mri **Technical Report**

IMPACT OF INDUSTRIALIZATION OF THE CALIFORNIA DELTA AREA

MRI 77 FR-1484

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SUMMARY

A field study was conducted in August-September, 1976 to investigate the potential effects of industrialization of the Montezuma Hills on downwind air quality. The study consisted of meteorological and air quality observations as well as the release and downwind sampling of tracer material. A total of eight tracer tests were carried out with sampling as far downwind as 50-70 km. The program was a cooperative study conducted by Meteorology Research, Inc. (MRI), California Institute of Technology (CalTech), and the Air Monitoring Center of Rockwell International (AMC).

The principal area of impact interest dealt with the potential formation and transport of oxidants into the Central Valley as a result of emissions at Montezuma Hills. The study was therefore conducted during the summer period when photochemical reactions might be expected. Tracer releases were made at different periods during the day to obtain a sample of the effects of diurnal variations on downwind concentrations.

It was found that the predominant wind pattern at Montezuma Hills (day and night) during the summer is from the west with moderate wind velocities. This pattern carries potential emissions from the site toward and beyond the Lodi-Stockton-Tracy area. Tracer releases from the site showed a consistent pattern within the first 10 km but considerable variation in trajectory occurred thereafter. During the tests conducted, material was observed as far north as Lodi and as far south as Tracy often with considerable variation within a given test. Tracer releases from Pinole and Martinez showed that material from these areas followed two paths, eastward through the Montezuma Hills and southeastward through Concord and into the Livermore Valley.

Substantial hydrocarbon (NMHC) concentrations were found during morning sampling at Carquinez Strait as the result of flow from the San Pablo Bay area. Later in the day it appeared that these concentrations were replaced with cleaner air of a more marine nature. Evidence was obtained of ozone production in this morning air as it passed through and downwind of the Montezuma Hills. At the same time, NO_x concentrations appeared to decrease as a result of dilution.

Significant impact of potential emissions from the Dow site would largely be confined to the immediate downwind areas where NO_x (NO_2) concentrations might be relatively high, assuming rapid conversion from NO to NO_2. In addition, the consistency of the tracer trajectories suggest that these concentrations would be realized in nearly the same location each day.

Summary (Continued)

Estimates were made of possible ozone generation resulting from potential emissions of NMHC at the Montezuma Hills site. These estimates were based on initial NMHC concentration values and results of chamber tests as well as stoichimetric arguments. Two scenarios were considered for the potential ozone formation. One of these was the introduction of emissions from the site during the afternoon when irradiation could occur between the site and the vicinity of Stockton. The second scenario involved the transport of NMHC in fairly large concentrations to the vicinity of Stockton in the early morning hours when stable dispersion conditions existed. Thereafter, the NMHC and NO_x concentrations could be irradiated during the day as the air parcels moved past Stockton and into the Central Valley, diluting with time. In both cases, it appeared that upper bound arguments led to a release rate estimate of 10 tons per day of NMHC at the Montezuma Hills site before a significant impact on ozone (e.g., an increase of 0.01 ppm) in the vicinity of Stockton might occur.

1. Introduction

The combination of an abundant petroleum resource from Alaska, undeveloped river frontage suitable for tanker access, and a ready West Coast petrochemical market all place strong pressure on industrializing that portion of Solano County known as the Montezuma Hills. Although the Dow Chemical Company has withdrawn its plans for the development of a 2,700 acre site on the McOmie Ranch, an impetus to develop the rolling hills from Collinsville to Rio Vista will continue to exist.

Because of the strongly conflicting positions between regulatory agencies charged with safeguarding environmental conditions and socio-economic forces pushing for industrialization, the California Air Resources Board (ARB) commissioned a study whose purpose was stated as follows:

> "Potential industrialization of the Montezuma Hills area has raised significant questions of the possible impact of new emissions on the surrounding areas. The proposed program is intended to provide the answers to some of the questions and to generate appropriate data for the overall assessment of the problem. Specific objectives of the proposed program are to:
>
> - Define the areas likely to be affected by new emission sources in the Montezuma Hills area.
> - Define the relative magnitude of the impact of the new sources upon these areas.
> - Measure the flux of background pollutants into the area and relate to potential new sources."
>
> State of California Air Resources Board
> Item No. 76-11-3bl, Resolution 76-27,
> June 24, 1976

Although the program was designed to develop data on a variety of scales of motion, it was the intent of this study to concentrate on the larger problem of understanding the dispersion climate of the whole region. The regional program was designed to emphasize the trajectory of potential releases at various distances from the source area rather than developing data for "localized" assessment of maximum or worst-case impact prediction. The study area thus encompassed the Bay area, the Delta region of the Sacramento and San Joaquin Rivers, and the Central Valley with the

Montezuma Hills located both geographically and meteorologically almost squarely in the middle of the grid.

The study program was structured into a multifaceted approach that combined the resources of Meteorology Research, Inc. (MRI), California Institute of Technology (CalTech) and the Rockwell Air Monitoring Center (AMC) in a program of data acquisition and analysis to address the foregoing objectives. A four task philosophy was adopted to carry out the program:

Task I - Meteorological Study

> Identify relevant weather regimes, locate important receptor areas, carry out supplemental meteorological measurements, prepare finalized experimental program design

Task II - Tracer Study

> Determine trajectories and dilution factors from the Montezuma Hills, determine location and dispersion from selected source areas in the Bay area

Task III - Flux Study

> Conduct study to determine flux of pollutants crossing Montezuma Hills, relate flux to Bay area sources through trajectory analysis

Task IV - Program Analysis

> Summarize program findings, quantify dispersion under typical and worst-case dilution conditions, determine relative magnitude of Montezuma Hills emissions and relate to existing ambient levels

A variety of approaches were used to address these tasks. In order to best plan the ultimate study, a literature search was conducted and contacts with all persons known to be active in the meteorology/air quality of the area were initiated. This preliminary analysis led to an identification of available data resources to be integrated into the program design. Each data source was then contacted to coordinate their data acquisition activities within the Montezuma Hills study. Groups contacted included two utilities, six air pollution control districts, three districts of the Department of Transportation (Cal Trans), three private environmental consulting firms, two universities, Dow Chemical Company, the Voice of America, the U. S. Coast Guard, and the California ARB.

In order to fill the data void over the Hills and the Delta, four additional mechanical weather stations were deployed early in the program and run through the summer of 1976. The combination of these stations and the coordinated data acquisition efforts of a number of cooperating agencies comprised the baseline meteorological inputs upon which an understanding of local weather phenomena was built. Historical data from the sources were analyzed and a field program was designed based on that understanding.

The field program was carried out in late August to mid September, 1976. A set of eight (8) tracer experiments involving single and multiple tracers was conceived to study the airflow and dispersion over the region. Each experiment was scheduled after a consideration of forecast weather conditions and carried out by the CalTech team following a prerelease conference among CalTech, ARB, and MRI. Subsequent debriefings and minor improvements in the sulfur hexafluoride (SF_6) tracer experiments were then incorporated in later studies. Three (3) pibal teams were deployed during the field study to obtain winds aloft data to aid in the analysis of the tracer/diffusion tests and to provide airflow data for the airborne pollutant flux measurements obtained during the last week of the field program.

The aircraft (an instrumented Cessna 205) was used to obtain measurements of gaseous pollutants, particulates, meteorological variables, and to take instantaneous "grab" samples of SF_6. Evacuated flask samples were also obtained for later gas chromatographic analysis of the hydrocarbon spectrum using cryogenic sample enrichment techniques. Flights were flown on three days for 23.8 hours of flying time to measure the Bay area "urban plume" flux through the Carquinez Strait and Hayward Gap into the San Joaquin Valley.

The principal analysis objectives have included the following goals:

- Characterize the existing environment

- Relate the local microscale phenomena to measured mesoscale parameters

- Relate the 1976 field data to historical (climatological) records

- Extrapolate the summer field program results into an annual cycle of variability

- Estimate typical and worst-case regimes for impact assessment

- Determine the Montezuma Hills background pollutant levels from ground data and airborne flux levels

- Perform an impact analysis of the industrialization of the area

- Compile the appropriate results from CalTech, AMC, MRI, and cooperating agencies into a comprehensive final report and back up data volume

The following report emphasizes the meteorology of the project and utilizes those data from the CalTech and AMC programs which illustrate the meteorological aspects. A more detailed analysis of the tracer and diffusion data are contained in a companion report prepared by the CalTech group (Lamb and Shair, 1977).

2. Meteorological Environment of the California Delta

2.1 General Meteorological Description

The Montezuma Hills lie in a transition zone between the maritime coastal climate to the west and the dry continental climate to the east. Figure 2-1 outlines the study area for this program and points out the dominant role of topography that generally separates the marine influence from California's interior Great Valley. The major entry points for surface air into the Valley are the major break in topography at the north end of San Francisco Bay and the small passes along the Coast Range.

Winds in central California are driven by a combination of synoptic and thermal pressure gradients and steered by the controlling influence of topography. During the warmer months with their associated high potential for stagnation and resulting air pollution episodes, the thermal forces dominate the circulation patterns. As the interior deserts and Valley heat during the summer, a strong thermal gradient develops between the cool marine air along the coast and the hot interior. The Coast Range blocks much of the marine air trying to enter the Valley except near the Sacramento-San Joaquin River entrance into San Pablo Bay. The narrow inlet from Cordelia to Martinez leads to strong winds in summer, often in excess of 20 mph during the afternoon and frequently through the night. By winter, the onshore gradient becomes weaker so that drainage or offshore winds can occasionally penetrate from the Montezuma Hills into the Bay area. Winter is thus characterized by a bimodal distribution of easterly and westerly components that are usually much weaker than the strong summer sea breezes.

As the air passes beyond the Montezuma Hills area during onshore flow it diverges rapidly with a resulting decrease in speed. The coupling of the inflow through the Strait with the predominately northwest-southeast flow along the central valley axis is a complex and variable phenomenon. The flow across the Hills may turn northeasterly toward Sacramento, proceed easterly toward the Sierras or turn southeast into the San Joaquin Valley. Although the sea breeze intrusion into the Valley is well understood in general terms, the smaller scale problems of understanding the effects of sea breeze deceleration and/or nocturnal drainage convergence east of the Montezuma Hills had to be addressed in the present study by detailed mesoscale analyses. These details may contribute significantly to determination of the trajectories of air parcels leaving the Montezuma Hills area.

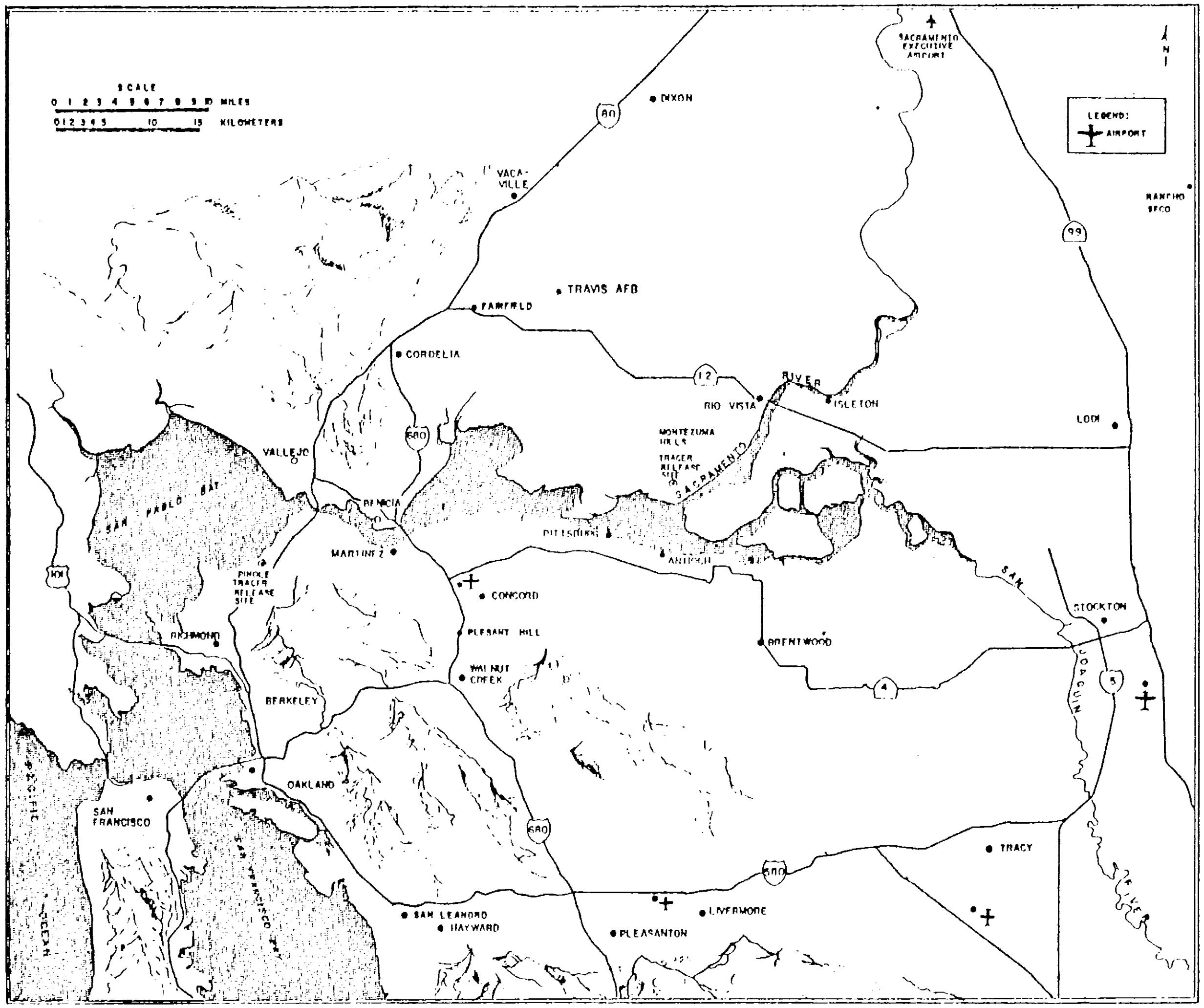

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Figure 2-1

Principal Study Area for Impact of Industrialization of the California Delta Project

Several studies have previously been carried out which provide some information on the meteorological environment of the California Delta. The early studies of flow characterization such as Smalley (1957) concentrated on the Bay area itself. Later works of Frenzel (1962) and Fosberg and Schroeder (1966) provided a detailed analysis of the sea breeze structure as it moves inland. Both studies pointed out the topographic constraints that modify the classical model of the sea breeze circulation as proposed by Defant (1950) and others. Of particular importance were Fosberg and Schroeder's conclusions that the temperature discontinuity (sea breeze front) associated with the onshore flow becomes quasi-stationary around 1100 PST slightly beyond the Carquinez Strait. However, a shear line (kinematic front) continues steadily across the Delta throughout the day as the depth of the onshore flow increases. Although fronts normally imply density differences, it is suggested that the principal density difference remains fixed near the coast while the sea air moves inland and is modified rapidly by surface heating. The kinematic front therefore represents the edge of the sea breeze effect rather than the thermal front farther west. The rapid modification of the marine air as it moves inland thus allows for very warm temperatures in the Montezuma Hills despite an extremely strong onshore wind.

