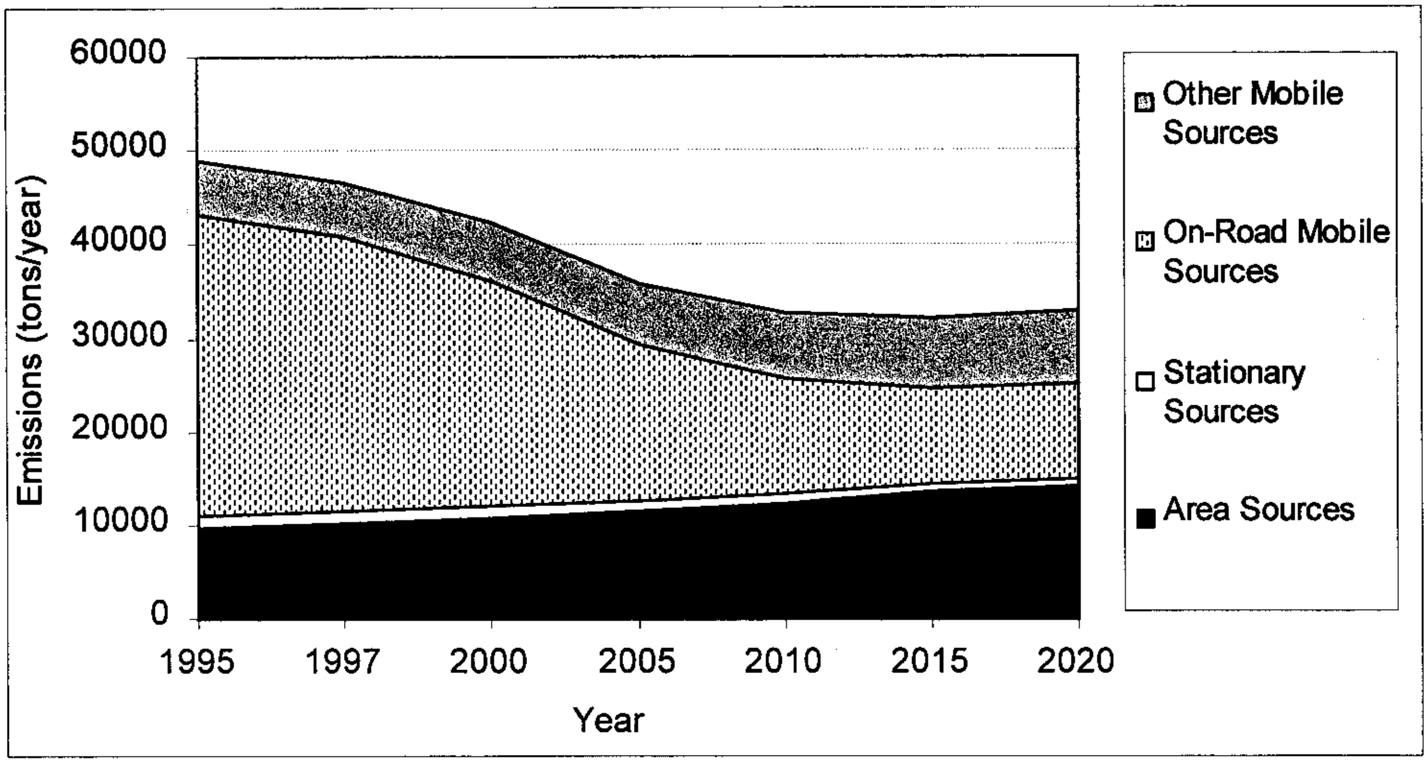


Figure 4-12. Future-year CO estimates by source category as projected by the ARB.

PM Emission Trends

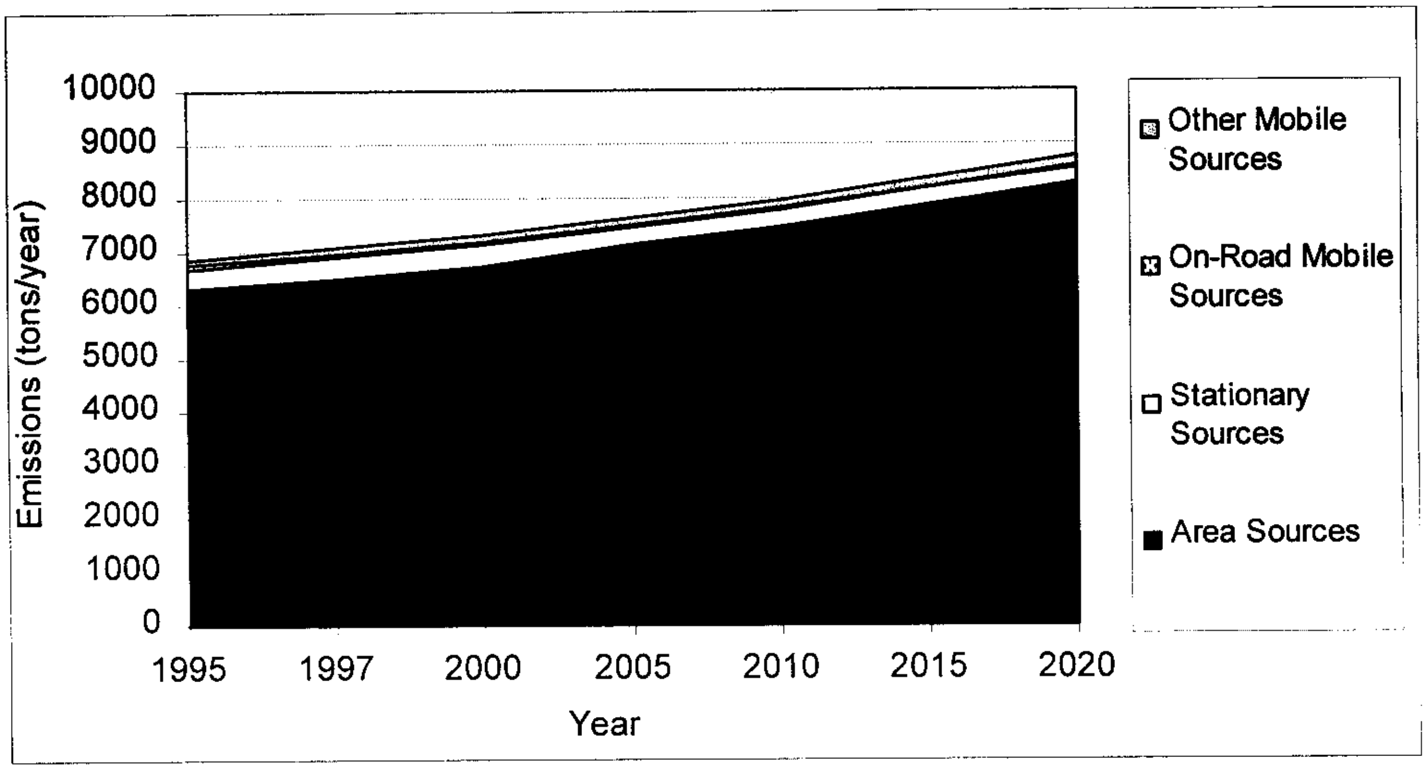


Figure 4-13. Future-year PM estimates by source category as projected by the ARB.

future-year projections as on-road mobile source ROG is expected to decline dramatically as noted above. **Figure 4-14** is a trend plot showing what future-year emissions would be if the 1995 emissions were increased by a factor of 2. Note that the emission trends do not change, however, total emissions and mobile source emissions are slightly higher in 2020. The MVEI7G model uses the latest available vehicle fleet (e.g., percent of cars, passenger vans, light duty trucks and sport utility vehicles) and VMT data, and uses built-in projected VMT data for estimating future-year emissions. Past studies have shown that VMT projections are often significantly underestimated (Fujita and Lawson, 1994). The fact that the MVEI7G model does not account for the high number of unregistered vehicles in Mendocino County and that the built-in VMT projections may be underestimated suggests that the future-year mobile source emission reductions for ROG (87 percent) and NO_x (30 percent) may be optimistic.

It is important to keep in mind that the emissions of ROG, NO_x, and CO projected in 2020 are less than the 1995 base-year emissions. The source category contribution comparisons discussed above are shown as a percentage of the total emissions. For example, if a source category contributes a larger percentage to total emissions in 2020, it does not necessarily mean that the mass of emissions from that category are greater than they were in 1995, it simply means that the source category is a larger contributor to the total emissions. **Figure 4-15** shows the source category contributions to total ROG, NO_x, CO, and PM_{10} emissions in 2020. Notice the differences in total emissions from 1995 to 2020 (noted above each pie chart) and source category contributions in 1995 versus 2020 (refer to Figure 4-2).

4.6 SUMMARY AND CONCLUSIONS

The 1995 Mendocino County emission inventory compiled by the ARB was evaluated in this study. The 1995 emission inventory was projected to 2020 using growth activity data supplied by the ARB. Total stationary and area source emissions were projected to 2020 and compared to 1995 base-year emissions in order to evaluate emission trends and source category contributions in future years. Mobile source contributions were examined including on and off-road sources. Mobile source emissions were projected using the latest version of EPA's mobile source emission estimation model, MVEI7G.

There are several general observations to be made from the 1995 emission inventory evaluation and the projected emission inventory. Currently, on-road mobile source emissions from light-duty vehicles are the largest contributor to emissions in Mendocino County. Assuming that on-road mobile source emissions are proportional to VMT, about 40 percent of the total on-road mobile source emissions come from Highway 101 which spans the length of the County and runs through the major urban regions. On average, approximately 20 percent of the total traffic along Highway101 can be attributed to traffic passing through the County while 80 percent is native traffic. Furthermore, 73 percent of the local traffic along Highway 101 is concentrated in the Little Lake Air Basin. Off-road mobile sources contributed 10 percent of man-made ROG and 34 percent of man-made NO_x emissions in 1995. Recreational boats, farm equipment, and industrial equipment were the major sources of off-road mobile source emissions.