2.2 Montezuma Hills Historical Data

The present program benefited greatly from meteorological data previously acquired by Pacific Gas and Electric (PG&E) at Collinsville, approximately three miles east of the present Dow Chemical Monitoring Station. The data were originally acquired as part of a siting study for a potential power plant at Collinsville. The data covered a time period from July, 1969 to December, 1971 with the highest quality data covering the time period from mid 1970 to the end of the program. PG&E kindly provided the results of their studies in the form of a computer tape of the final data base, listings of the processed hourly observations, and several summaries and analyses contained in Mooney (1971) and Lunn (1972).

Following PG&E's division of the year into a dry season (May through September), a wet season (November through March), and the two transitional months (April and October), the frequency distribution of various wind directions is shown in Figures 2-2 through 2-5. As seen in Figure 2-2, 88 percent of all winds during the dry season were recorded in a 90° sector encompassing the west-southwest, west, west-northwest and northwest directions. The average wind speed was 15.6 mph with 34 percent of all winds in excess of 18 mph. These strong winds are responsible for an unusual phenomenon in the area in that windmills for pumping water are only about 10-15 feet tall. A local rancher supplied the following wisdom -

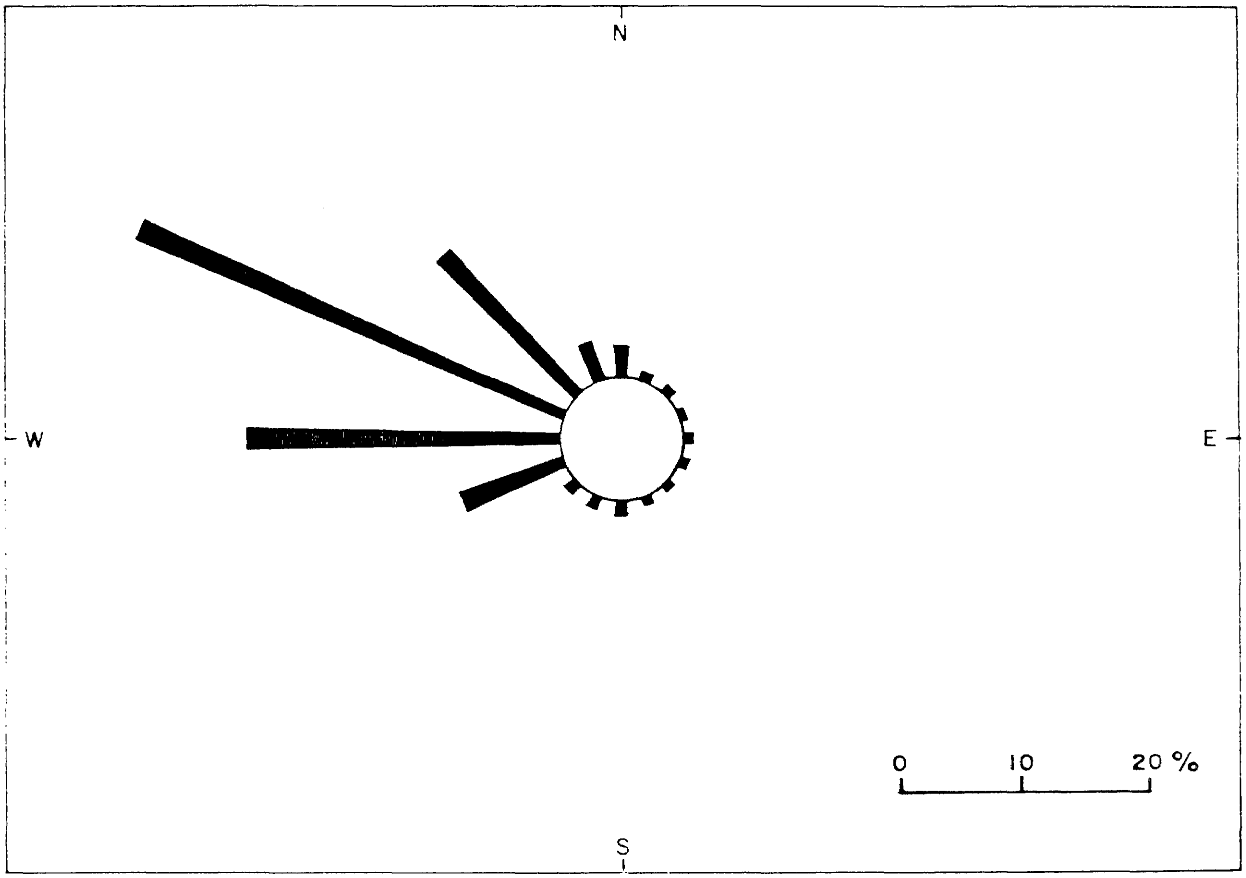


Figure 2-2

Montezuma Hills Dry Season
Wind Direction Frequency
(May-September)

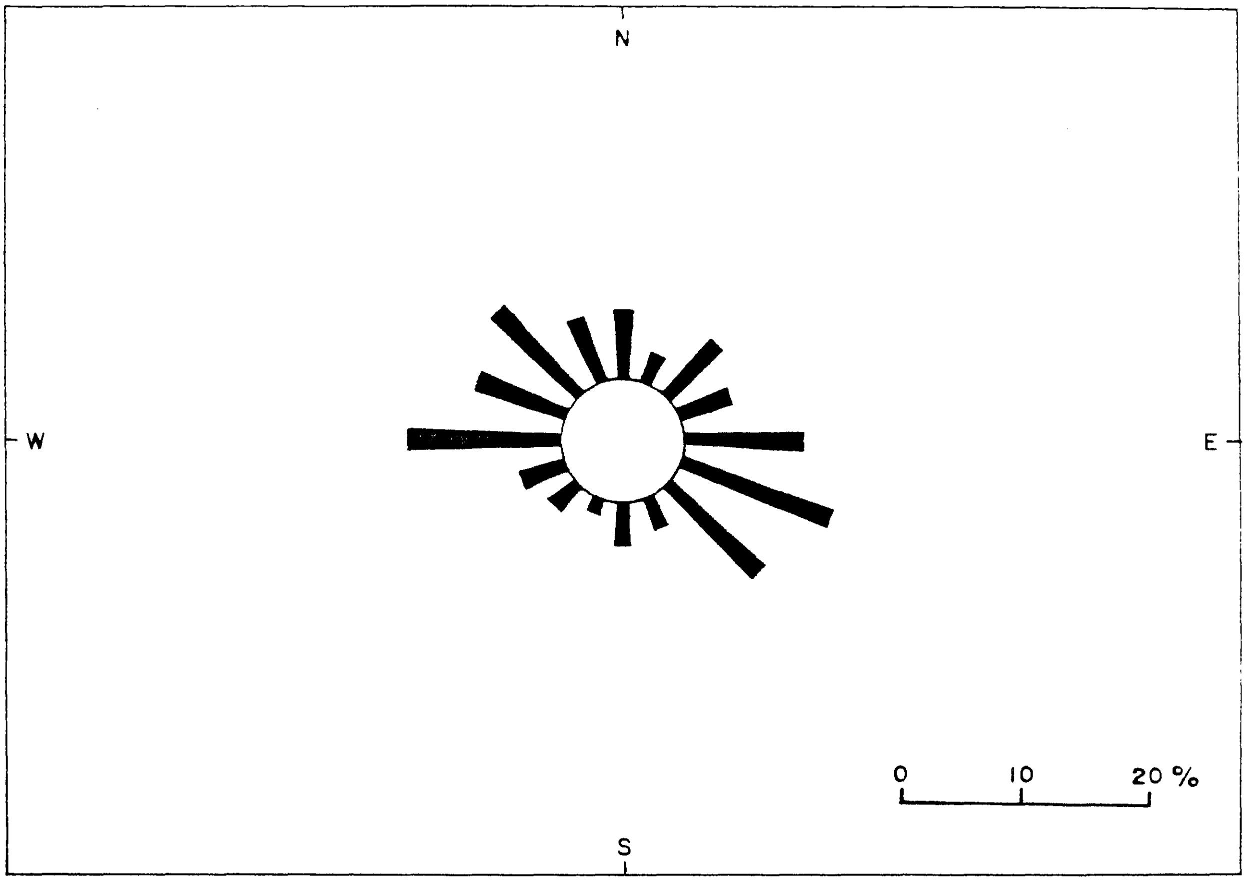


Figure 2-3

Montezuma Hills Wet Season
Wind Direction Frequency
(November-March)

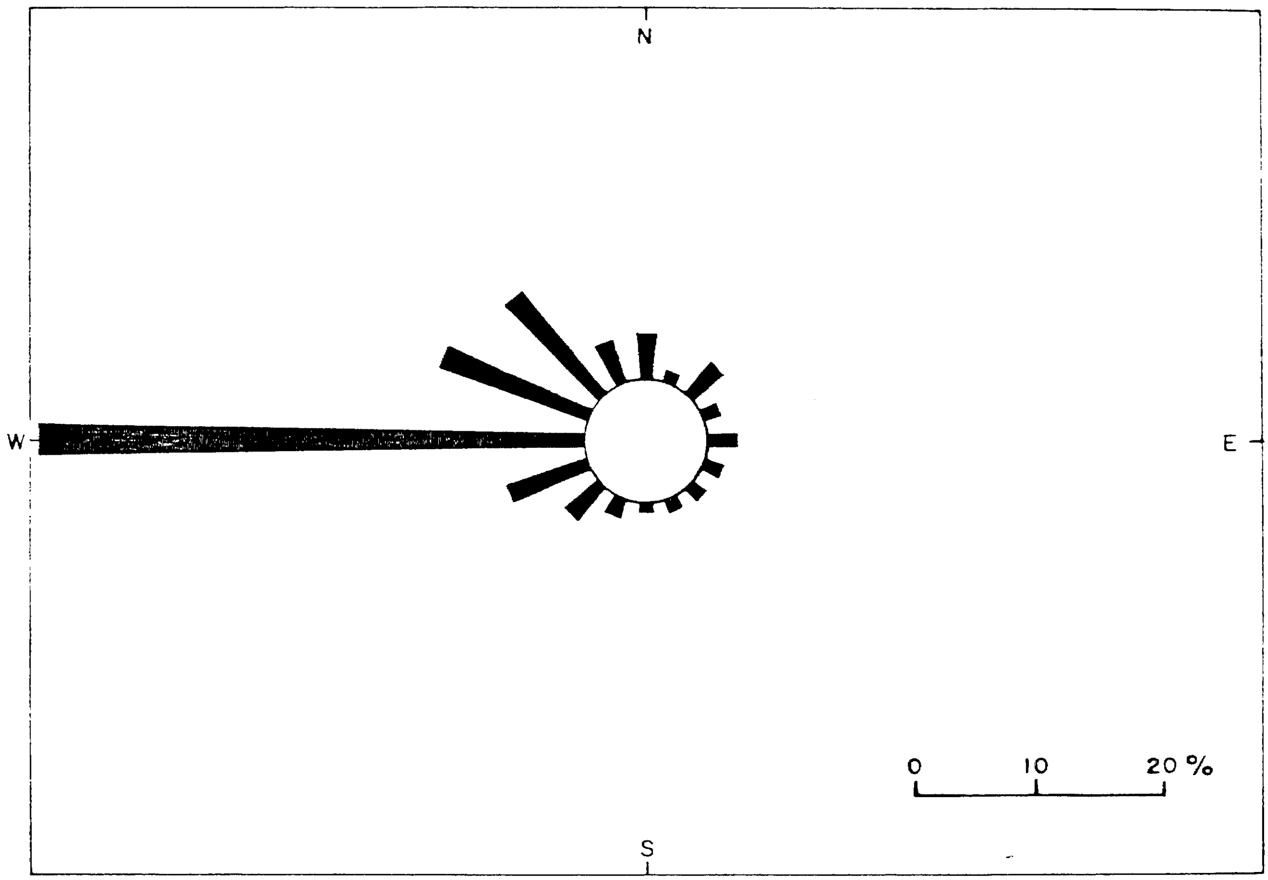


Figure 2-4

Montezuma Hills Transitional
Wind Direction Frequency
(April and October)