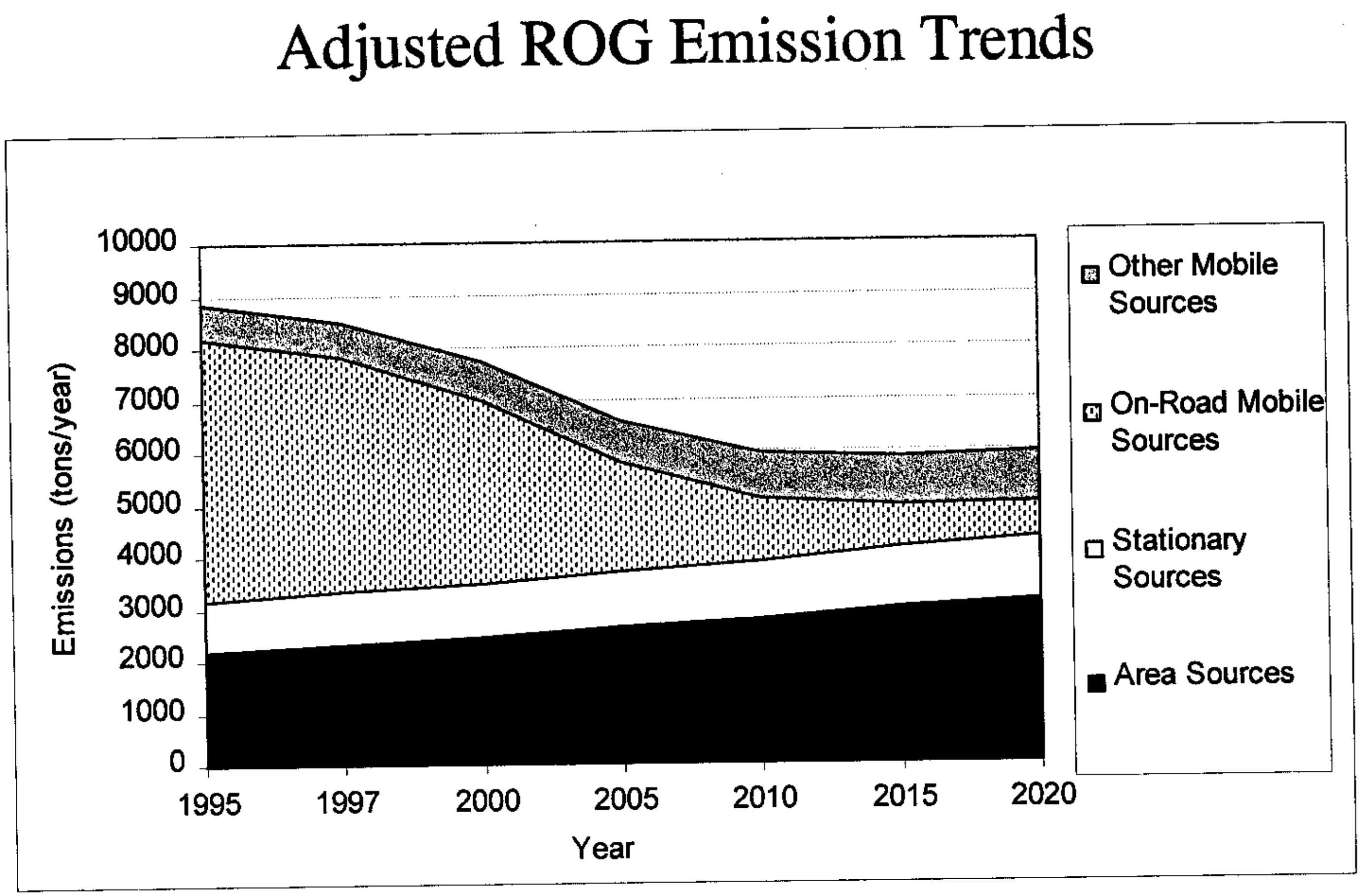


Figure 4-14. Future-year ROG estimates by source category as projected by the ARB, assuming mobile source ROG is underestimated by a factor of 2 in the 1995 inventory.

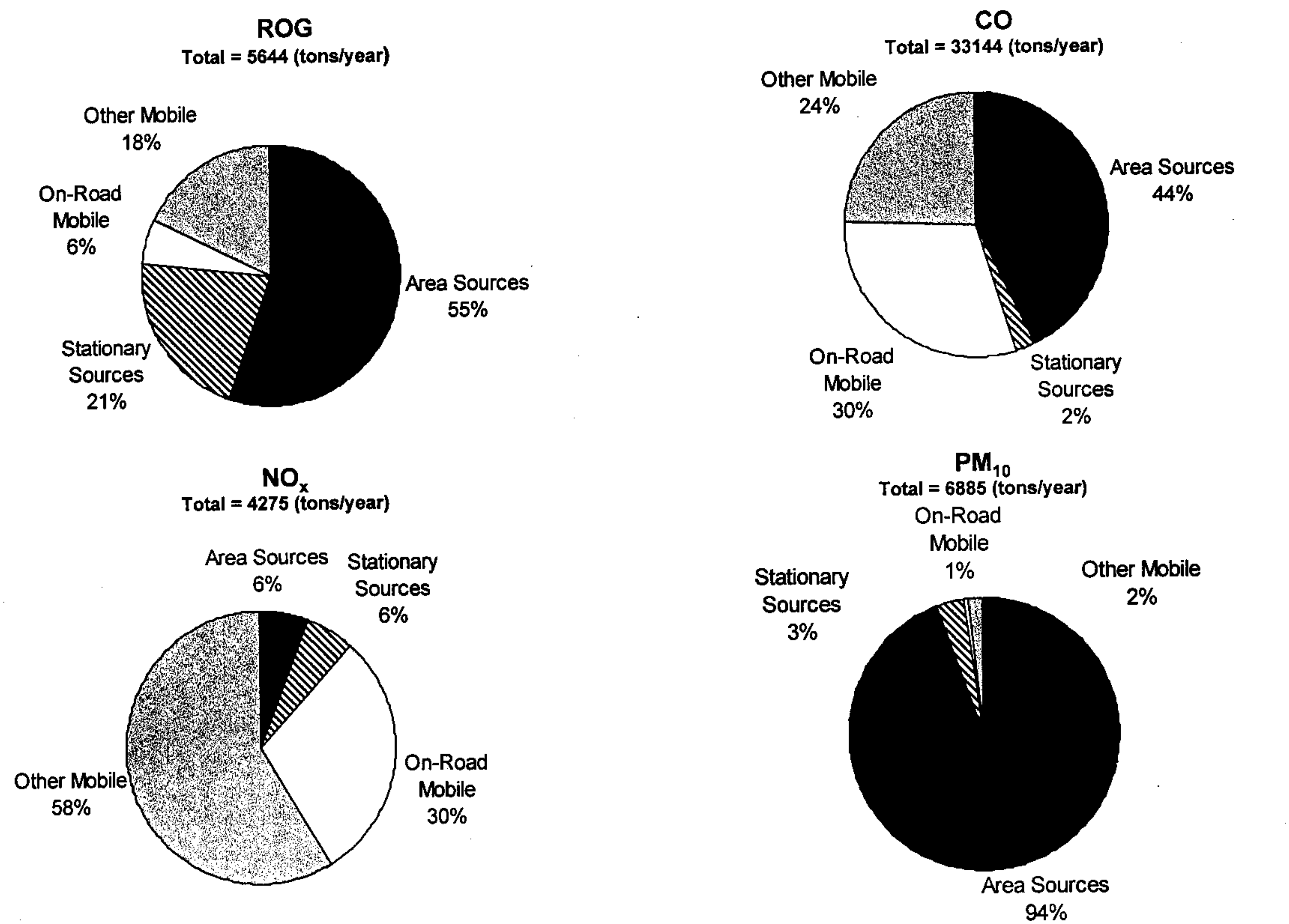


Figure 4-15. Source category contributions to the 2020 ROG, CO, NO_x, and PM_{10} emission inventory in Mendocino County.

In 1995, the major stationary and area source emission categories were vehicle refueling at service stations, two large industrial facilities, commercial landscaping equipment, cutback asphalt, and residential fuel combustion. After reviewing ARB methodology for estimating area source emissions, it was determined that commercial landscaping equipment and cutback asphalt emission estimates are likely outdated and not representative of actual emissions in Mendocino County (e.g., it is likely that the default assignments made by ARB are outdated). It is recommended that these categories be investigated by the district and current emission estimates be submitted to ARB.

Mendocino County is a large, heavily forested County, total biogenic VOC emission estimates were considerably higher than total man-made ROG emissions in 1995 (about 20 times greater) and are not expected to change significantly over time. However, in the urban Ukiah valley, where there is a significant amount of urban land use, and not a lot of forested land, biogenic VOC emissions are less than man-made ROG emissions. Nevertheless, if one considers the emission density of biogenic VOC and man-made ROG in the urban Ukiah area biogenic VOC is an important contributor to total ROG emissions. Regardless of the precise share of Mendocino County's 17 tons per day of man-made ROG emissions that are from the Ukiah area, the 3 to 31 tons per day of biogenic VOC emissions estimated to be from the urban Ukiah and Little Lake Air Basin, respectively, are quite significant. Thus, biogenic VOC emissions are important contributors to local ozone.

Seasonal analysis of PM_{10} emissions for Mendocino County show that residential wood combustion, man-made dust, and stationary sources are the main contributors to wintertime PM_{10} emissions. In the summertime when temperatures are higher and there is less moisture, man-made sources of dust including paved and unpaved road dust, dust from construction and demolition activities, and dust from farming operations are the main contributors to PM_{10} emissions.

Fuel sales in Mendocino County are about four times higher per capita than other counties in California. Mendocino County is unique in that it is a popular tourist destination and contains nearby lakes, recreation areas, and a large number of unpaved roads. It is estimated that Mendocino County also contains a high percentage (about 20 percent) of unregistered vehicles and recreational vehicles including boats, off-road motorcycles, all terrain vehicles, and four-wheel drive vehicles. The statewide average for unregistered vehicles in California is 6-8 percent which means that Mendocino County has twice as many unregistered vehicles as is typical for California. In addition, because of Mendocino County's terrain there are larger numbers of sport utility vehicles (with poorer fuel economy) than the statewide average. It is likely that all of these factors combined contribute to the higher fuel sales in Mendocino County.

Growth factors supplied by ARB were used to project future-year emissions. The growth factors are socio-economic and demographic (i.e., population, employment) surrogates assigned to emission source categories. Based on the growth factors supplied, the emission source categories showing the largest increases in future-year activity are furniture manufacturing, registered recreational boats (both gasoline and diesel), and the service and manufacturing industries. As population increases, so does the demand for products and services, which explains the growth in the service and manufacturing sectors. The number of registered recreational boats is predicted to increase significantly. When investigating future-year growth factors, it is important to keep in mind the implications of the growth factors on future-year emissions. For emission source categories with little or no base-year emissions, large changes in growth factors and industrial activity are not going to have as large an impact on total emissions as categories that are significant contributors to base-year emissions.

It is important to keep in mind that projecting future-year emissions is difficult because of the complexities and uncertainties of economic and demographic variables. In addition, the default surrogates assigned to emission source categories are often non-representative of the emission source. For example, consider the case of recreational boats; as population increases it would be expected that the number of boats would increase. However, the number of boats within a county is also a function of the amount of recreational area, or lake capacity in the county. It is likely that as population increases, the number of registered boats may increase but the county recreational areas can only support a limited amount of boat traffic. In this case, the growth surrogate should be a function of population and recreational area capacity.

Based on the emissions projections, the total man-made ROG, NO_x, and CO emissions are projected to decline by 11 to 30 percent from 1995 to 2020 while PM_{10} emissions are expected to increase by about 25 percent. There is a 50 percent projected increase in population by the year 2020 which will result in area source emissions contributions increasing significantly for the service industry and several manufacturing sectors. Off-road mobile source emissions contributions are projected to increase from 20 to 50 percent by 2020. On-road mobile sources were the largest contributors to emissions in1995; however, MVEI7G predicts emissions from mobile sources to decrease by 85 percent over the next 25 years due to vehicle fleet turnover and advanced engine technology. Large emission reductions in the face of VMT growth could seem unlikely, however, as depicted in **Figures 4-16 through 4-18** over the last 20 years in Mendocino County, ROG emission reductions are reported in the ARB emission inventory. The figure also shows that NO_x emissions are also trending down and that PM emissions are on the rise.

Although MVEI7G uses the latest vehicle registration and VMT data, it does not account for the high number of unregistered vehicles in Mendocino County. Also, VMT forecasts have historically been significantly underestimated, and emission inventory reconciliation studies have shown that mobile source ROG emission inventory estimates are often underestimated by a factor of 2. Because MVEI7G does not account for the high number of unregistered vehicles in Mendocino, VMT estimates are potentially lower than actual VMT, and total mobile source ROG emissions are typically underestimated, it is likely that the future-year decreases projected by MVEI7G are optimistic. Although mobile source emissions will decrease in the future, an 85 percent decrease is unlikely. Furthermore, as noted previously, slower than statewide average fleet turnover and higher than statewide average sport utility vehicle populations suggest that the projected emission reductions may not be achieved.

Historical ROG Emission Trends 1975-1995

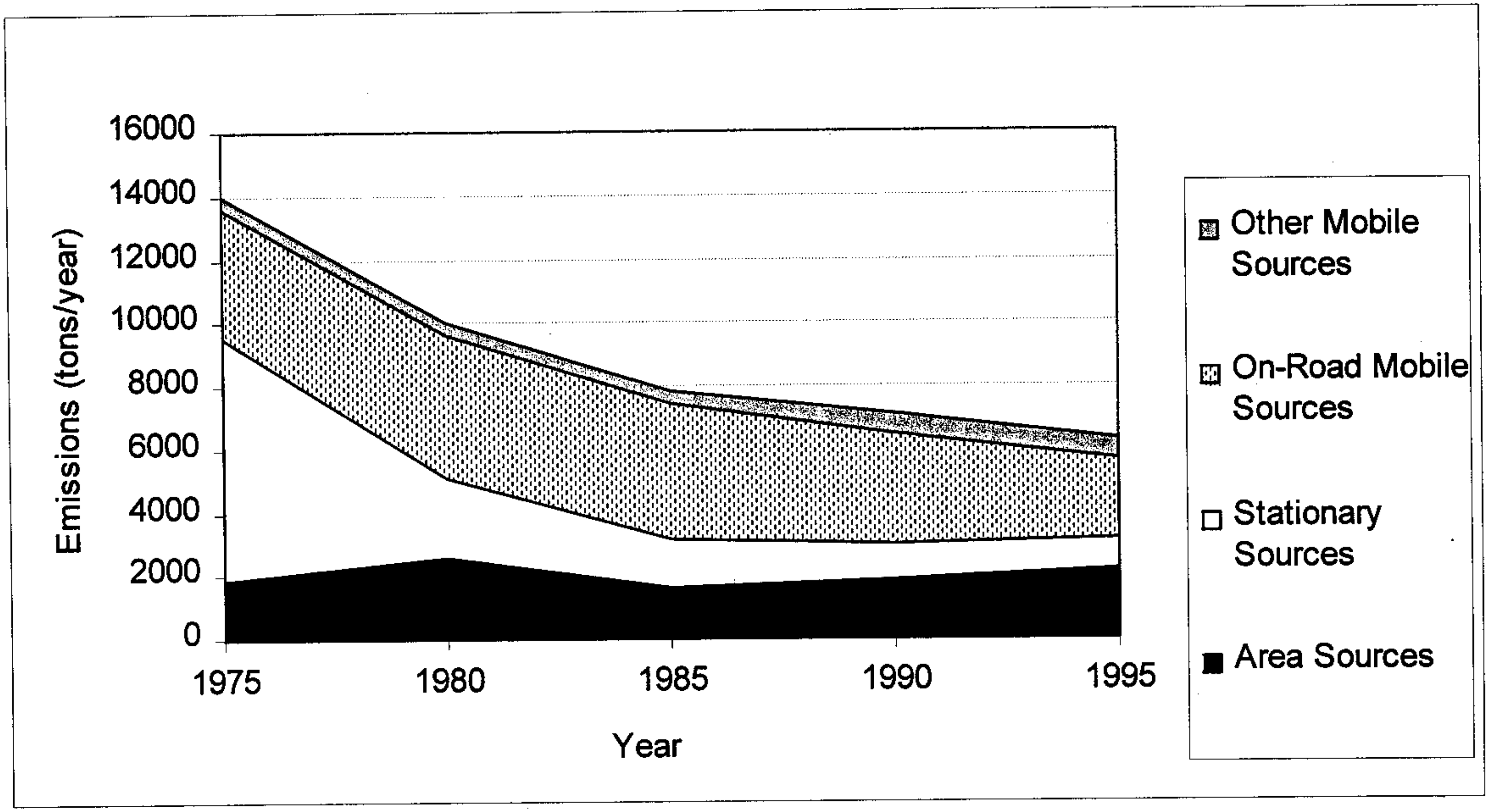


Figure 4-16. Historical ROG emission estimates by source category as projected by the ARB.

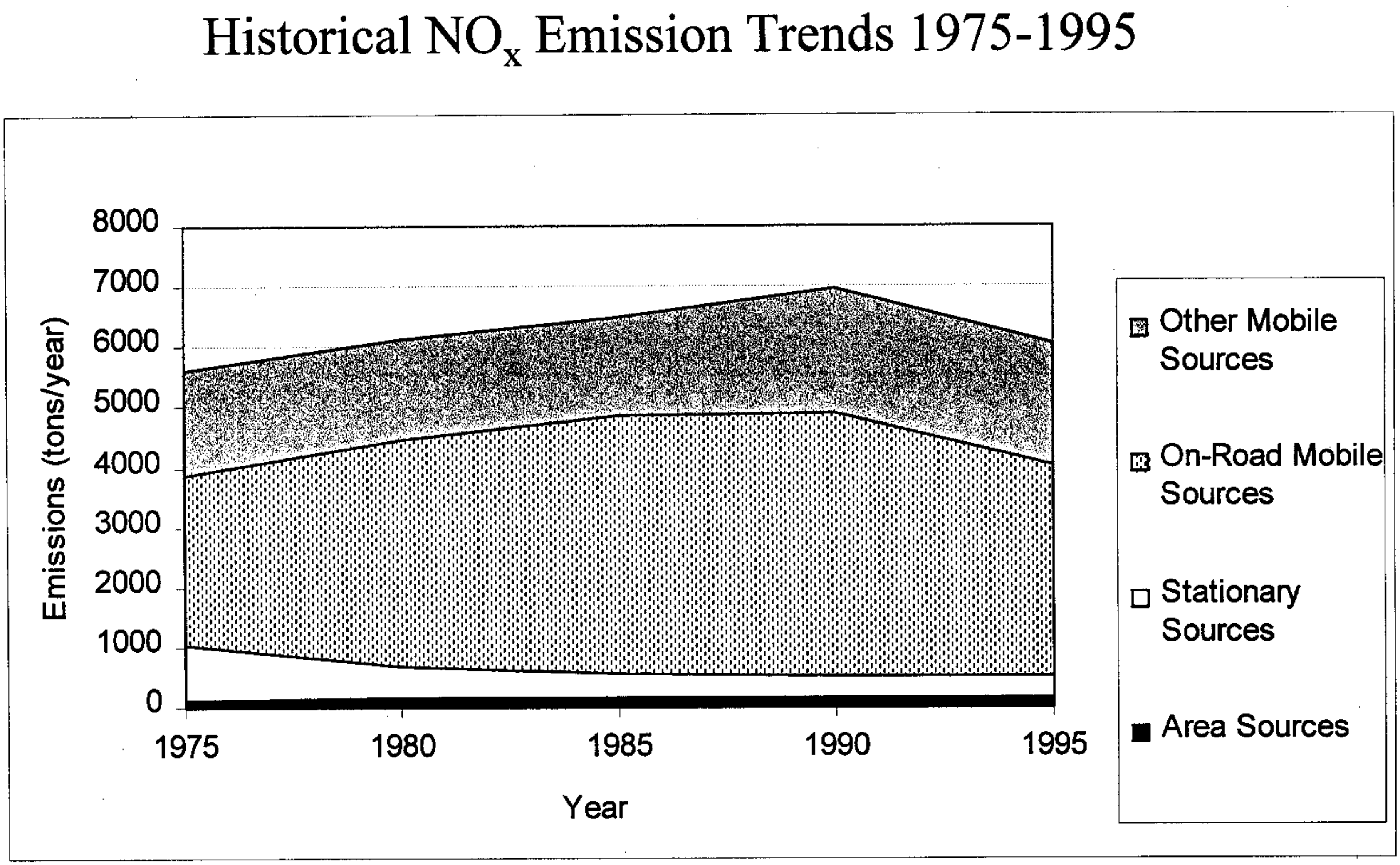


Figure 4-17. Historical NO_x emission estimates by source category as projected by the ARB.

Historical PM_{10} Emission Trends 1975-1995

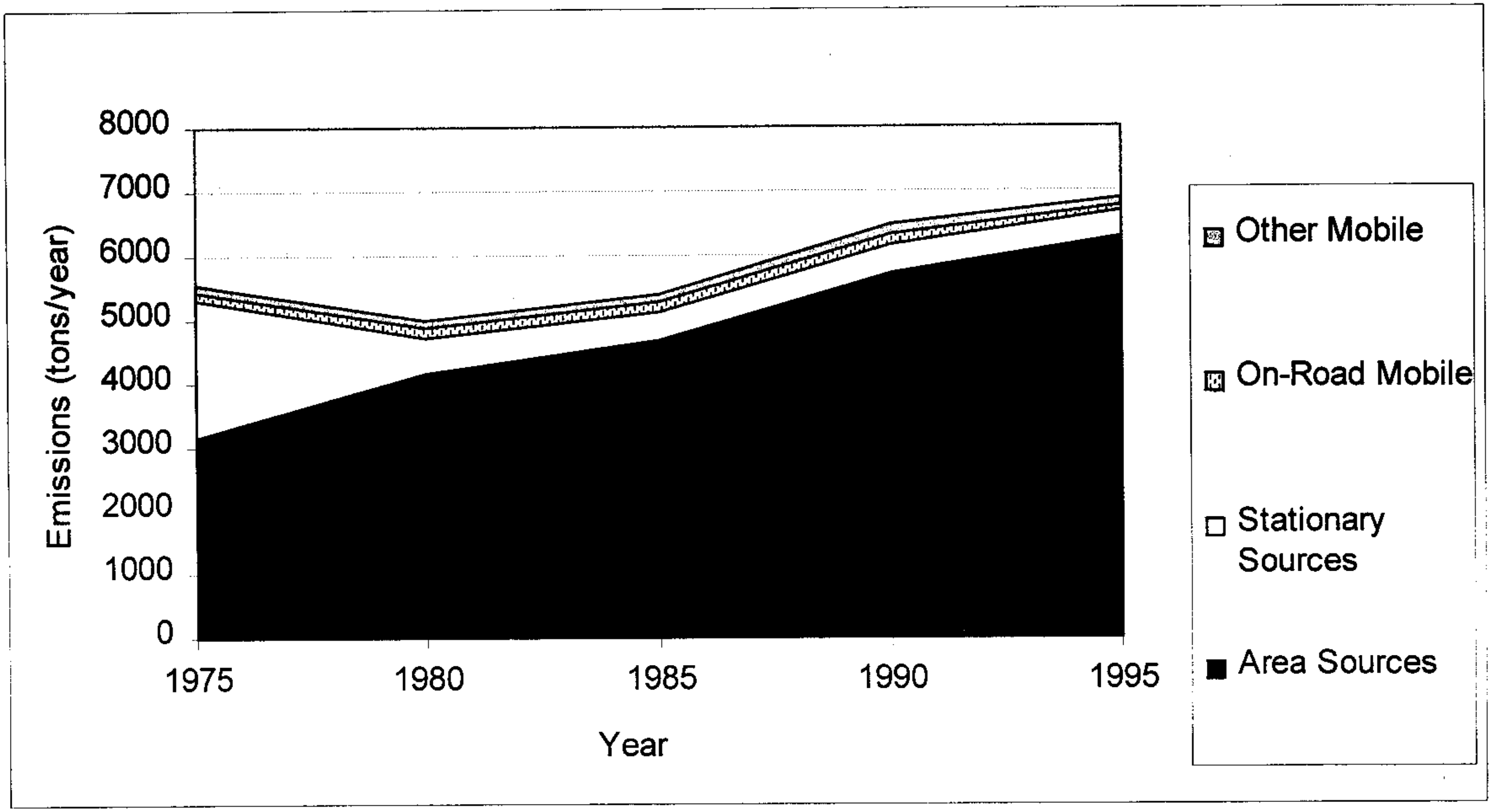


Figure 4-18. Historical PM_{10} emission estimates by source category as projected by the ARB.