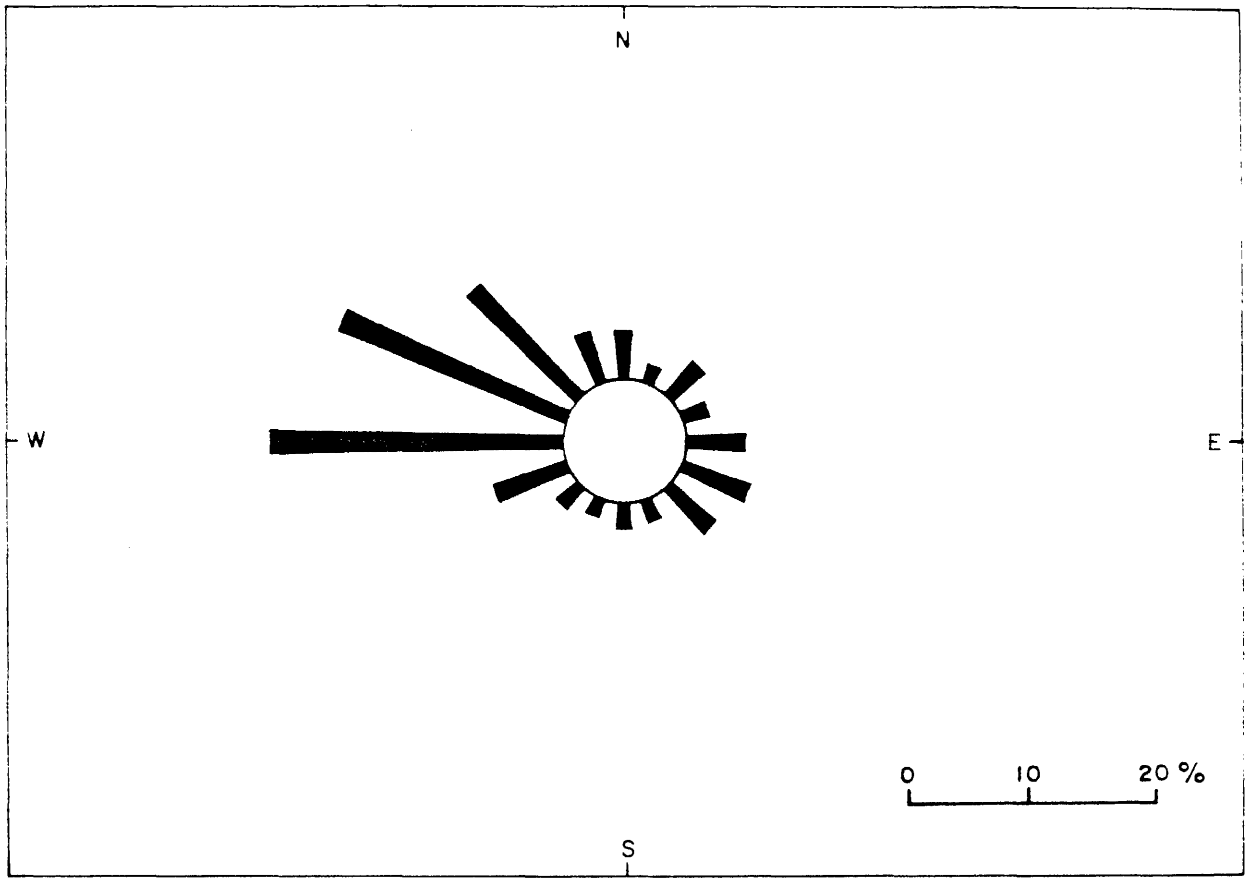


Figure 2-5

Montezuma Hills Annual
Wind Direction Frequency

"If we build them any taller, the wind blows them off their foundations. The only reason we build them as tall as we do is to keep the sheep from getting knocked in the head by the blades."

Figure 2-3 shows the strong reversal of wind direction when the pressure over the interior rises during the cooler months. The wet season is characterized by a bimodal split between the onshore west-northwesterlies and the offshore southeasterly winds. The weakening of the thermally driven pressure gradient is also responsible for the decrease in speed to an average of 7.5 mph with less than six percent of all winds in excess of 18 mph. Winter wind maxima are associated with synoptic features that yield strong onshore pressure gradients funneled by the Carquinez Strait and with extremely strong post-frontal winds blowing from the north or north-northeast.

The transitional period is characterized by westerly winds with intermediate speeds as seen in Figure 2-4. The dominance of westerly winds was heavily weighted by the April 1971 data which indicated westerlies on almost 50 percent of the observations. Later data showed the transitional months to be very similar to the dry season except that average speeds are somewhat less in April and October.

The annual wind rose in Figure 2-5 reflects the dominance of the westerly winds and the general well-ventilated nature of the region. Even with the typical problems involved in low speed wind measurements, the annual wind distribution showed only a 2.7 percent frequency of winds less than 1.5 mph with only 0.2 percent (15 hours per year) reporting calm conditions.

Because of the diurnal nature of inland surface heating and the resulting daily cycle of pressure differences between the coast and the interior, the wind speeds at Montezuma Hills would be expected to show a similar cyclical response. As seen in Figure 2-6, the winds at the Montezuma Hills show unique multiple maxima and minima that are consistent enough from month to month to be considered significant. The wind speeds generally show minima at sunrise, near noon, and near sunset with corresponding intermediate maxima. The figure also shows seasonal variations in average wind speed with highest values occurring in July and August.

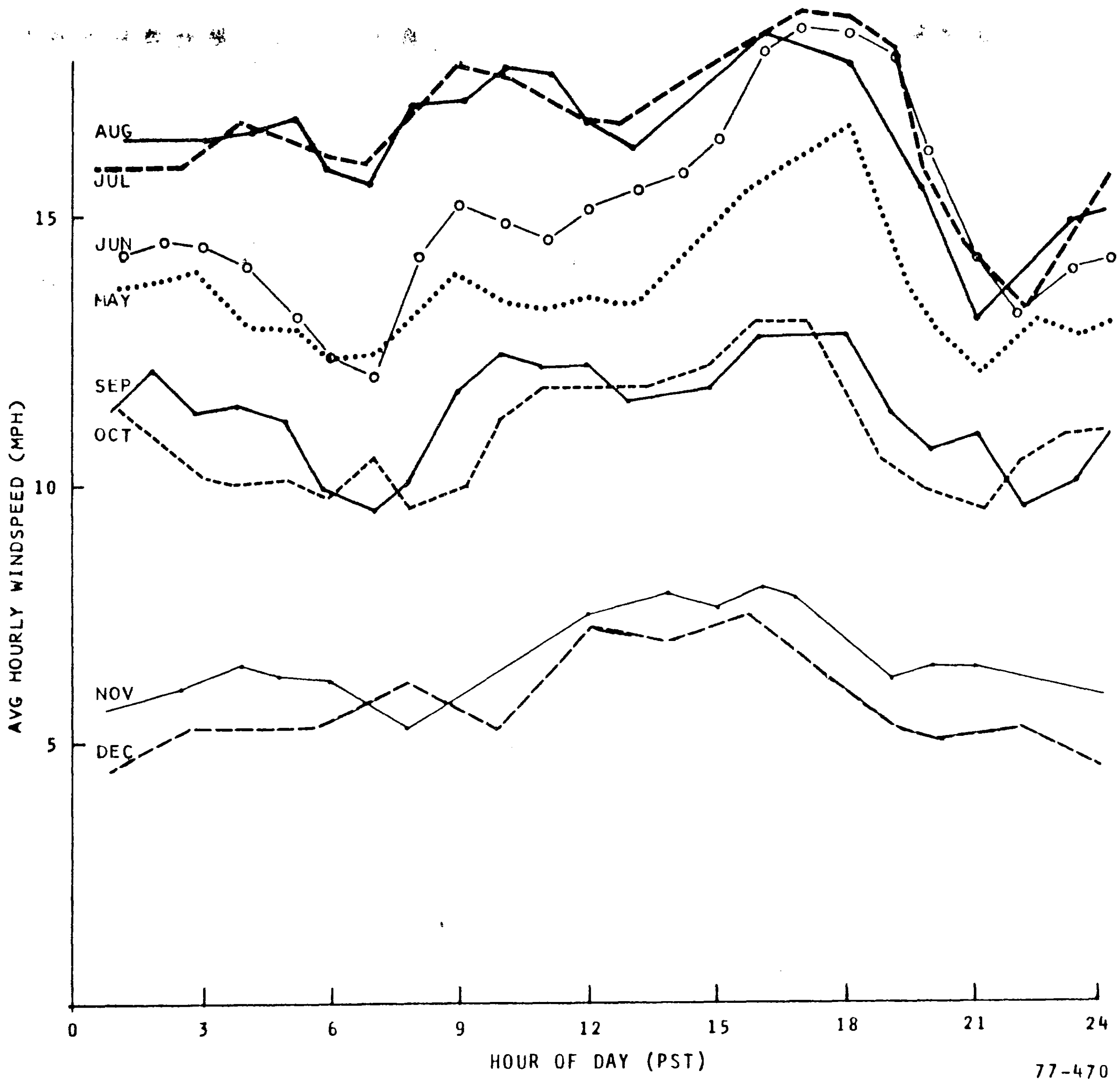


Figure 2-6

Collinsville Diurnal Wind Speed Characteristics

As shown previously, the winds across the Montezuma Hills during the summer are remarkable for their speed and direction persistence. Table 2-1 gives the maximum wind persistence for winds from a given 45° sector (8-point compass). In the extreme, the wind flow was from the western sector for 113 consecutive hours, the corresponding wind driven by the synoptic gradient instead of the thermal gradient persisted for 47 hours in January, 1971. Even when the winds are divided into 22-1/2 degree segments (16-point compass) as shown in Table 2-2, the wind persisted for 48 hours from the same west-northwest sector and for 38 hours from the west under onshore conditions. Another 38 consecutive hours were recorded from the north during post-frontal weather. The implication of such directional persistence is that the same area can be exposed to potential emissions from the Montezuma Hills site for extended periods. Such persistence also does not permit simple time-scaling of short-period, predicted or measured concentrations to longer periods because the wind direction is more persistent than such techniques permit.

In terms of classical diffusion, persistence causing high integrated dosage (cumulative exposure) is important primarily for low wind speeds. Mooney's data summaries showed two occurrences in one year of low wind speed (0-3 mph) persistence of 30 and 33 consecutive hours.

Mooney and Lunn also tabulated a Pasquill stability distribution based on a scaled measurement of sigma-theta, the azimuthal wind angle fluctuation. Because of the pronounced speed changes in the flow divergence over the Delta area, the atmospheric stability is probably strongly spatially inhomogeneous. Nevertheless, Table 2-3 shows a trend toward suppression of large-scale eddies in strong winds (dominance of E Category) at least over the Montezuma Hills area. Considerable spatial variation in diffusion characteristics should be expected as a result of marked gradients in wind speed throughout the area.

2.3 Summer 1976 Supplementary Meteorological Data Program

Supplementary meteorological information for use in planning the late summer intensive field program was acquired by deploying four MRI mechanical weather stations (MWS) early in July near the proposed Dow site and at three locations downwind. The deployment locations of these stations are shown in Figure 2-7. Coupled with the data from the tower at the Dow site and the air quality trailer in Brentwood, the deployment was intended to effectively bracket any trajectories from the Montezuma Hills. The information obtained from the weather stations both confirmed some preconceived ideas about air flow in the Delta as well as providing some new insight into the windfield mechanisms of the area. The prevailing wind directions for each station during the observational period,

Table 2-1

MAXIMUM WIND PERSISTENCE MONTEZUMA HILLS

May 1970 - April 1971

(8-Point Compass)

Direction	No. Hours	Month
N	47	January
NE	14	March
E	14	December
SE	20	December
S	14	March
SW	27	May
W	113	June
NW	23	July

Table 2-2

MAXIMUM WIND PERSISTENCE MONTEZUMA HILLS

May 1970 - April 1971

(16-Point Compass)

Direction	No. Hours	Month
N	38	January
NNE	8	March
NE	14	March
ENE	3	November
E	7	January
ESE	11	December
SE	10	November
SSE	4	February
S	5	December
SSW	5	May
SW	6	October
WSW	18	May
W	38	October
WNW	48	July
NW	15	September
NNW	10	August

Table 2-3

MONTEZUMA HILLS PASQUILL STABILITY CLASS DISTRIBUTION DETERMINED FROM SCALED SIGMA-THETA MEASUREMENTS

Stability Class	Dry Season	Wet Season	Transitional Months	Annual Summary
A	1.9	4.3	6.0	3.7
B	2.0	4.6	3.8	3.4
C	4.3	11.7	6.2	7.8
D	29.5	28.8	30.2	29.3
E	55.8	34.3	46.9	44.9
F and G	6.5	16.3	7.0	10.8