5. AIR QUALITY MITIGATION MEASURES

Section 3 demonstrated that Mendocino County's air quality currently meets national and California ozone standards but violates California's 24-hr PM_{10} standard. Section 4 projected the combined effects of previously enacted control strategies and socio-economic growth on emissions in Mendocino County. The projections forecasted an overall increase in PM_{10} emissions (in spite of ARB and EPA control strategies) and a modest decline in ozone precursor emissions. In themselves, these results constitute a clear motivation for local PM_{10} mitigation measures. In addition, the EPA's newly promulgated air quality standards, which regulate $PM_{2.5}$ concentrations, represent a potential area for future concerns.

Given projected declines in ozone precursor emissions, the need for local ozone mitigation measures is somewhat less clear. A photochemical box model provides a means to evaluate the potential effectiveness of local ozone mitigation measures. The remainder of this section evaluates photochemical box modeling results, provides supporting rationales for a strategic air quality plan, and discusses PM_{10} and ozone mitigation options.

5.1 PHOTOCHEMICAL BOX MODELING

A two-layer photochemical box model generated estimates of future ozone concentrations in Ukiah on the basis of 1995 hourly ozone data, 1995 episode-specific meteorological data, and alternately, 1995 emissions or projected future emissions. The use of two layers (ozone and aloft) supported an evaluation of aloft (or transported) ozone and its impact on surface concentrations. Aloft ozone contributes to surface concentrations when the mixed layer rises and aloft ozone mixes downward to ground level. Alternate analyses of 1995 and future-year emissions permitted year-to-year estimates of differences in the peak ozone concentrations.

The box model was applied to the Ukiah region, which encompasses an area of 129 km^2. On the basis of VMT and population distributions, 25 percent of Mendocino's county-wide mobile emissions and one-sixth of its area and stationary source emissions were assigned to the modeled Ukiah region. Mobile emissions were distributed over the course of the day according to a travel pattern that is typical for urban areas (with two peak travel hours, corresponding to morning and evening rush hours). The area and stationary source emissions were distributed evenly from 0800 PST to 1800 PST Biogenic emissions were estimated with the PCBEIS-2 model (see Section 4).

5.1.1 Base Year Modeling Results

The ozone episode selected for modeling was the July 27, 1995 episode with a peak observed ozone of 84 ppb. Air quality observations at distant monitoring sites indicated that the July 27, 1995 episode was regional in scope. **Table 5-1** tabulates peak ozone observations for selected northern California sites on July 26 and July 27. On July 26, monitoring sites in Napa, Santa Rosa, San Rafael, Vacaville, and Fairfield recorded high levels of ozone.

Table 5-1. Peak ozone concentrations (ppb) observed at selected sites.

Site	July 26, 1995	July 27, 1995
Ukiah	54	84
Lakeport	50	70
Healdsburg	65	100
Sonoma	50	60
Napa	82	103
Santa Rosa	75	98
San Rafael	76	60
Vacaville	77	106
Fairfield	92	114

The initial modeling run began at 0600 PST on July 27, 1995 and continued for 12 hours. **Figure 5-1** displays the agreement between modeled and observed ozone concentrations for July 27, 1995. The model estimated a peak ozone concentration of 87 ppb, which compares well to the observed peak of 84 ppb. However, the observed peak occurred at 1400 PST, while modeled ozone concentrations continued to rise until 1700 PST (not shown). These results indicate that the box model cannot simulate the phenomena that cause ozone concentrations to fall after 1400 PST. The likely reason is that afternoon winds advect the morning urban plume away from Ukiah and draw fresh air from outside the urban area. In order to simulate advection phenomena, a sophisticated trajectory model or a three-dimensional model is necessary. In order to simplify the modeling process, the ozone peak was reasonably assumed to occur between 0600 PST and 1400 PST, and further modeling runs were halted at 1400 PST.

Tables 5-2 and 5-3 document the base-year emissions estimates and initial modeling conditions. The initial surface ozone concentration used was the actual observed value. In consideration of the regional nature of the July 27, 1995 episode, a reasonably high value for aloft ozone (60 ppb) was assumed.

5.1.2 Effects of Emission Changes

Different emissions scenarios were simulated to estimate their effect on ozone concentrations in Ukiah. Specifically, anthropogenic VOC and NO_x emissions were alternately increased or reduced by 25 percent. **Table 5-4** shows the peak ozone concentrations for each of the modeled emissions scenarios. Note that the variation in the peak estimated ozone concentration is small, considering the magnitude of emissions changes. For example, the peak modeled ozone concentration increased from 87 ppb to 91 ppb (only 5 percent) when

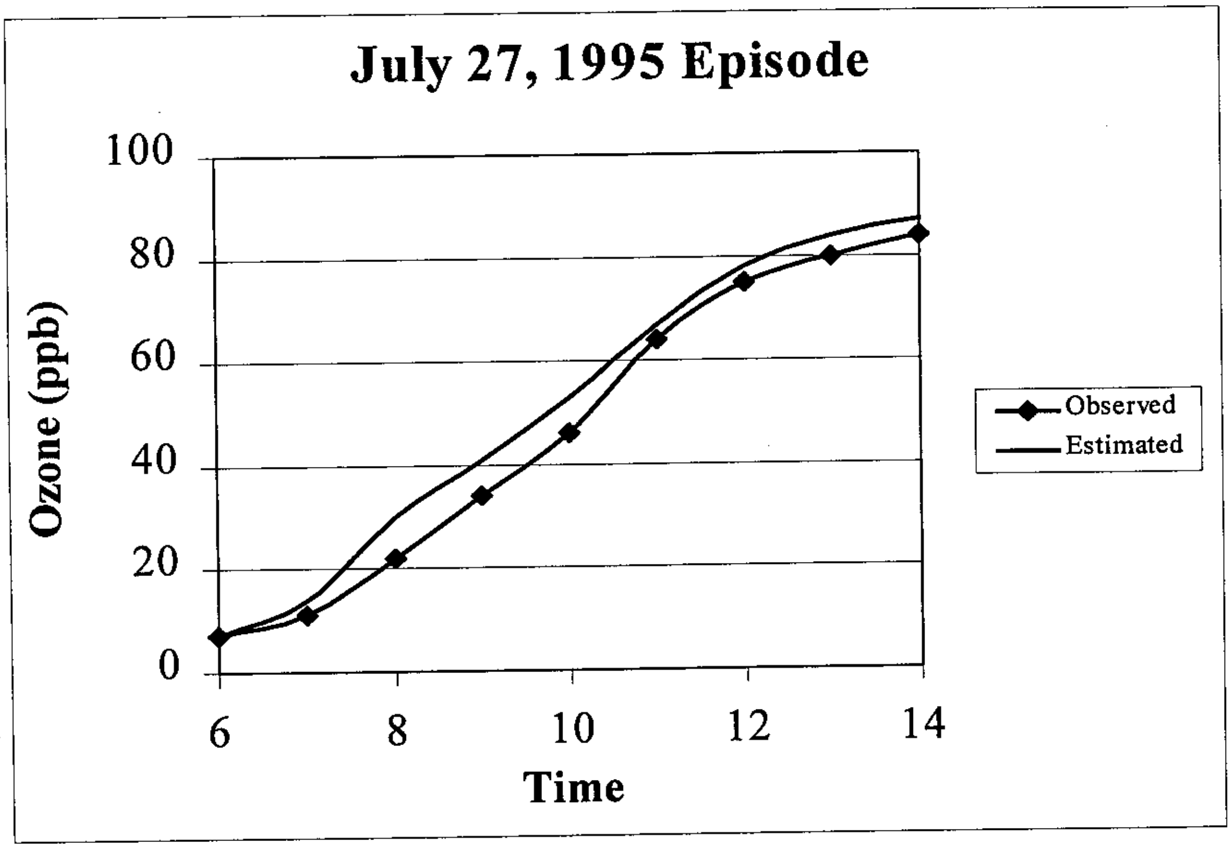


Figure 5-1. Observed and estimated ozone concentrations on July 27, 1995.

Table 5-2. Base-year hourly emissions (kg/hr) for the Ukiah modeling region.

Hour	Mobile			Area and Stationary			Biogenics		
	ROG	CO	NO_x	ROG	CO	NO_x	Isoprene	Mono-Terpene	Other VOC
6	98	1264	136				2	9	11
7	163	2107	227				7	9	11
8	98	1264	136	124	404	9	18	14	17
9	82	1053	114	124	404	9	52	27	32
10	82	1053	114	124	404	9	99	40	48
11	82	1053	114	124	404	9	122	46	54
12	82	1053	114	124	404	9	138	49	58
13	82	1053	114	124	404	9	147	52	61
14	82	1053	114	124	404	9	148	53	62
15	98	1264	136	124	404	9	141	52	62
16	163	2107	227	124	404	9	123	50	59
17	131	1685	182	124	404	9	93	46	54

Table 5-3. Initial conditions assumed for box modeling.

Species	Surface Concentration (ppb)	Aloft Concentration (ppb)
Ozone	7	60
NO	1	0.01
NO_2	2	0.2
CO	100	100
Paraffin	12	12
Ethene	1	1
Olefins	1	1
Isoprene	0.01	0.01
Toluene	0.5	0.5
Xylene	0.3	0.3
Formaldehyde	1	1
Aldehydes	0.5	0.5

Table 5-4. Peak ozone concentrations (ppb) estimated for different emissions scenarios on July 27, 1995 with an aloft ozone of 60 ppb.