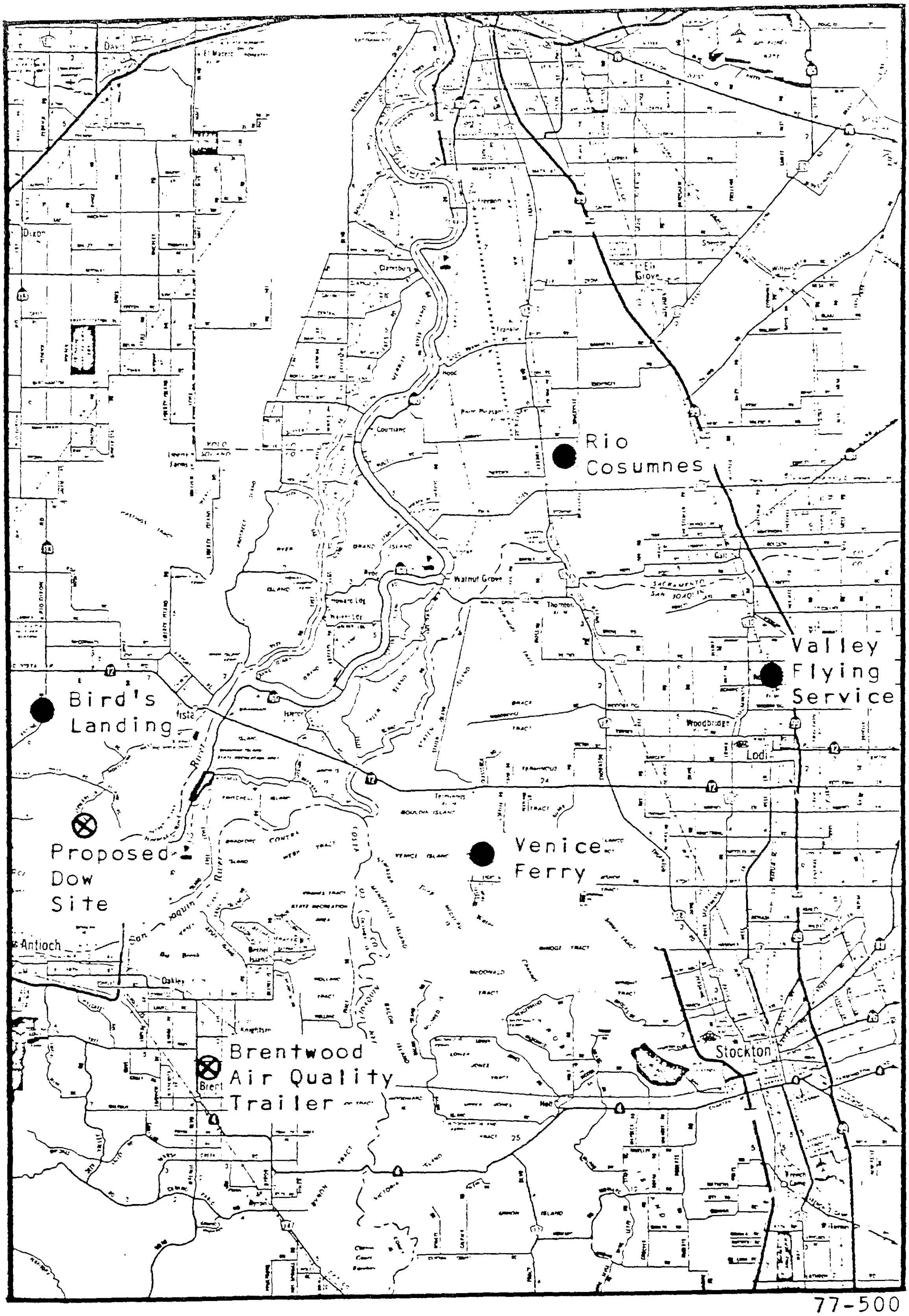


Figure 2-7

Summer 1976 Meteorological Station Deployment

Bird's Landing	-	WSW
Rio Cosumnes	-	SW
Valley Flying Service	-	W
Venice Ferry	-	WNW

well documents the flow divergence downwind of the Hills. The very strong winds at Bird's Landing (average August speed - 18 mph) provide an indication of the width of the high speed "core" of westerlies that influence the Montezuma Hills area. Travis Air Force Base and Pittsburg winds are relatively strong in summer ($\sim$10 mph in the afternoon) but are outside the main core of the westerly flow.

One of the significant results of the wind observations was the extent of penetration of an easterly or northeasterly drainage component in the face of strong, steady westerly winds. Winds at all three Delta stations (Rio Cosumnes, Venice Ferry and Valley Flying Service) at 5-6 am would blow at 2-4 mph from 40-80° while the Bird's Landing winds continued to blow at 15 mph at 250°. Although this drainage penetration did not appear on all nights, it was a frequent summertime phenomenon. Based on the slightly colder temperatures at the Delta stations, it is implied that a convergence zone or nocturnal front forms along a line from Sacramento to Stockton or Brentwood. The sea breeze air must ride up over the drainage component and turn either up or down the Central Valley. During the summer, transport out of the northern end of the Bay area apparently continues throughout the night without the usual stagnation during the early morning hours. With fairly strong winds aloft and a nocturnal jet along the Valley axis during the night, Bay area emissions from one 24-hour period can be effectively carried inland over 200 miles as opposed to the 80-100 mile maximum in the South Coast Air Basin.

3. Air Quality Environment of the California Delta

The area of the California Delta and the Montezuma Hills is characterized by fairly strong pollutant gradients due to the unique meteorological conditions and the geographical distribution of sources. The area lies in the transition zone between the complex pollutant distributions of the Bay area and the far more homogeneous patterns in the Central Valley. Flow convergence in the Carquinez Strait and the subsequent divergence in the Delta lead to unusual features in the pollution patterns.

Because of the complex mechanisms of oxidant formation and since oxidant represents a serious regional air quality problem its distribution in space and time are emphasized in the subsequent discussion.

3.1 Spatial Variability of Oxidant

Figures 3-1 and 3-2 show the major mobile and stationary pollutant sources generally upwind of the Montezuma Hills. Some emissions from these sources are advected into the area by the channeled wind system previously described. Because of a frequent wind component from the north over the Bay area, many of the mobile emissions are carried away from the study area toward the Hayward Gap and the southern half of the Bay area. The pollutants transported into the Collinsville area generally originate in the northern sections of the Bay area. This source area includes much of the heavily industrialized region from Richmond to Antioch along the south shore of San Pablo Bay and the Sacramento River. Small variations in specific source locations appear to have a marked effect on the ultimate trajectory of the pollutants in the Delta area and farther downwind.

While the data density within populated areas of the Bay area APCD (BAAPCD) jurisdiction is quite good, the Montezuma Hills are very poorly characterized by existing data resources. The nearest complete BAAPCD air quality station at Pittsburg was of limited value in defining the ambient air quality in the hills across the river. The oxidant measurements at Fairfield were also not well correlated with measurements in the hills during August-September of 1976. Nevertheless, some basic ideas about the mechanisms responsible for the air quality climate of the Montezuma Hills can be inferred from an analysis of the historical data in the Strait and the Central Valley.

As seen in Figures 3-3, 3-4, and 3-5 for the annual oxidant maxima in 1973-75, the Pittsburg area generally shows an ozone minimum. Typically, Fairfield, Concord, Walnut Creek, Stockton, and Sacramento all have higher annual maxima than Pittsburg. Figure 3-6 shows that Pittsburg

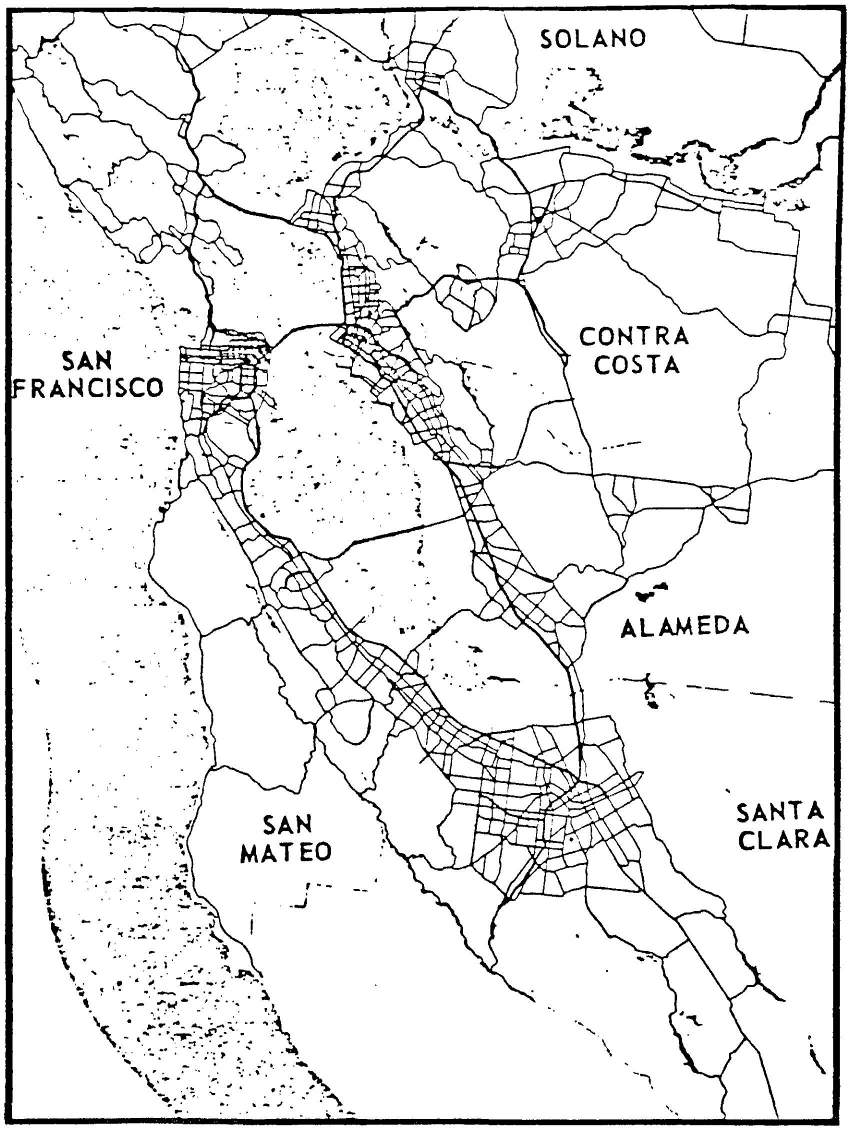


Figure 3-1
Roadway Network in the Bay Area

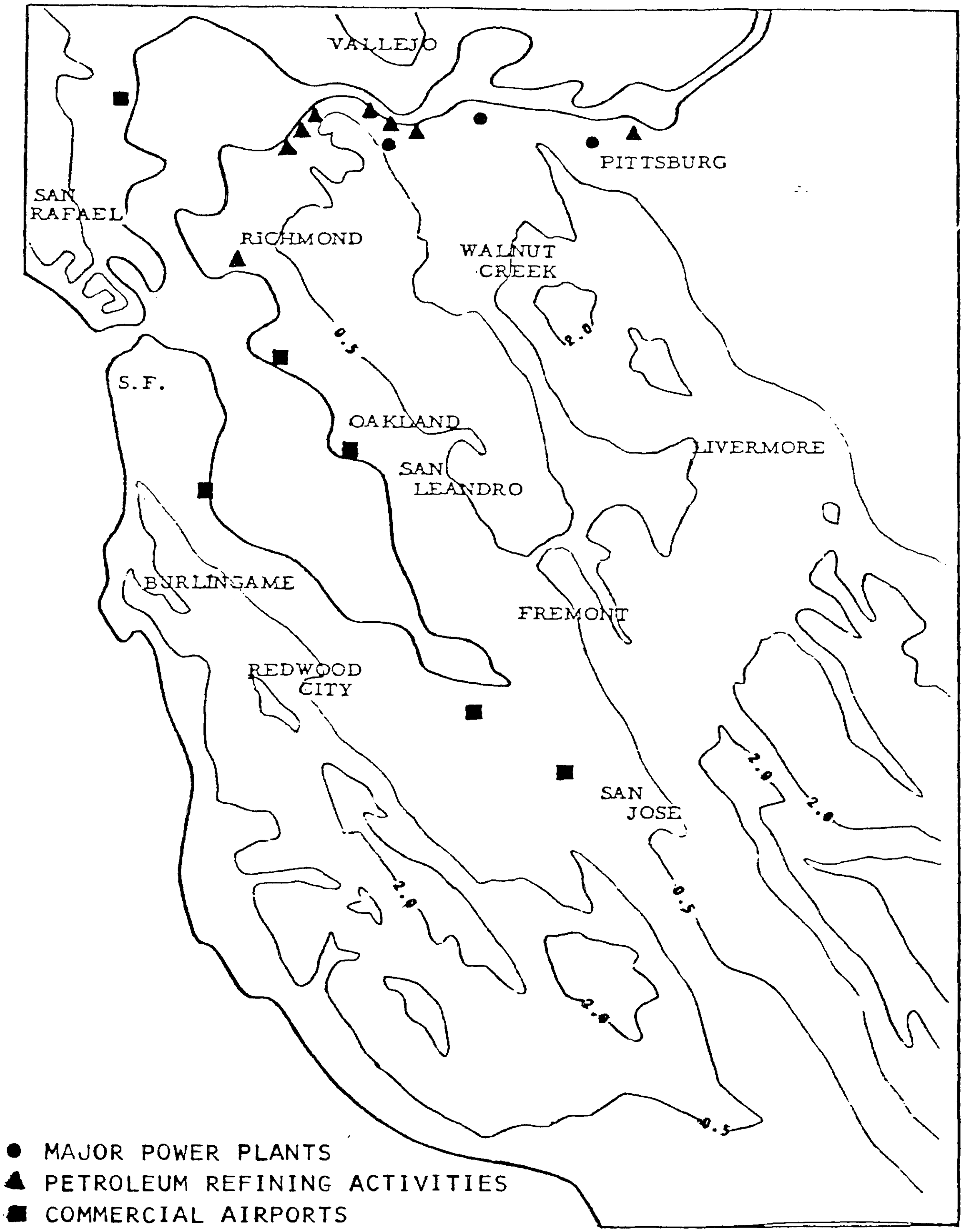


Figure 3-2

Major Point Sources in the Bay Area

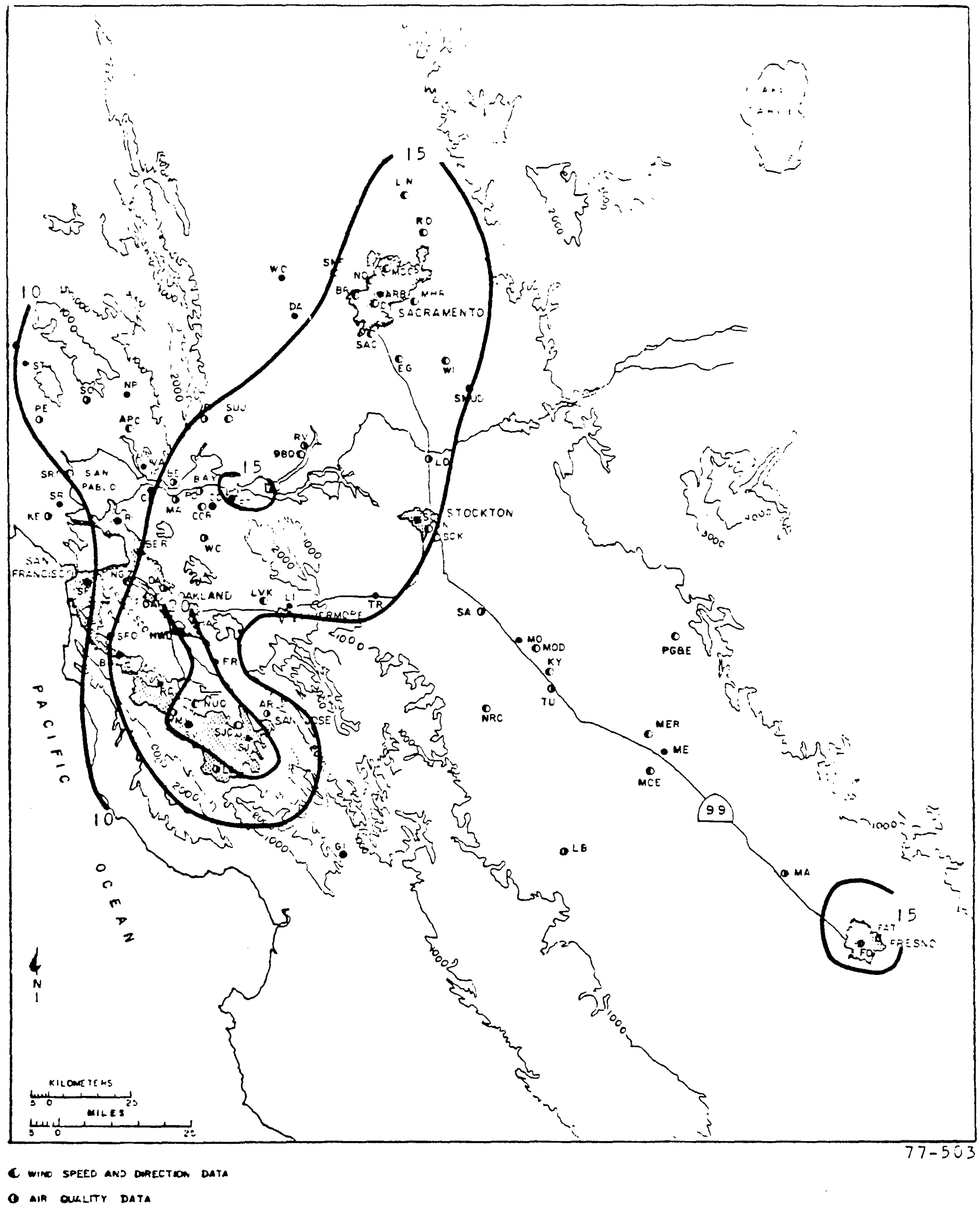
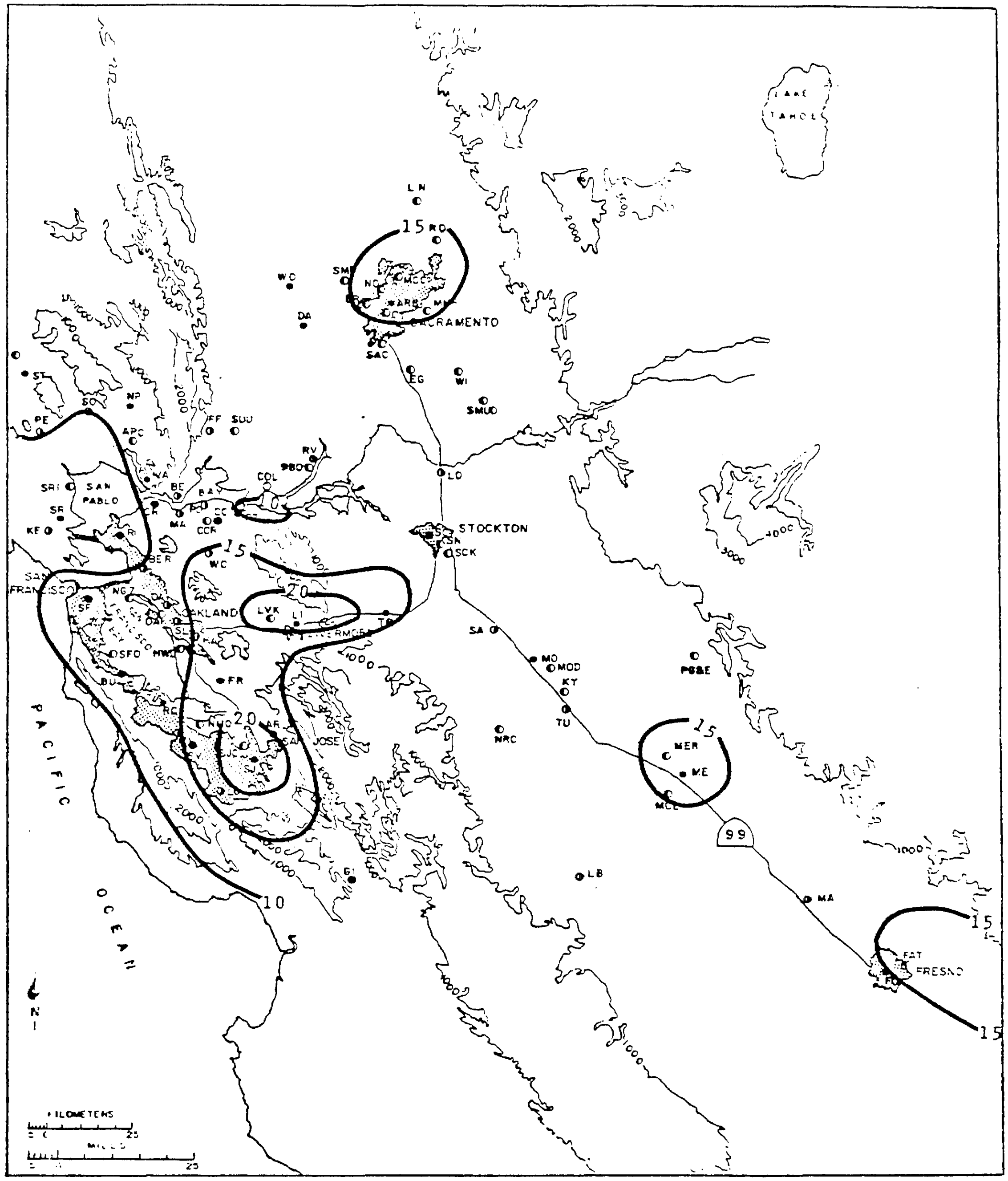