Different Cases	Base Case	25% NO_x increase	25% NO_x reduction
Base Case (1995 actual)	87	90	82
25% VOC increase	88	91	83
25% VOC reduction	85	88	81

VOC and NO_x emissions increased 25 percent. Similarly, the peak modeled ozone concentration dropped from 87 ppb to 81 ppb (only 7 percent) when VOC and NO_x emissions both fell 25 percent. The box model appears insensitive to emissions changes due to the large contribution of aloft ozone to the modeled surface concentration for this episode. These results suggest that for a regional episode, the impact of increased or decreased emissions in Ukiah is relatively small. Another important finding is that the estimated peak ozone is more sensitive to changes in NO_x emissions than to changes in VOC emissions. For example, a 25 percent reduction in NO_x emissions alone reduces the estimated peak ozone by 6 percent, whereas a 25 percent reduction in VOC emissions alone reduces the estimated peak ozone by 2 percent.

A similar modeling scenario was run using VOC and NO_x emissions projected for the year 2010. Compared to 1995 levels, the projected emissions for 2010 were 11 percent lower for VOC, 32 percent lower for NO_x, and 30 percent lower for CO. Due to these reductions, peak estimated ozone concentrations dropped from 87 ppb to 80 ppb.

Since the previous runs (e.g., where background ozone was 60 ppb) demonstrated the model's insensitivity to changes in VOC and NO_x emissions, additional runs tested its sensitivity to aloft ozone concentrations. The same inputs were used, except an aloft concentration of 40 ppb was used instead of 60 ppb. **Table 5-5** shows the results of the sensitivity tests to aloft ozone. Although the absolute change in estimated peak ozone concentrations is similar to that obtained when the aloft ozone concentration was 60 ppb, the percent change is greater. This result demonstrates that there could be significant production of ozone in the surface layer.

The previous sensitivity analyses were refined through an additional simulation. The initial surface and aloft ozone concentrations were set to 0 ppb. Under these scenarios, 40 to 70 percent of the peak modeled ozone concentration is attributable to local emissions sources and the remainder is due to the background concentration. In conclusion, it is theoretically possible to reduce peak ozone observations, however, it would require much larger emissions reductions than those modeled (25 percent).

Table 5-5. Peak ozone concentrations (ppb) estimated for different emission scenarios on July 27, 1995 with an aloft ozone of 40 ppb.

Different Cases	Base Case	25% NO_x increase	25% NO_x reduction
Base Case	74	78	70
25% VOC increase	76	79	71
25% VOC reduction	73	76	69

5.2 DEVELOPING A STRATEGIC PLAN

5.2.1 Key Technical Issues

The main goal of Mendocino County's control strategy program should be to reduce PM_{10} concentrations in order to meet state air quality standards, and to consider mitigation measures to prevent any future problems with ozone or $PM_{2.5}$. There are a number of air pollution control strategies of potential use to Mendocino County. Possible strategies may be drawn from recently published literature and other communities' experiences, with due consideration given to the special circumstances that surround Mendocino County's air quality issues. The purpose of this discussion is to present various control strategy options and consider their applicability to Mendocino County. Further details on approaches used in other communities including cost benefit analyses can be found in EPA guidance documents such as "Technical Information Document for Residential Wood Combustion Best Available Control Measures", "Prescribed Burning Background Document and Technical Information Document for Prescribed Burning Best Available Control Measures", and "PM-10 Innovative Strategies: A Sourcebook for PM-10 Control Programs". In addition, the State and Territorial Air Pollution Program Administration (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO) have published "Controlling Particulate Matter Under the Clean Air Act: *A Menu of Options*".

In order to plan effective control strategies, local agencies must consider the meteorological, transport, and emissions patterns that are associated with air quality episodes. They must also consider the relative significance of man-made pollutant emissions in comparison to sources that are beyond their control, such as biogenic emissions. Finally, agencies should weigh any uncertainties and information gaps present in their analyses in order to maximize the potential success of an air quality plan.

A number of key technical issues have been addressed in the earlier sections of this report and are summarized below.

- Ozone and PM concentrations infrequently approach or exceed the air quality standards. No exceedances of the ozone standard have occurred, but the highest levels are reached during the summer months under hot, stagnant conditions. PM_{10} exceedences typically occur during winter conditions, when cold, calm conditions favor low-level inversion layers that trap air pollutants in Mendocino County. (Note that the PM_{10} exceedences that occur in Fort Bragg during the spring and summer are most likely due to unrelated phenomena.)
- PM_{10} air quality episodes are most likely attributable to local emissions. However, under certain conditions, pollutant transport impacts ozone air quality in Mendocino County.
- Mobile sources dominate ozone precursor emissions (e.g., ROG and NO_x) in Mendocino County. For example, mobile sources contribute 91 percent of the total NO_x emissions. Over the next 10 years, NO_x emissions in Mendocino County are predicted to fall by 24 percent. This reduction is primarily due to control measures enacted by the ARB and EPA, which are anticipated to greatly reduce on-road emissions. As a result of decreased on-road emissions, other sources are anticipated to become relatively more important. Off-road mobile sources, such as farm equipment, trains, off-road vehicles, and boats are predicted to contribute more than half of the NO_x inventory in 2010. Area and stationary sources are also expected to become somewhat more important, respectively contributing 5 and 7 percent of the projected 2010 NO_x inventory.
- A variety of sources emit organic gases. At the countywide level, biogenic emissions of organic compounds overwhelm man-made emissions in Mendocino County. At smaller scales, such as within the Little Lake Air Basin, biogenic ROG emissions are on the same scale as man-made emissions. (Biogenic NO_x emissions are much more modest, representing less than 10 percent of the countywide inventory and an even smaller percentage of the Little Lake inventory.) The most significant man-made sources of reactive organic gases (ROG) for the 1995 inventory are listed in **Table 5-6**. From 1995 to 2010, man-made ROG emissions are predicted to fall by 13 percent. This modest reduction reflects a large anticipated drop in on-road mobile source emissions that is mostly offset by modest growth in area sources, other mobile sources, and industrial sources.

The lack of chemically speciated PM_{10} data eliminates the opportunity to perform source-apportionment modeling for Mendocino County. In other parts of California, PM_{10} episodes are caused by a combination of primary PM_{10} emissions and secondary aerosol formation. However, given Mendocino County's geography and climate, secondary aerosol formation is likely to be a relatively small contributor to PM_{10} episodes. Mendocino County's PM_{10} emission inventory shows a strong seasonal pattern, especially in the geologic dust component. **Table 5-7** lists the most significant sources of primary PM_{10} emissions for the wintertime, the season with the highest observed PM_{10} concentrations. Geologic dust is likely to be a relatively small contributor to regional wintertime PM episodes, but it may be important in certain localities with unpaved roads, agricultural operations, or lumber harvest activities. Projected future decreases in on-road mobile source emissions and industrial emissions are largely offset by growth in area source emissions and off-road mobile emissions.

Table 5-6. Significant man-made sources of ROG.

Source of ROG Emissions	Percent Contribution to Total Inventory 1995	2010
Mobile Sources	51	27
On-Road Mobile Sources	41	11
Other Mobile Sources*	10	16
Solvent Evaporation (Area)	14	21
Lawn & Garden + Charbroiling (Area)	14	21
Petroleum Production and Marketing (Stationary)	7	8
Industrial/Commercial Solvents (Stationary)	5	8
Residential Wood Combustion (Area)	5	8
Industrial Point (Stationary)	3	3
Waste Burning (Area)	1	2
Remainder	0	2

*planes, trains, farm equipment, off-road vehicles, boats

Table 5-7. Significant sources of wintertime PM_{10}.

Source of PM_{10} Emissions	Percent Contribution to 1995 Inventory
Residential Wood Combustion (Area)	33
Man-made Dust Sources* (Area)	27
Industrial Point Sources (Stationary)	24
Mobile Sources	12
On-Road Mobile Sources	4
Other Mobile Sources	8
Natural Dust Sources (Area)	2
Misc. Area Sources	2

*road dust, construction, farming operations

5.2.2 Uncertainties

Despite the efforts of air quality regulators at the state, federal, and local levels, a considerable number of uncertainties and information gaps still exist. Meteorological and transport influences on air quality are highly uncertain in Mendocino County, insufficient aloft meteorological and air quality data exist. The emission inventory and future-year projections are matters of great uncertainty. Much of the emission inventory is based on highly uncertain emission factors, statewide or regional averages, and extrapolated or interpolated estimates. Future projections are based on key assumptions regarding future socio-economic growth patterns in Mendocino County, which are highly uncertain by their nature. The emission inventory for mobile sources is a particularly contentious source of local debate. County officials indicate that Mendocino's mobile source ROG and NO_x emissions may be grossly underestimated, and the effectiveness of future statewide control programs may be overestimated. In addition, recent research is beginning to suggest that mobile sources are a far more important source of PM_{10} emissions than previously thought (Fujita et al., 1998). Additionally, Caltrans believes that there is a relatively large unregistered vehicle population in Mendocino County. If these hypotheses regarding the mobile source inventory turn out to be justified, then mitigation strategies for mobile sources will become increasingly important.

5.3 MITIGATION MEASURES

The concepts discussed in Section 5.2 lead to a few preliminary conclusions regarding potential control strategies in Mendocino County. Note that these conclusions are subject to the areas of uncertainty and information gaps discussed above. Improved research in these areas could either support or contradict this discussion.

Local man-made air pollutant sources contribute significantly to PM_{10} air quality episodes in Mendocino County. Transport of air pollutants from outside the County may contribute to only some ozone episodes. Therefore, a local control program has the potential to improve or prevent deterioration of Mendocino County's air quality.

In Mendocino County, man-made emissions of ROG are relatively small compared to biogenic emissions, whereas man-made NO_x emissions are relatively large compared to biogenic emissions. This observation, in addition to the relatively rapid projected decline in man-made NO_x emissions, supports the hypothesis that ozone formation in Mendocino County tends to be NO_x-limited and will grow to be even more NO_x-limited in the future.

For PM_{10}, proposed control strategies should focus on man-made sources that are significant during the wintertime, when the highest concentrations of PM_{10} are typically observed in Ukiah and Willits. For both PM_{10} and ozone, preventative strategies should address man-made sources that are likely to grow to be important in future years. Under these criteria, the following emissions sources should receive the greatest prioritization.

- Residential Wood Combustion
- Man-made Dust Sources
- On-Road Mobile Sources
- Gross-Polluting Vehicles
- Other Mobile Sources
- Solvent Evaporation (Consumer and Industrial)
- Lawn, Garden, and Charbroiling Equipment
- Petroleum Marketing

Discussions with local officials have indicated that voluntary and public outreach programs should be included as important goals for any planned air quality program in

Mendocino County. This conclusion is supported by the experiences of other regions, where public involvement and support have been critical components to the success rates of air quality programs.

5.3.1 Residential Wood Combustion

Definition: Wood burning involves the use of wood burning stoves and fireplaces. Wood burning during the winter holidays has been shown to be a significant contributor to PM_{10} emissions in other parts of California (Fujita et al., 1998).

Possible Control Actions:

1. Restrict burning when monitored or forecasted conditions indicate that the region's air quality standard is likely to be exceeded.
2. Establish a public information program to support local ordinances restricting wood burning, such as the voluntary "Don't Light Tonight" public outreach campaign in San Francisco, California; or "Spare the Air" campaigns in several areas of California.
3. Require EPA-defined clean burning fireplaces and wood burning devices in all new residential construction (Portland, Oregon).
4. Require uncertified wood stoves to be replaced or removed upon the sale of residences (mandatory in Crested Butte, Colorado since 1989; also required in Washoe County, Nevada and Seattle, Washington) (STAPPA and ALAPCO, 1996). May include wood stove retrofits or be limited to those wood stoves that are the primary heat source.
5. Ban the installation of wood burning devices in new residential construction (Clark and Washoe Counties, Nevada). Experience in Mammoth Lakes, California, and in Reno, Nevada, demonstrates that local real estate practices are able to adapt well to these restrictions (STAPPA and ALAPCO, 1996).
6. Provide incentive programs to promote installation of better performing wood burning devices for low income households.
7. Develop an integrated program to reduce wood burning emissions.
8. Develop financial assistance/rebate programs to replace or retrofit existing wood stoves.

5.3.2 Man-Made Dust Sources

Definition: Man-made dust sources include unpaved road traffic, construction and demolition activities, and farming operations. Note however, in the absence of chemically speciated PM filter samples it is not clear which, if any, man-made dust sources may be contributing to local PM exceedances.

Possible Control Actions:

1. Require fugitive dust controls such as wetting, dust suppressants, ground cover, or wind breaks at construction sites and during logging and farming operations. Site specific air dispersion analyses may be used to avoid triggering compliance requirement.

2. Pave roads or apply dust suppressants in neighborhoods where there is a local dust problem due to unpaved roads.

3. Apply control programs during the winter, to selectively address the time of year when exceedances of the PM_{10} air quality standards are most likely.

4. Evaluate the subdivision/development road standards to reduce particulates on unpaved roads. Ensure funding measures are identified for improvements or dust suppression.

5. Address the role of the development process in avoiding or modifying discretionary projects that increase traffic on unpaved roads, by time of day or year.

6. Examine road standards toward limiting construction or extensive use of unpaved roads.

7. Identify unpaved County roads that do or will make a sufficient contribution to the pollutant load to warrant future paving or dust suppressants. Identify unpaved private roads that do or will make a sufficient contribution to the pollutant load to warrant future paving, dust suppressants, or County acceptance and improvement.

8. Evaluate an air quality mitigation program/fund for in-lieu fees to be applied to roads in more heavily trafficked areas to offset particulate generation on projects where paving is not reasonably feasible or traffic is light.

9. Evaluate the usefulness of more restrictive speed limits in reducing particulates in specified circumstances or on specified roads.

5.3.3 On-road Mobile Sources

Definition: On-road mobile sources include passenger vehicles, trucks, and buses. A disproportionate fraction of PM_{10} emissions is related to heavy-duty vehicle exhaust.

Control Actions Already Taken: The EPA promulgated new and retrofit truck and urban bus standards that were phased-in from 1991 to 1994. These standards reduce PM_{10} emissions more than 80 percent in affected vehicles, and the reductions will continue to accrue as truck and bus vehicle fleets turn over. Nationally, the average truck in 1994 was 8.4 years old (NESCAUM, 1997), so there is a lag time between the introduction of new standards and fleet emissions reductions. Additionally, in October 1997, the EPA announced more stringent NO_x and hydrocarbon (HC) emissions standards for diesel trucks and buses.

In California, the use of reformulated diesel fuel is mandatory. The reduction in sulfur oxides leads to reduced levels of secondary aerosols. California's lower aromatic formulation results in approximately a 10 to 20 percent reduction in PM emissions beyond what is achieved with federal fuel requirements (Brasil, 1997; NESCAUM, 1997).

In December 1997, California announced a new heavy-duty diesel vehicle inspection and maintenance (HDDV I/M) program with two key components: an annual self-inspection program for fleets of two or more vehicles (the "periodic smoke inspection" program), and a random roadside program using snap acceleration testing. The random roadside program will likely begin in spring or summer of 1998, and will be based on a similar program in place from 1991 to 1993. British Columbia has operated a successful roadside inspection pilot program since February 1996.

Possible Control Actions:

1. Encourage vehicle retirements or retrofits for pre-1993 heavy-duty diesel vehicles.
2. Synchronize traffic signals to prevent stop-and-go traffic and reduce the corresponding increase in PM_{10} emissions.
3. Promote the use of alternative fuels. For example, convert all or part of the area's bus and government vehicle fleets to alternative fueled vehicles.
4. Encourage construction and operation of alternative fuel refueling stations, with fuel tax credits.
5. Supplement California's existing HDDV inspection and maintenance program.
6. Limit vehicle idling in areas such as truck stops and weigh stations. Voluntary programs, based on reduced engine wear-and-tear, have been effective in other areas such as Arizona (Eisinger et al., 1998).

5.3.4 Gross Polluting Vehicles

Definition: A small fraction, up to 10 percent, of light duty automobiles emit much higher than average quantities of PM. For example, a study published in 1996 (Sagebiel et al., 1997) measured emissions from 23 vehicles identified as high emitters by remote sensing and roadside inspections. The average particle emission rate, as measured by advanced technology inspection equipment ("IM240" inspection equipment) showed that of the 23 vehicles, 17 were non-smoking vehicles that emitted approximately 51 mg of PM per mile. The remaining six vehicles emitted visible smoke and averaged 558 mg of PM per mile with a high of 1,342 mg per mile. In contrast, a "clean" vehicle typically emits 5 mg per mile. On average, most of the particulate mass was carbon with an average split of 75 percent organic carbon (OC) and 25 percent black carbon (EC), or soot.

Possible Methods to Identify Gross Polluters:

1. Initiate a public education program to help vehicle owners self-identify smoking vehicles.
2. Link smoking vehicle inspection with vehicle registration.

3. In California, state officials have developed a computer program that identifies vehicle types most likely to be high emitting vehicles. The program, the "high emitter profile" (HEP) program, relies upon past and current inspection and maintenance (I/M) data, as well as remote sensing results.

Possible Control Actions:

1. Initiate a public education program to encourage voluntary vehicle repairs.
2. Link a "pollution charge" to vehicle registration for identified gross polluters.
3. Encourage early vehicle retirement. Owners of gross emitting vehicles could become eligible for low interest new vehicle purchase loans, vehicle scrappage payments, or other incentives or disincentives (such as the vehicle pollution charge) designed to promote early vehicle retirement.

5.3.5 Other Mobile Sources

Definition: Other mobile sources include industrial and commercial equipment, locomotives, boats, off-road vehicles, and farm equipment.

Control Actions Already Taken: The EPA has proposed (August 29, 1997) emissions controls for virtually all off-road equipment. If finalized, these federal regulations will apply to new equipment and will be phased in during the 1999 to 2006 time period. EPA estimates that the new standards will result in approximately a 13 percent reduction in PM emissions by the year 2010, and a 16 percent reduction by the year 2020 (U.S. Environmental Protection Agency, 1997).

In California, the use of reformulated diesel fuel is mandatory. The reduction in sulfur oxides leads to reduced levels of secondary aerosols. California's lower aromatic formulation results in approximately a 10 to 20 percent reduction in PM emissions beyond what is achieved with federal fuel requirements (Brasil, 1997; NESCAUM, 1997).

The EPA has implemented emissions standards for gasoline and diesel marine engines for recreational boats. VOC emissions are expected to be reduced 75 percent by 2025.

The EPA also proposed locomotive standards in 1997, ultimately expected to reduce emissions of VOCs, NO_x, and PM_{10} by 50 percent.

Possible Control Actions:

1. Encourage state and local government agencies to seasonally adjust their activity to minimize PM emissions during periods when the PM air quality standards might be exceeded.

2. Encourage exhaust system retrofits with more effective exhaust technology. Incentive programs could include government contract award preferences for retrofit exhaust technology, tax incentives, low interest loans, and/or rebates to retrofit diesel equipment or purchase new equipment.
3. Encourage voluntary replacement of off-road equipment with low or zero emission equipment.
4. Promote cleaner burning fuel formulations.
   - French petroleum producer Elf-Aquitaine plans to introduce "Aquazole" fuel in spring of 1998; the fuel combines diesel and water and may reduce fine PM emissions up to 70 percent (with a catalytic converter); the target market is public transit fleets (Technology Report, 1997).
   - Sacramento, California and Clark County, Nevada are testing "A-55," a naphta/water fuel to replace diesel; it may cut emissions up to 40 percent (Platt, 1996).
5. Promote the voluntary purchase of cleaner operating equipment in advance of its normal introduction into the equipment fleet. The EPA's off-road proposed rule making includes a "Blue Sky Series Engines" program; this is a voluntary program to encourage very low emitting diesel engines (e.g., CNG or propane) (U.S. Environmental Protection Agency, 1997). Mendocino area officials could offer contract award incentives, tax rebates and incentives, or low interest loans to encourage participation in the Blue Sky program.

5.3.6 Solvent Evaporation

Definitions: Solvent evaporation sources arise from aerosol consumer products, asphalt application, pesticides, architectural coatings, solvents, inks, stains, adhesives, degreasers, dry cleaning, wood coatings, and cleaning products.

Control Measures Undertaken: In 1994, ARB regulations regarding dry cleaning took effect. These included control measures and a training program for perchloroethylene operations.

The Department of Pesticide Regulation (DPR) regulates pesticide use. A proposed statewide program is anticipated to reduce VOC emissions from pesticides by 20 percent. From 1995 to 2005, VOC emissions due to pesticides are projected to fall by 20 percent statewide.

The ARB possesses jurisdiction over consumer products and aerosol coatings. The ARB has phased in regulations from 1991 to 1996.

Possible Control Measures:

1. The ARB possesses jurisdiction over consumer products, and DPR controls pesticide use. However, there are a few things local agencies can do as public outreach and education programs, including:
   - Initiate education or outreach programs for small businesses (e.g., beauty salons, carpenters, housepainters) regarding environmentally friendly products and good housekeeping programs.
   - Initiate local outreach programs to encourage DPR's standards for improved pesticide application techniques, reformulated low-VOC products, new low-dose pesticides, and Integrated Pest Management (IPM). (IPM systems combine biological controls, crop rotation, and improved field monitoring.)
2. For commercial and industrial purposes, require the use of coatings with low VOC content, and adhesives that are waterborne, hot melt, UV cured or reactive diluent type. (Add-on controls such as carbon absorption and afterburners are more costly for these operations and are generally not used.)
3. Restrict the use of highly volatile asphalt mixes.

5.3.7 Lawn, Garden, and Charbroiling Equipment

Definition: Lawn and garden equipment includes handheld devices such as chain saws, string trimmers, and leaf blowers. Larger lawn and garden equipment includes lawn mowers, garden tractors, tillers, and certain construction equipment. Charbroiling equipment includes both restaurant-owned and privately-owned devices that are used to flame cook foods.

Control Measures Undertaken: In 1997, the first EPA rules took effect to regulate small non-road engines (below 25 horsepower). These regulations are expected to result in a 32 percent reduction in hydrocarbon emissions from these engines. Additional proposed regulations are anticipated to reduce hydrocarbon plus NO_x emissions by 30 percent and improve engine durability.