Figure 3-3

1973 Oxidant Maxima (pphm)



- WIND SPEED AND DIRECTION DATA
- AIR QUALITY DATA
- BOTH

Figure 3-4

1974 Oxidant Maxima (pphm)

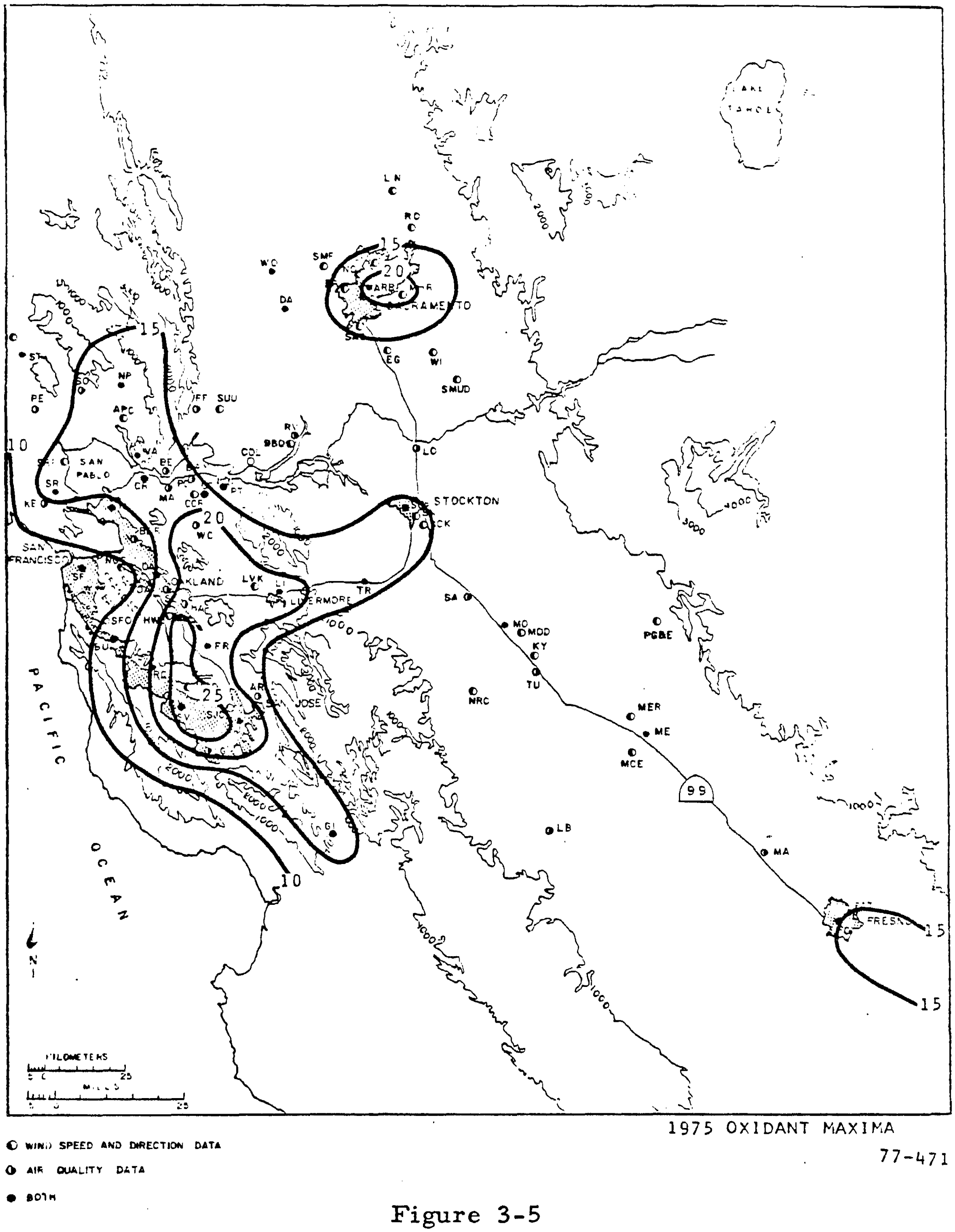


Figure 3-5

1975 Oxidant Maxima (pphm)

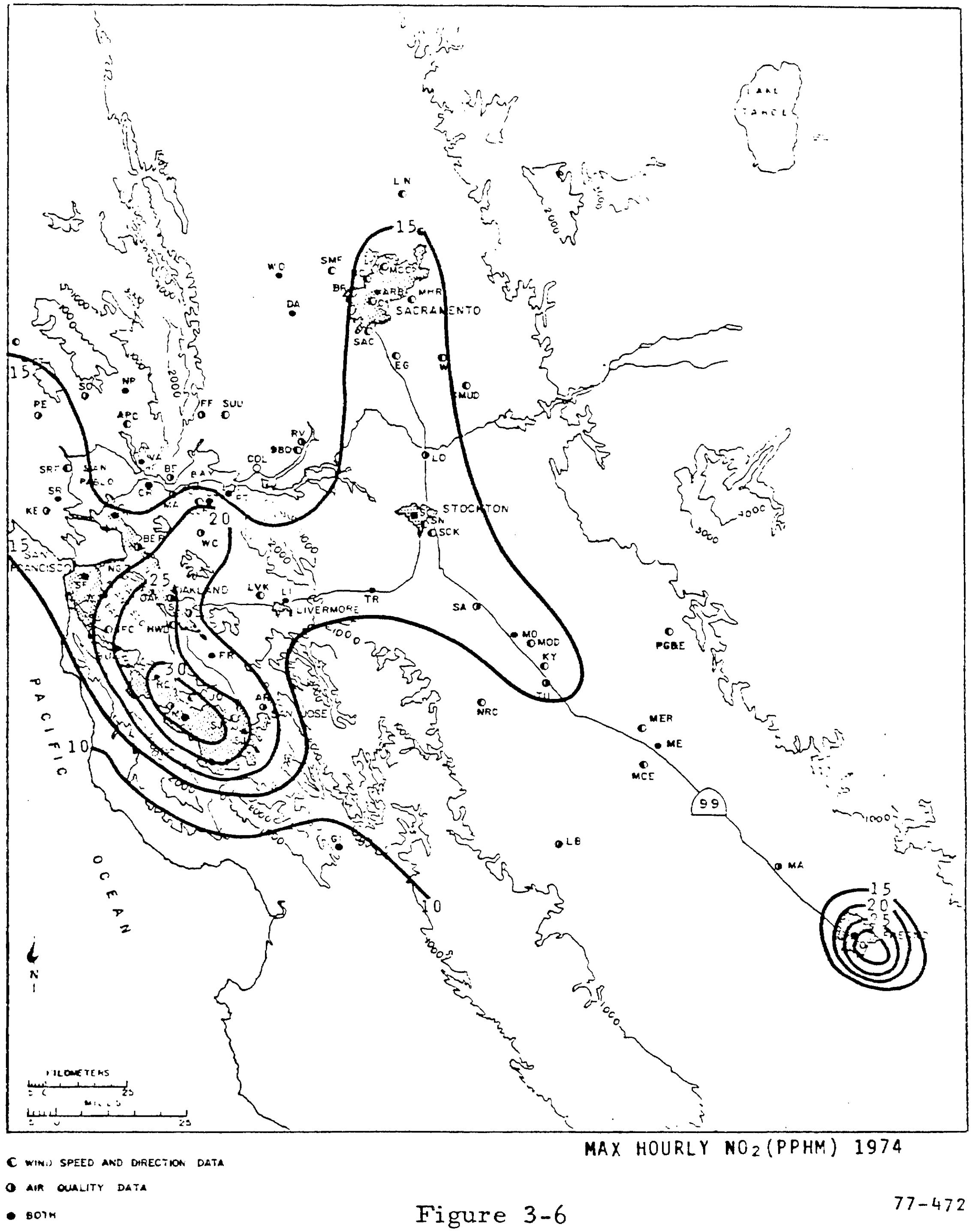


Figure 3-6

1974 Maximum Hourly NO_2 (pphm)

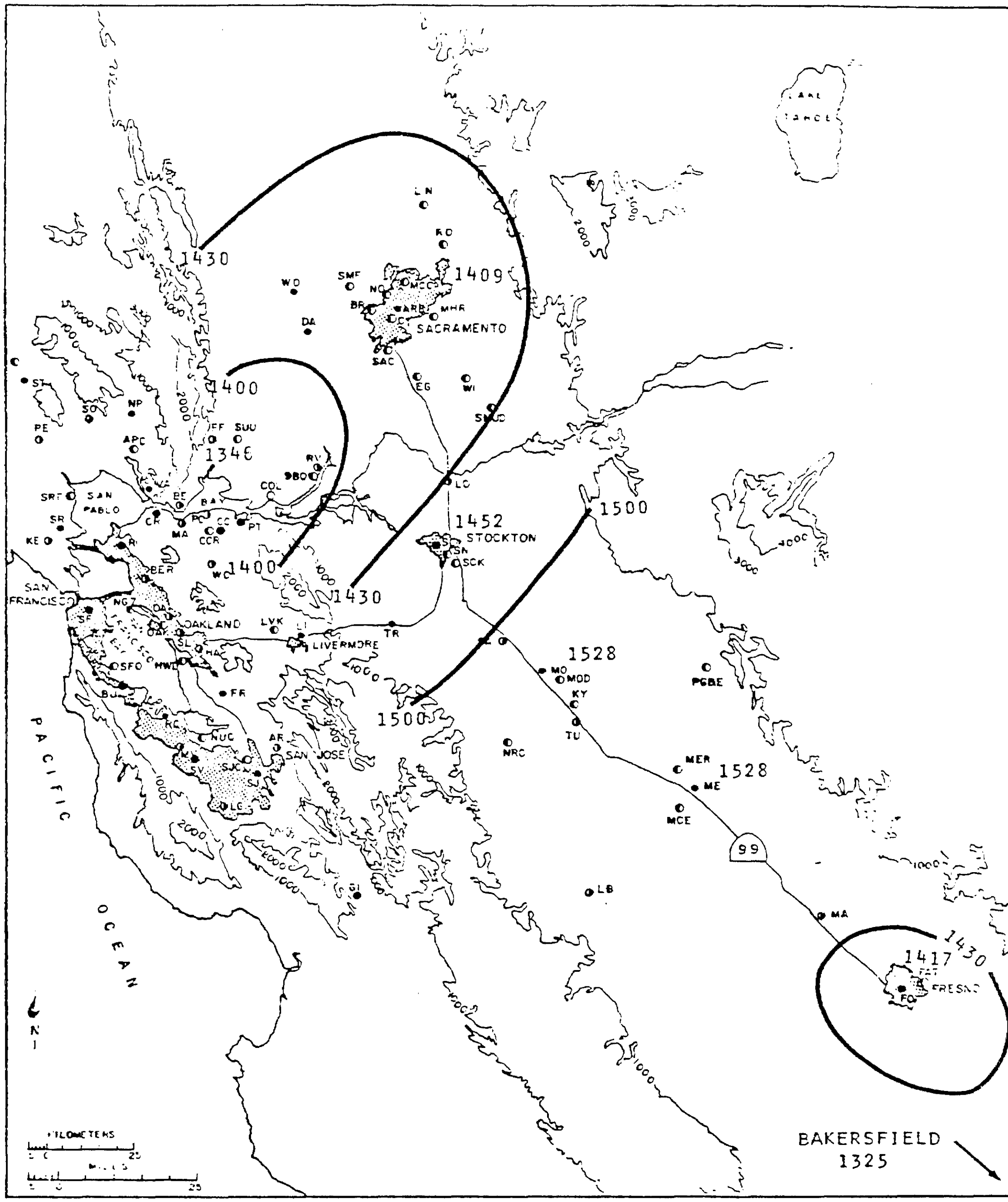
does not experience unusually high localized NO_2 levels that might be indicative of extensive NO-scavenging of ozone. Therefore, it is suggested that meteorological factors such as wind ventilation are probably responsible for the ozone reduction in the area.

3.2 Temporal Variability of Oxidant

Some useful information about pollutant behavior can be obtained from an analysis of the time characteristics of ozone maxima in the Delta and the Valley beyond. Figure 3-7 shows a fairly steady progression of the average time of occurrence of the ozone maximum towards the southeast except for the anomalous situations at Fresno and Bakersfield. Although the timing of the maximum is caused by a combination of both source configuration and ventilation, there are definite indications that the peaks in metropolitan areas such as Fresno and Bakersfield are more locally dominated while the peaks in less populated areas are primarily advected phenomena. A scatter diagram of the time of occurrence of the ozone maximum for Modesto versus Fresno in Figure 3-8 shows that Modesto had no recorded maxima before noon and that the highest concentrations (> 12 pphm) occurred from 1500-1700 PDT. Conversely, Fresno's high maxima (> 12 pphm) occurred from 1100-1500 PDT with a much broader time distribution of daily maxima. The implication is that locally generated emissions in Fresno cause early peaks and advected emissions in Modesto cause much later peaking. The difference between Sacramento (locally-dominated) and Stockton (advection-dominated) in Figure 3-9 is not as dramatic, but certain features parallel the Modesto-Fresno comparison. The daily maxima show that the six highest peak days in Sacramento in 1974 occurred at or before 1400 with the annual maximum at 1100 PDT. The five highest days in Stockton occurred on or after 1500 with the highest annual peak at 1700 PDT.

3.3 Other Criteria Pollutants in the Bay Area/Delta/Central Valley

As shown in Figure 3-6, the 0.25 ppm hourly NO_2 concentration was exceeded in the Bay area and Fresno primarily as a result of motor vehicle activity. Similarly, the 9-hour federal standard of 9.0 ppm carbon monoxide is often exceeded at most San Joaquin Valley stations and in the San Jose and Vallejo areas of the Bay area. In 1974, the CO standard was exceeded on 22 and 21 days at Vallejo and San Jose, respectively, 17 days at Bakersfield and 9 at Stockton. Once Fresno's air quality monitoring site was moved from the courthouse, Fresno also showed a relatively high incidence of CO problems.



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● WIND SPEED AND DIRECTION DATA
○ AIR QUALITY DATA
● BOTH

Figure 3.7

Average Time (PDT) of Occurrence of Oxidant Maximum - Selected Stations, 1974

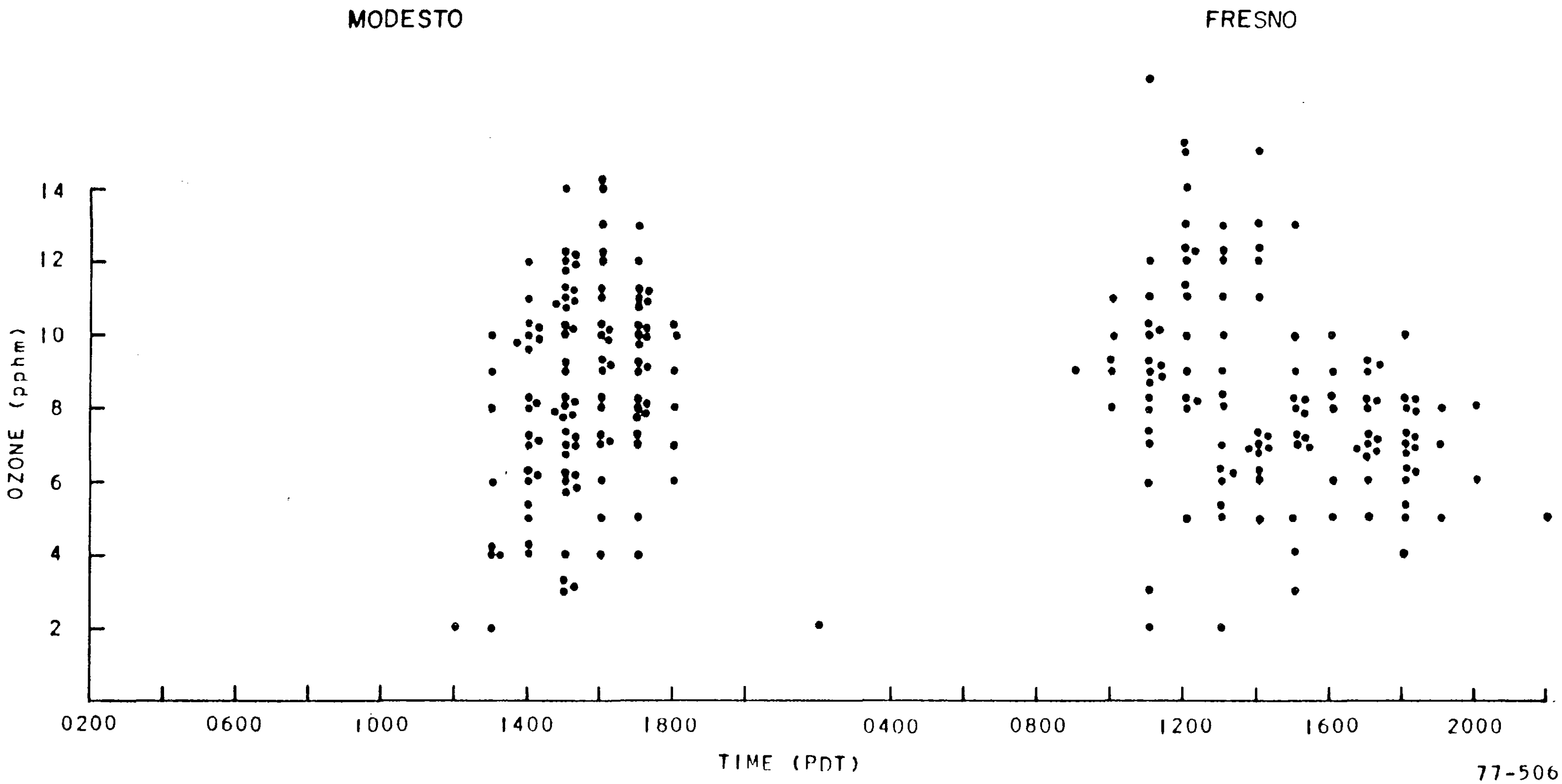

Figure 3-8

Time Variations of Daily Ozone Maxima

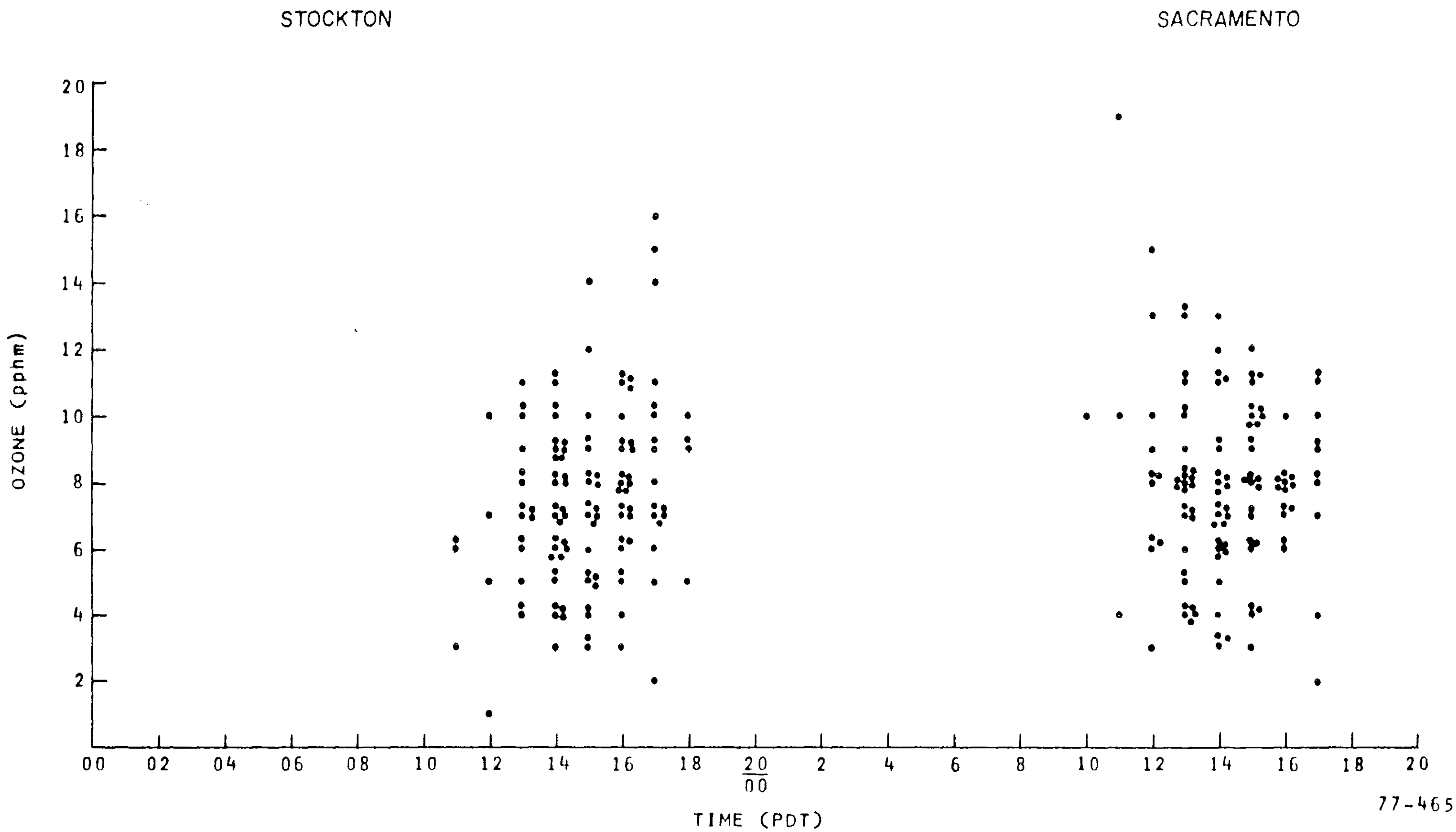

Figure 3-9

Time Variations of Daily Ozone Maxima

As in any dry agricultural environment with restricted ventilation, the total suspended particulate concentration is often quite high. Maxima in excess of 1000 $\mu g/m^3$ have been recorded in the southern San Joaquin Valley at a number of stations. All 24 "regular" measurement locations in the San Joaquin Valley registered particulate emission levels in excess of the 24-hour state standard in 1975 with all but one station showing an annual geometric mean (agm) in excess of the 60 $\mu g/m^3$ agm state standard. The 1975 24-hour maxima were 640 $\mu g/m^3$ agm at Stockton and 470 $\mu g/m^3$ at Visalia. Values in the BAAPCD are not as high, but Pittsburg's 1975 maximum of 180 $\mu g/m^3$ also points out the regional nature of the particulate problem.