Possible Control Measures:

1. Initiate an incentive or public outreach program to replace older, gasoline-powered lawn equipment with electric-powered models or newer models built with the EPA's improved control technologies. For example, through its "Spare the Air" program, Sacramento sponsored a trade-in sale to provide clean technology lawn equipment to consumers at a reduced cost. A similar program could be developed to exchange privately-owned charcoal-fired broilers for propane models.
2. Encourage or require government-paid maintenance crews to use electric-powered or clean technology equipment for landscaping maintenance.
3. Restrict lawn equipment or charbroiling equipment use when monitored or forecasted conditions indicate that the region's air quality standard is likely to be exceeded.

4. Establish a public information program to support local ordinances restricting the use of lawn or charbroiling equipment, similar to the one suggested above to reduce emissions from residential wood combustion.
5. Encourage the use of chimney-type or electric charcoal starters instead of lighter fluid for charcoal-fired barbecues.

5.3.8 Petroleum Production and Marketing

Definition: Emissions due to petroleum production and marketing arise from leaking transfer lines or storage tanks, due to transfer operations, or due to accidental spills.

Control Measures Undertaken: Mendocino has initiated the conversion of its larger gas stations to Stage I and Stage II vapor recovery. This technology is estimated to reduce emissions of ROG due to transfer operations by 90 percent or better.

Possible Control Measures:

1. The Stage I and Stage II vapor recovery program is very effective and should be continued.
2. The County could initiate voluntary or agency-sponsored leak detection programs at service stations and storage facilities.
3. Foster public outreach or education programs regarding petroleum spillage. Encourage the use of proper storage containers with nozzles that minimize spillage and vaporization.

5.4 SUMMARY

In conclusion, the goals of Mendocino County's air quality program should focus on reducing PM_{10} concentrations and preventing future ozone and $PM_{2.5}$ air quality problems. In order to formulate the most effective strategy, local planners need to consider many factors: meteorology, transport conditions, emissions patterns, biogenic emissions, socio-economic considerations, and analytical uncertainties. A few key considerations for Mendocino County's air quality program include:

1. Public outreach and education programs are critical to develop support for any local mitigation measures.
2. Some of the more important emissions source categories include residential wood combustion, man-made dust sources, on- and off-road mobile sources, gross-polluting vehicles, solvent evaporation, lawn/garden equipment, charbroilers, and petroleum marketing. However, mobile source mitigation strategies may be even more important than the current- and future-year inventories suggest.

3. Seasonal or temporary control measures can be highly effective to reduce peak air pollutant concentrations.
4. Several critical uncertainties and knowledge gaps exist regarding emissions patterns, air quality data, and meteorological observations. Investment in a few key areas would return a significant degree of value, including upper-air meteorological and air quality sampling programs, speciated PM and/or VOC monitoring programs, and/or a research program to study local motor vehicle use patterns.

6. RECOMMENDATIONS FOR IMPROVED MONITORING AND EMISSION INVENTORIES

As a result of our assessment of ozone and PM air quality in Mendocino County, a number of air quality, meteorology, and emission inventory issues have been raised. In this section, the key issues, recommendations for future monitoring, and steps to improve the emission inventory for Mendocino County are presented.

6.1 POLLUTANT MONITOR SITING ISSUES

6.1.1 Ozone Monitoring Issues

Key monitoring issues that pertain to ozone formation and transport include:

- **Comprehensive ozone precursor data are non-existent.**

Air quality stations established to monitor compliance with air quality standards do not provide sufficient data to understand fully the causes of ozone formation and transport in the region. For example, in Mendocino County, the ozone precursors, hydrocarbons and NO_x, are not adequately measured for ozone studies in Mendocino County. Currently, as in all but the most populous urban areas of the State, no hydrocarbon samples are collected in Mendocino County. The lack of these precursor measurements limits the types of analyses that can be performed and the conclusions that can be drawn. For example, VOC and NO_x measurements are critical to a better assessment of the emission inventory (i.e., comparing ambient and emission inventory ratios), a more complete understanding of the transport of pollutants from upwind (i.e., assessing the age of an air mass), and an indication of the important sources of pollutants (i.e., source attribution).

- **Ozone concentrations measured in Ukiah may not represent the highest concentrations in the Ukiah Valley.**

Background or clean air, e.g., air that has been transported for some time without fresh emission inputs, generally has a natural ozone concentration of up to about 30 to 40 ppb (Seinfeld and Pandis, 1998). In order for ozone concentrations to be below background levels, the ozone must be titrated by reaction with fresh NO emissions as discussed in Section 1. The ozone data collected at the E. Gobbi site in Ukiah appear to be somewhat titrated by fresh emissions of NO. Of the entire data set obtained from the E. Gobbi Street site, about three-fourths of the hourly ozone concentrations were below 30 ppb. A monitoring site impacted by fresh NO emissions may under-report the true regional ozone value at any time of the day when the fresh NO emissions are present. Typically, nighttime ozone concentrations below background levels (e.g., 30-40 ppb), or no ozone (e.g., 0 ppb), are strong indicators of a site subject to titration. The E. Gobbi site appears to be subject to both of these indicators.

Although the ozone measured at the E. Gobbi site are probably representative of the Ukiah urban core, they are probably not representative of the highest values for the Ukiah Valley. Since a large percentage of Mendocino County's population (i.e., 69 percent of the County total according to the 1996 U.S. Census Bureau) lives outside of the urbanized areas of Ukiah, Fort Bragg, and Willits, ozone levels measured at titrated downtown sites are probably under-representing the region's population exposure to ozone. To better understand the ozone levels outside Ukiah, establishment of an ozone monitoring site away from and upwind of any local NO_x emissions would be necessary.

- **Ozone concentrations at the borders of the Ukiah Valley are not known.**

The air quality assessment in Section 3 showed that transport of ozone and ozone precursors into the Ukiah Valley may be a significant contributor to ozone levels in the Valley. However, with monitors only in downtown Ukiah and Willits, the contribution of upwind ozone to the Valley cannot be quantified. To better assess the contribution of transported ozone on Mendocino County, the background concentrations at or near the border of the County need to be determined. Possible locations for a "border" site are between Hopland and Ukiah, or on a ridge above the Ukiah Valley; a site like this would provide important information regarding the regional background ozone concentrations.

One of the likely paths for transported ozone and precursors into the Ukiah Valley is via aloft transport as discussed in Section 3. To best quantify the contribution of aloft ozone, ozone concentrations within the potential mixed layer need to be characterized. Possible methods for quantifying aloft ozone concentrations include conducting a short-term study including aircraft measurements, or installing an ozone monitor at an elevated location along the line of potential aloft transport.

6.1.2 PM_{10} Monitoring Locations

Key monitoring issues that pertain to PM concentrations include:

- **Rural population exposure to PM should be measured.**

Although no sites have exceeded the State standard for the annual geometric mean of 30 $\mu g/m^3$, there have been exceedances of the State 24-hr PM_{10} standard of 50 $\mu g/m^3$ in every year between 1993-1997. However, the median values show no declining trend. The median is consistently in the 10 to 20 $\mu g/m^3$ range for Ukiah and Willits, and between 10 and 30 $\mu g/m^3$ in Fort Bragg.

PM measurements at Fort Bragg, Ukiah, and Willits may be under-estimating the regional PM_{10} air quality. All three sites are located adjacent to paved roads. However, as discussed above, nearly 70 percent of Mendocino County's population lives outside of the urbanized areas of Ukiah, Fort Bragg, and Willits and many of the rural Mendocino County roadways are unpaved. Thus, the concentration of particulate matter may be under-represented, since the monitoring sites are not impacted by as much fugitive road dust as is common outside of the urbanized areas.

- **Speciation of the PM mass is not available.**

As is typical of most rural districts in the State, little or no speciated PM data is routinely available. Only under special circumstances, such as a special regional air quality field study, is such data available for all but the most populous urban areas of the State. Contributors to PM exceedances in Mendocino county include: unusual emissions events, fire activity (e.g., wildfires, control burns, urban fires, etc.) in and outside of Mendocino County, residential wood combustion for fuel and space heating, sea-salt spray (Fort Bragg), mobile source-related emissions, fugitive dust, and point sources. However, due to the lack of chemical speciation of the PM_{10} samples, source contributions cannot be quantitatively assessed.

6.1.3 Meteorological Monitoring

In the future, analysis of ozone and PM air quality could be improved by increasing the quantity and type of meteorological data available. The routine meteorological data collected by smaller rural Districts is not sufficient to perform sophisticated ozone or PM episode analyses. Improvement in the analysis of ozone and PM episodes can be achieved by the collection of much more extensive meteorological data during seasons or at times when such episodes are expected to occur. Currently, there are one "pseudo" winds aloft station and only two surface meteorological stations in the Ukiah Valley, a region with highly complex wind flow patterns.

Likewise, for PM analyses, meteorological data are necessary to help assess the likely sources of PM. In order to better assess ozone transport and recirculation, the surface and aloft meteorology need to be better characterized in the Valley and upwind.

6.2 RECOMMENDATIONS

Recommendations for improved monitoring to address the key issues discussed above are described next for ozone and PM separately.

6.2.1 Ozone Air Quality

We recommend that Mendocino County consider the following actions to provide better data with which to characterize and assess ozone conditions:

- Add an ozone monitor at the southern boarder of Mendocino County to assess concentrations entering the County when winds are from the south. Likely candidate sites include Hopland or the ridgeline between Hopland and Ukiah.

- Add an ozone monitor at a more rural location (i.e., away from fresh NO_x sources) in the Ukiah Valley in order to better assess the exposure of the predominantly rural population to ozone. Good candidate sites would include locations north of Ukiah.
- Currently the District operates a CO monitor in accordance with the State monitoring requirements. However, if CO in Ukiah could be monitored to a higher level of resolution than required by the State (i.e., ppb, rather than ppm); better resolution in the data could be used for meaningful comparisons to the emission inventory.
- Collect a few fully speciated ambient hydrocarbon samples during the summer at the Ukiah site, collocated with the NO/NO_x monitor and an enhanced sensitivity CO monitor (e.g., concentrations reported in ppb, rather than ppm). These data are useful for assessing the emission inventory, pollutant transport, and source attribution. Three-hour average samples should be collected in the morning (i.e., 0600-0900 PST). A few samples collected in the afternoon, say 1400-1700 PST, would be useful for assessing the importance of transport.
- Enhance the surface meteorological measurement network in the Ukiah Valley to better assess ozone transport and recirculation. Simple surface wind monitoring stations placed at various locations throughout the Little Lake Air Basin (e.g., valley floor, mountain peaks, canyons to the north and south, etc.) could provide data for more quantitative transport analysis.
- Add aloft meteorological measurements at the upwind boundary of the Valley in order to better assess the possibility of transport and recirculation. Options include vertical profile measurements such as from a radar profiler or a surface site situated high on a ridge (similar to the Geysers site).