As indicated earlier, air quality conditions in the Montezuma Hills area, based on historical considerations, are difficult to estimate in detail as a result of complex interactions of pollutant gradients and meteorological factors.

4. Summer Intensive Study - Operational Summary

In order to meet the specific objectives of the program with regard to characterizing the existing air quality background and defining the impact of the industrialization of the California Delta, an intensive field program was carried out between August 30 and September 15, 1976. The combined resources of MRI, AMC, CalTech, the ARB staff and a number of cooperating agencies were employed in the program. The following sections summarize the observational locations, schedules, and data resources available during the study. Pertinent data have been compiled into supporting data volumes that can be used by other investigators.

4.1 Meteorological Baseline Data

Meteorological data resources are shown on Figure 4-1 and tabulated in Table 4-1 according to the operating agency. Although there may be additional resources not previously identified, every effort was made to include all reliable sources of data that might have been useful for this study. Where station locations were very close together, some data were eliminated to avoid redundancy and expense. Seventy-two meteorological data locations were identified and about 65 were subsequently used in the program analysis.

4.2 Air Quality Data Resources

Air quality data are generally plentiful in the Bay area but only sparse coverage is available in the San Joaquin Valley. To supplement the available data, additional funding was provided to monitor the air quality station and meteorological tower at the Dow site and a mobile site in the maintenance yard of the school district in Brentwood. Although the data density was far lower than the corresponding meteorological data, it provided sufficient continuity to characterize the air quality of the study region. The matrix of stations and their locations are shown in Table 4-2 and Figure 4-2, respectively. Not all parameters are measured at all stations (some are only oxidant or SO_2 stations). Air quality data from 37 locations were incorporated into the study with the primary emphasis on the relationship between the Bay area and the Central Valley in terms of oxidant/ozone. Documentation on the data from the Dow-Collinsville and Brentwood sites is contained in a separate project summary by AMC. Pertinent analyses of the entire data network are contained in subsequent sections of this report.

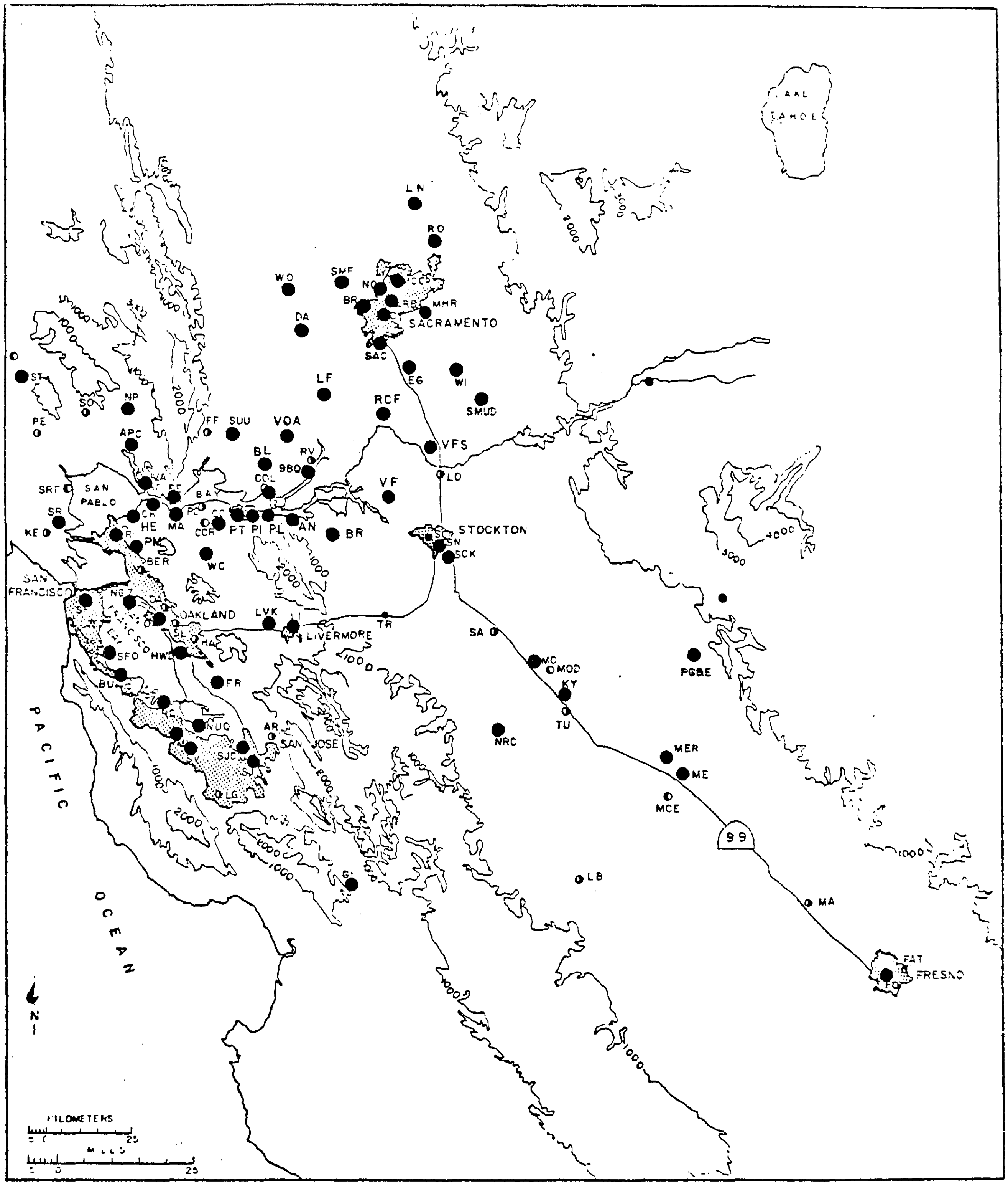

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Figure 4-1

Surface Wind Data Availability During Summer Intensive Study (See Table 4-1 for Location Identifier Key)

Table 4-1

METEOROLOGICAL DATA MATRIX
(Primarily Surface Winds)

Station Name	Location Identifier	Operating Agency*
Concord (Buchanan Field)	CCR	NWS/FAA
Fresno Air Terminal	FAT	NWS/FAA
Oakland International	OAK	NWS/FAA
Sacramento Executive	SAC	NWS/FAA
Sacramento Metropolitan	SMF	NWS/FAA
San Francisco International	SFO	NWS/FAA
San Jose Municipal	SJC	NWS/FAA
Stockton Metropolitan	SCK	NWS/FAA
Hayward Air Terminal	HWD	NWS/FAA
Livermore Municipal	LVK	NWS/FAA
Merced Municipal	MCE	NWS/FAA
Modesto City-County	MOD	NWS/FAA
Napa County	APC	NWS/FAA
Sonoma County-Santa Rosa	STS	NWS/FAA
Castle AFB, Merced	MER	USAF
Mather AFB, Sacramento	MHR	USAF
McClellan AFB, Sacramento	MCC	USAF
Travis AFB, Fairfield	SUU	USAF
NAS Alameda	NGZ	USN
NAS Moffett Fld, Sunnyvale	NUQ	USN
Crow's Landing Navy Auxiliary	NRC	USN
Rio Vista Coast Guard	98Q	USCG
Davis	DA	YSAPCD
Liberty Farms	LF	YSAPCD
Woodland	WO	YSAPCD
Fremont	FR	BAAPCD
Livermore	LI	BAAPCD
Napa	NP	BAAPCD
Pittsburg	PT	BAAPCD
Redwood City	RC	BAAPCD
Richmond	RI	BAAPCD
San Francisco	SF	BAAPCD
San Jose	SJ	BAAPCD
San Rafael	SR	BAAPCD
Santa Rosa	ST	BAAPCD
Vallejo	VA	BAAPCD
Gilroy	GI	BAAPCD
Sunnyvale	SV	BAAPCD
Burlingame	BU	BAAPCD
Concord	CC	BAAPCD
Crocket	CR	BAAPCD
Benicia	BE	BAAPCD
Martinez, Mt. View Sanitary Pl.	MA	BAAPCD
Richmond, Pt. Molate	PM	Cal Trans, SF
Walnut Creek	WC	Cal Trans, SF
Hercules-Collier	HE	SRI
Pittsburg-Loveridge Rd.	PL	SRI
Antioch-Wilbur Avenue	AN	SRI
Stockton-Interstate 5	SN	Cal Trans, SCK
Keyes	KY	Cal Trans
Vallejo	VL	Cal Trans
Bryte	BR	Cal Trans, SAC

Table 4-1 (Continued)

METEOROLOGICAL DATA MATRIX
(Primarily Surface Winds)

Station Name	Location Identifier	Operating Agency*
Transportation Lab	CT	Cal Trans, SAC
Elk Grove CHP Academy	EG	Cal Trans, SAC
Lincoln Airport	LN	Cal Trans, SAC
Roseville	RO	Cal Trans, SAC
Wilton	WI	Cal Trans, SAC
Northgate	NO	Cal Trans, SAC
Stanislaus Nuclear Project	PG&E	PG&E
Pittsburg Power Plant	PI	PG&E
Rancho Seco Nuclear Plant	SMUD	SMUD
Modesto-J Street	MO	ARB
Sacramento ARB Headquarters	ARB	ARB
Merced Trailer	ME	ARB
Stockton-Hazelton Street	SC	ARB
Fresno-Cedar Street	FO	ARB
Voice of America Transmitter	VOA	VOA
Dow-Collinsville Site	COL	DOW
Brentwood Trailer	BR	DOW
Venice Ferry	VF	MRI
Valley Flying Service	VFS	MRI
Rio Cosumnes Correctional Facility	RCF	MRI
Bird's Landing	BL	MRI

* Operating Agency Code:

NWS/FAA	National Weather Service/Federal Aviation Agency
USAF	U.S. Air Force
USN	U.S. Navy
USCG	U.S. Coast Guard
YSAPCD	Yolo Solano County APCD
BAAPCD	Bay Area APCD
Cal Trans, SF	California Department of Transportation, San Francisco Region
SRI	Stanford Research Institute
Cal Trans, SCK	California Department of Transportation, Stockton Region
Cal Trans, SAC	California Department of Transportation, Marysville Region
PG&E	Pacific Gas and Electric
SMUD	Sacramento Municipal Utility District
ARB	California Air Resources Board
VOA	Voice of America
DOW	Dow Chemical Corporation
MRI	Meteorology Research, Inc.

Table 4-2

AIR QUALITY DATA AVAILABILITY MATRIX

Location	Station Identifier	Operating Agency*
San Francisco (Ellis Street)	SF	BAAPCD
San Francisco (23rd Avenue)	SW	BAAPCD
Kentfield	KE	BAAPCD
San Rafael	SR	BAAPCD
Richmond	RI	BAAPCD
Crocket	CR	BAAPCD
Pittsburg	PT	BAAPCD
Martinez	MA	BAAPCD
Benicia	BE	BAAPCD
Concord	CC	BAAPCD
Walnut Creek	WC	BAAPCD
Oakland	OA	BAAPCD
San Leandro	SL	BAAPCD
Hayward	HA	BAAPCD
Fremont	FR	BAAPCD
San Jose	SJ	BAAPCD
Livermore	LI	BAAPCD
Gilroy	GI	BAAPCD
Los Gatos	LG	BAAPCD
Sunnyvale	SV	BAAPCD
Mountain View	MV	BAAPCD
Redwood City	RC	BAAPCD
Burlingame	BU	BAAPCD
Petaluma	PE	BAAPCD
Santa Rosa	ST	BAAPCD
Sonoma	SO	BAAPCD
Napa	NP	BAAPCD
Vallejo	VA	BAAPCD
Fairfield	FA	BAAPCD
Rancho Seco GT	SMUD	SMUD
Dow-Collinsville	COL	DOW
Brentwood	BR	DOW
Woodland	WO	YSAPCD
Davis	DA	YSAPCD
Sacramento	ARB	ARB
Stockton	SN	ARB
Modesto	MO	ARB
Fresno	FO	ARB
Merced Trailer	ME	ARB

*See Table 4-1 for specific identification of operating agency.