6.2.2 PM Air Quality

We recommend that Mendocino County consider the following actions to provide better data with which to characterize and assess PM conditions:

- Chemically speciate PM samples from historical episodes, if available, or from current samples above the standard.
- Add a PM monitor at a more rural location (i.e., near unpaved roads) in Mendocino County in order to better assess the PM concentrations the predominantly rural areas.
- Co-locate meteorological stations with sampling locations at Willits and Ft. Bragg to improve probability of pin-pointing any point source contributors.

6.3 EMISSION INVENTORY ISSUES AND RECOMMENDATIONS

The current emission inventory and future-year projections are matters of great uncertainty. Much of the emission inventory is based on highly uncertain emission factors, statewide or regional averages, and extrapolated or interpolated estimates. Future projections are based on fundamental underlying assumptions regarding future socio-economic growth patterns in Mendocino County, which are highly uncertain by their nature. Furthermore, the assumptions are built on state-wide averages, whereas Mendocino County will likely be quite different than the state-wide average for many growth factors. The emission inventory for mobile sources is a particularly contentious source of debate. In addition, recent research is beginning to suggest that mobile sources are a far more important source of PM_{10} emissions than previously thought (Fujita et al., 1998).

6.3.1 Key Emission Inventory Issues

A variety of "reality" checks relying on engineering judgement were used to review the existing emission inventory for Mendocino County. Using this approach, a number of emission inventory issues were identified in Section 4. A few of the key issues are listed below:

- The large area sources of ozone precursor emissions for commercial landscape equipment and cutback asphalt were estimated by the ARB using default values that appear to be inaccurate for Mendocino County.
- The ARB on-road motor vehicle emissions model assumes 6 to 8 percent unregistered vehicles per county, which likely results in an underestimate of emissions in the County because of the higher percentage of unregistered vehicles in Mendocino County. (Through discussions with Caltrans it was learned that about 20 percent of the vehicles in Mendocino County are unregistered.)
- Caltrans suggests that the estimates of unpaved roadway mileage are highly uncertain and thus could severely impact PM emission estimates for road dust. However, in the absence of speciated PM filter data proving otherwise, our preliminary findings suggest that road dust is not a primary cause of PM exceedances in Mendocino County. Thus, although uncertain, this PM emission category may not warrant further investigation.
- Although the ARB projects a 50 percent increase in population by the year 2020 in Mendocino County, the ARB emission forecasts predict reductions in ozone precursor emissions (almost entirely due to a large drop in on-road motor vehicle emissions resulting from fleet turnover). As noted in Section 4, the on-road mobile source emissions in Mendocino County play a dominant role in current year ozone formation and yet are projected to play a much smaller role in the future. Should the ARB's projections prove to be overly optimistic, future year ozone air quality could deteriorate in Mendocino County.
- Vehicle miles traveled (VMT) forecasts have historically been significantly underestimated, and emission inventory reconciliation studies have shown that the mobile source ROG emission inventory estimates are often underestimated by a factor of 2. Because the ARB does not account for the high number of unregistered vehicles in Mendocino County, VMT estimates are potentially lower than actual VMT levels, and total mobile source ROG emissions are typically underestimated; therefore, it is

likely that the future-year decreases projected by MVEI7G are optimistic. Although mobile source emissions will decrease in the future, an 85 percent decrease is unlikely.

6.3.2 Recommendations for Improving Emission Estimates

Emission inventories can be assessed in a variety of techniques that address the emission inventory from either a "top-down" or "bottom-up" perspective. The bottom-up approaches rely on a detailed evaluation of each source category's emission factors and activity data. The top-down approaches use regional indicators to assess the reasonableness of the emission estimates. Comparing the use of ambient air quality measurements with emissions estimated to occur close to the monitoring sites is a popular top-down approach, often referred to as emission reconciliation. Some of the most important emission inventory improvement steps that can be taken by Mendocino County are listed below:

- For this study, the lack of ambient VOC data limited a top-down assessment approach to using regional indicators, as discussed in Section 4. A speciated VOC sampling program would allow analyses of VOC:NO_x ratios. This type of analysis would (1) support more definitive conclusions regarding emission inventory under-estimations and (2) provide another tool for evaluating the quality of the emission inventory.
- Emission factors and activity data indicators used by the ARB to estimate area sources of ozone precursor emissions for commercial landscape equipment and cutback asphalt appear to be inaccurate for Mendocino County and should be updated.
- The ARB on-road motor vehicle emissions model should be re-run, accounting for the much higher than normal unregistered vehicle fleet in Mendocino County. This should result in a substantial increase in ozone precursor emissions.
- If in the future, speciate PM filter samples identify road dust as a significant contributor to PM exceedances, PM emissions from unpaved road dust should be re-calculated using revised estimates of unpaved roadway mileage. If warranted, revised estimates of unpaved roadway mileage can be obtained from remote sensing images or aerial photography.

Lastly, to more fully understand the uncertainties in Mendocino County's emission inventory, a detailed bottom-up inventory assessment should be performed. The bottom-up approach examines in detail the number, type, size, and activity of various emission sources within a county.

7. REFERENCES

Brasil A. (1997) California Air Resources Board, Sacramento, CA. Personal communication.

California Air Resources Board (1986) Personal communication.

California Air Resources Board (1995) Development of an improved inventory of emissions from pleasure craft in California. Report prepared by Systems Applications International, June.

California Air Resources Board (1997a) California emission inventory development and reporting system II. 1995 estimated emissions for Mendocino County. Web site: http://www.arb.ca.gov/ceidars.

California Air Resources Board (1997b) Emission inventory procedural manual, Volume III: Methods for assessing area source emissions., October.

Caltrans (1996) 1995 Traffic volumes on California state highways. Report prepared by the State of California Business, Transportation and Housing Agency Department of Transportation, Division of Traffic Operations, May.

Dye T.S., MacDonald C.P., Roberts P.T., and Kumar N. (1998) The influence of mixing depth evolution on ozone concentrations. *J. Appl. Meteorol.*, (STI-1812), (submitted).

Eisinger D.S., Richards L.W., Higgins T., Lloyd A., and Pierson W. (1998) MAG Brown Cloud Study: control measures to reduce the brown cloud and improve visibility in the Maricopa County area. Draft Working Paper No. 4 prepared for Maricopa Association of Governments, Phoenix, AZ by Sonoma Technology, Inc., Santa Rosa, CA, STI-996345-1776-DWP4, January.

Fujita E.M. and Lawson D.R. (1994) Evaluation of the emissions inventory in the South Coast Air Basin. Final report prepared for California Manufacturers Association, Southern California Air Quality Alliance, Southern California Gas Company, California Aerospace Environmental Association, Hughes Aircraft Company, Southern California Edison, and Anheuser-Busch Corporation by Desert Research Institute, Reno, NV, August.

Fujita E.M., Hayes T.L., McDonald J.D., Sagebiel J.C., Zielinska B., Chow J.C., Watson J.G., and Lawson D.R. (1998) Source apportionment of ambient PM2.5 carbon in the northern front range of Colorado. Paper presented at the *8th CRC On-road Vehicle Emissions Workshop, San Diego, CA, April 20-22.*

Haste T.L., Chinkin L.R., Kumar N., Lurmann F.W., and Hurwitt S.B. (1998a) Use of ambient data collected during IMS95 to evaluate a regional emission inventory for the San Joaquin Valley. Final report prepared for the San Joaquin Valleywide Air Pollution Study Agency, c/o the California Air Resources Board, Sacramento, CA by Sonoma Technology, Inc., Petaluma, CA, STI-997211-1800-FR, July.

Haste T.L., Chinkin L.R., Main H.H., Kumar N., and Roberts P.T. (1998b) Use of PAMS data to evaluate a regional emission inventory in the northeastern United States. Final report prepared for Coordinating Research Council, Atlanta, GA under subcontract to ENVIRON International Corporation, Novato, CA by Sonoma Technology, Inc., Santa Rosa, CA, STI-95424-1737-FR, March.

Hayes T.P., Kinney J., and Wheeler N. (1984) California surface wind climatology. Report prepared by the California Air Resources Board, Aerometric Data Division, Meteorology Section, Sacramento, CA, June.

Korc M.E., Jones C.M., Chinkin L.R., Main H.H., Roberts P.T., and Blanchard C. (1995) Use of PAMS data to evaluate the Texas coast emission inventory. Final report prepared for U.S. Environmental Protection Agency, Research Triangle Park, NC by Sonoma Technology, Inc., Santa Rosa, CA, Work assignment 2-95, EPA Contract No. 68D30020, STI-94520-1558-FR, December.

Lerch V. and Yajima Y. (1993) The California Air Resources Board's emission forecasting system. Report prepared by the California Air Resources Board's Emission Forecasting System, Sacramento, CA, October.

Main H.H., Richards L.W., Chinkin L.R., Evans V.A., Chow J.C., and Divita F. (1995) PM_{10} chemical analysis and source receptor modeling study for the Seattle-Tacoma area. Final report prepared for Puget Sound Air Pollution Control Agency, Seattle, WA by Sonoma Technology, Inc., Santa Rosa, CA, RMI, Novato, CA, and Desert Research Institute, Reno, NV, STI-93140-1444-FR, April.

NESCAUM (1997) Heavy-duty engine emissions in the Northeast. Report prepared by Northeast States for Coordinated Air Use Management, Boston, MA, Michael J. Bradley & Associates, and Michael P. Walsh, ESI, May.

Platt K. (1996) A-55 Limited Partnership, Reno, NV. Personal communication.

Roberts P.T. and Anderson J.A. (1991) Pollutants measured in forest fires and agricultural burn plumes and their potential influence on exceedances on the ozone standard. Paper no. 91-67.10 presented at the *A&WMA 84th Annual Meeting & Exhibition, Vancouver, BC, June 16-21.*

Sagebiel J.C., Zielinska B., Walsh P.A., Chow J.C., Cadle S.H., Mulawa P.A., Knapp K.T., Zweidinger R.B., and Snow R. (1997) PM_{10} exhaust samples collected during IM-240 dynamometer tests of in-service vehicles in Nevada. *Environ. Sci. Technol.* **31**, 76-83.

Seinfeld J.H. and Pandis S.N. (1998) *Atmospheric chemistry and physics: from air pollution to global change*. J. Wiley, New York.

STAPPA and ALAPCO (1996) Controlling particulate matter under the clean air act: a menu of options. Report prepared by State and Territorial Air Pollution Program Administrators, Association of Local Air Pollution Control Officials, Washington, DC, July.

Technology Report (1997) New eco-fuel mixing water, diesel to be on market in 1998, refinery says. *Technology Report.* **28** Published by the Bureau of National Affairs, Inc., Washington D.C., September.

U.S. Environmental Protection Agency (1992a) Prescribed burning background document and technical information document for best available control measures. Report prepared by the Office of Air and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-450/2-92-003, September.

U.S. Environmental Protection Agency (1992b) Technical information document for residential wood combustion best available control measures. Report prepared by the Office of Air and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-450/2-92-002, September.

U.S. Environmental Protection Agency (1993) PM-10 innovative strategies: a sourcebook for PM-10 control programs. Report prepared by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-452/R-93-016, December.

U.S. Environmental Protection Agency (1997) Control of emissions of air pollution from non-road diesel engines. Prepared by the U.S. Environmental Protection Agency, Research Triangle Park, NC, 62 FR 50152, September.