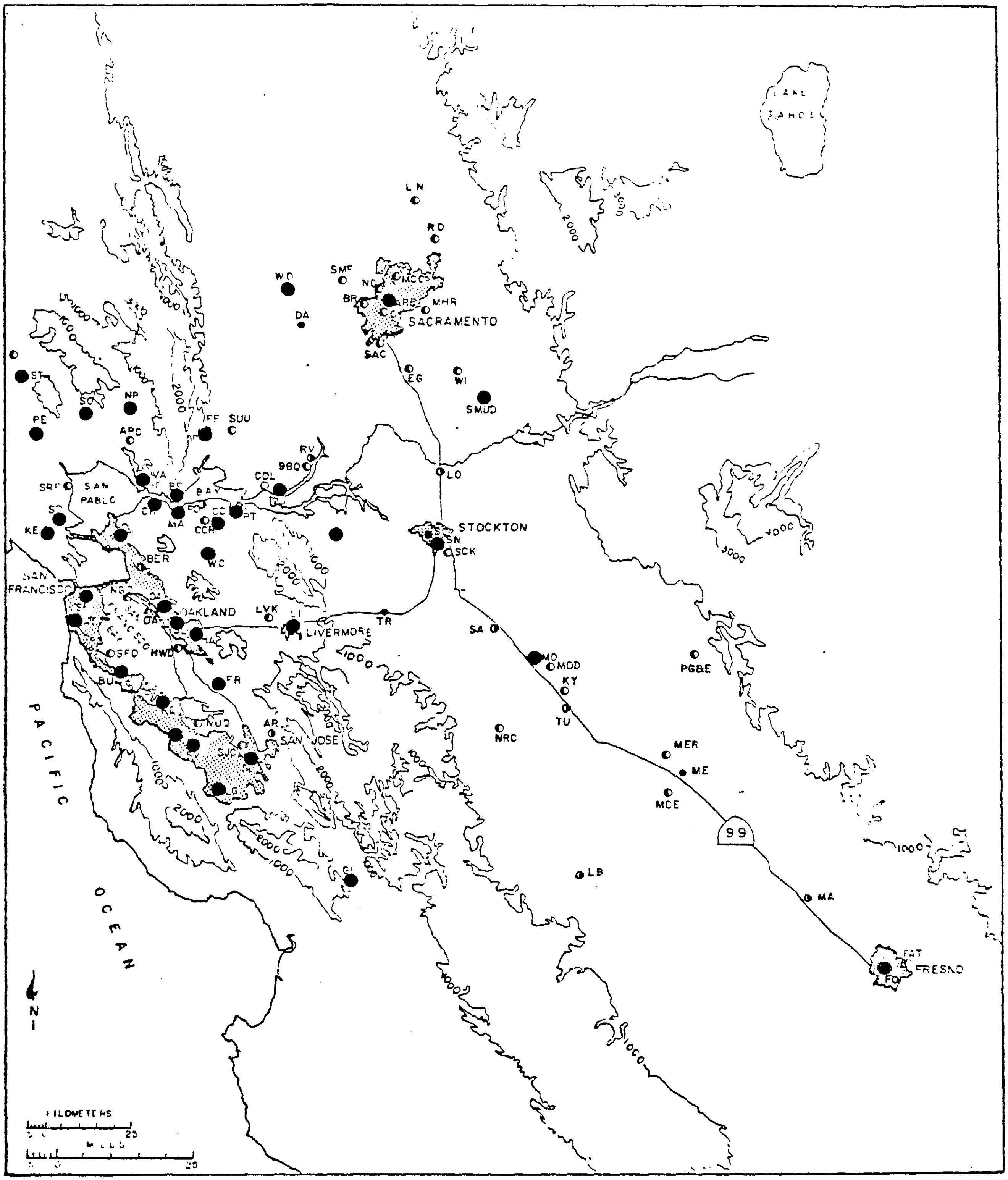

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Figure 4-2

Air Quality Data for Summer Intensive Study

Early morning flights were generally flown close to the Bay area across the Carquinez Strait and through the San Ramon Valley to Livermore. Later flights were flown further downwind after Bay Area-generated precursors had had an opportunity to generate pollutants on their path to the Central Valley. The instrumentation on board the aircraft obtained both continuous pollutant and meteorological data as well as grab samples for later chromatographic analysis. The instrumentation on the Cessna 205 is shown in Table 4-4. Hydrocarbon samples were taken in evacuated stainless steel tanks for analysis by Dr. Rei Rasmussen at his laboratory at Washington State University. Tracer gas samples were taken in labeled syringes and transferred to the CalTech team during refueling stops between sampling missions.

A sampling summary of the nine flights on three sampling days (September 10, 13, and 14) is shown in Table 4-5. Sampling patterns during these flights included broad-reach horizontal traverses and vertical spirals over designated points. Traverse altitudes were selected to both maximize the information content and still be consistent with aircraft safety. Generally three sampling altitudes were chosen. One flight was typically near the top of the mixed layer, one flight as low as safety permitted, and one altitude half way between the first two. Spirals were generally flown at the beginning and end of each set of traverses. Spirals were often flown over airports to allow for structure measurements to ground level. Instrument calibrations were performed both in the field and at the beginning and end of the sampling program using NBS-traceable standard calibration gases. Data were recorded on a magnetic tape cassette data logging system and subsequently transferred to permanent archive on 1/2-inch computer tape. Traverse and spiral pollutant plots are summarized in an aircraft data volume and the flux analysis is contained in a subsequent chapter.

4.5 Vertical Structure Data

Efforts to obtain a three-dimensional representation of conditions aloft were made through pilot balloon (pibal) soundings at several locations in the study area and by integrating the limited temperature sounding data at Oakland, Sacramento, and MRI's aircraft into the program analysis.

Temperature measurements are routinely made at Sacramento with an instrumented aircraft under Cal Trans contract at about 0600 PDT for mixing layer and pollution forecasts. Radiosonde ascents from Oakland were made twice per day at 0500 and 1700 PDT. Given the complex nature of the inversion and mixing depth over the Bay area, such few data points are hardly sufficient, but little more is available. A network of

Table 4-4

CESSNA 205 INSTRUMENTATION

O_3	REM Model 612 Ozone Monitor
NO, NO_x	Monitor Labs Model 8440 Nitrogen Oxides Analyzer
SO_2	Theta Sensors Model LS-400 SO_2 Monitor
b_{scat}	MRI Model 1550B Integrating Nephelometer
Dew Point	EG&G Model 137 Dew Point Hygrometer
Temperature Pressure (altitude) Indicated Airspeed Turbulence	MRI Airborne Instrument Package

Table 4-5

MRI AIRBORNE SAMPLING SUMMARY

Date	Start	Stop	Flight Hours	Sampling Routes	Number of Hydrocarbon Samples	Tracer Samples: Release Site	Tracer Samples: Material	Tracer Samples: Number of Samples
9/10/76	0859	1335	4.6	Vacaville - Tracy	2	Montezuma Hills	SF_6	217
				Tracy - Lodi		Montezuma Hills	SF_6	34
	1535	1811	2.6	Cordelia - Pleasanton	1	---	---	---
9/13/76	0659	1024	3.4	Cordelia - Walnut Creek	2	Pinole	SF_6	354
	1241	1605	3.4	Vacaville - Tracy	2	Pinole	SF_6	325
						Montezuma Hills	$CBrF_3$	
	1722	1931	2.2	Livermore - Tracy -	1	Pinole	SF_6	123
				Stockton - Sacramento - Vacaville		Montezuma Hills	$CBrF_3$	
9/14/76	0717	0748	0.5	Spiral over Concord	0	---	---	---
	0817	1100	2.7	Cordelia - Walnut Creek	2	Pinole	SF_6	374
	1312	1613	3.0	Vacaville - Tracy	1	---	---	---
	1654	1817	1.4	Tracy - Stockton - Sacramento	2	---	---	---
	TOTALS		23.8		13			1427

acoustic sounders was operated by the Stanford Research Institute (SRI) for the ARB. Data from the network proved to be of only limited value since the primary concern of the program was in the Central Valley.

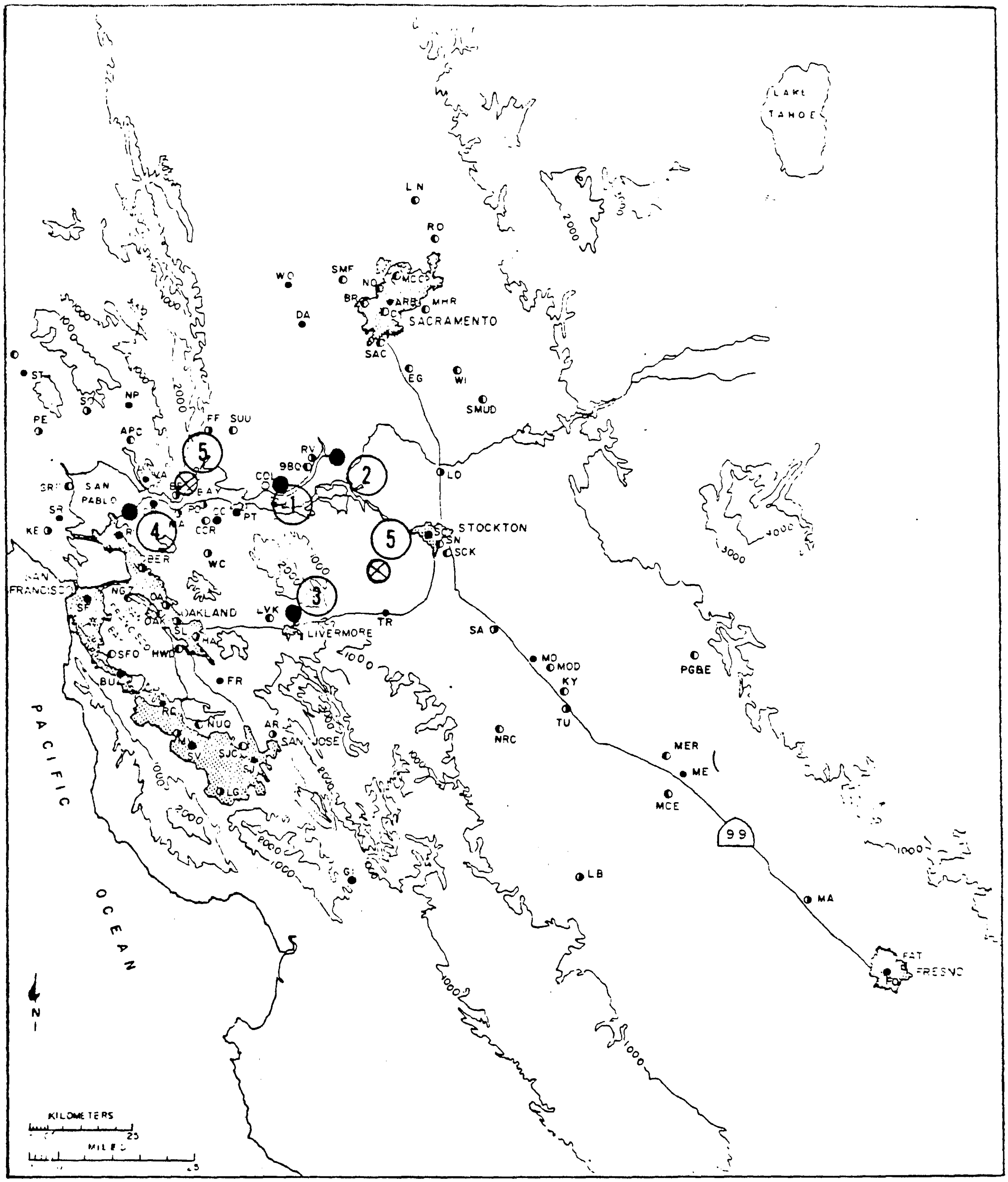
Pibal data were obtained throughout the intensive study period on an hourly basis during tracer releases and on a less frequent schedule on nonrelease days. The pibal data matrix is shown in Table 4-6 with the station location identified in Figure 4-3. A total of 221 pibal soundings were made and the relationship between the windfield in the vertical and the dispersion of Delta emissions is included in subsequent analyses.

Table 4-6

PIBAL DATA MATRIX - MONTEZUMA HILLS STUDY

Date	Pibal Release Site				
	Dow = 1	B&W = 2	Livermore = 3	Pinole = 4	Other = 5
8/31/76	1125-1700 (7)	1000-1745 (8)	1000-1800 (9)		
9/1/76	0930-1730 (6)	0940-1700 (5)	0900-1700 (5)		
9/2/76	0945-1710 (8)	1000-1755 (9)	0900-1000 (2)		
9/3/76	-	-	-		
9/4/76	1720-2300 (7)	1800-1900 (2)	-		
9/5/76	0000-0500 (6)	0000-0600 (6)	-		
9/6/76	1640-2300 (7)	1620-0000 (9)	-		
9/7/76	1350-1745 (3)	-	-		
9/8/76	-	1000-1700 (4)	0920-1700 (5)	-	
9/9/76	1120-1405 (4)	1000-1400 (4)	0920-1855 (11)		
9/10/76	0730-1200 (5)	0800-1900 (12)	1055-1750 (8)		1430 (1)
9/11/76	-	-	-		
9/12/76	-	-	0900-1700 (5)		
9/13/76	0730-1705 (10)	-	0800-1800 (11)	0630-1600 (11)	
9/14/76	0800-1605 (7)	-	0800-1500 (8)	0630-1700 (12)	1630-1900 (4)
Total Pibals	70	59	64	23	5

Key: $\frac{\text{xxxx - xxxx}}{\text{(x)}} = \frac{\text{Time Span (PDT)}}{\text{Number of Pibals}}$



REGULAR SAMPLING SITES
SPECIAL SAMPLING SITES

77-504

Figure 4-3

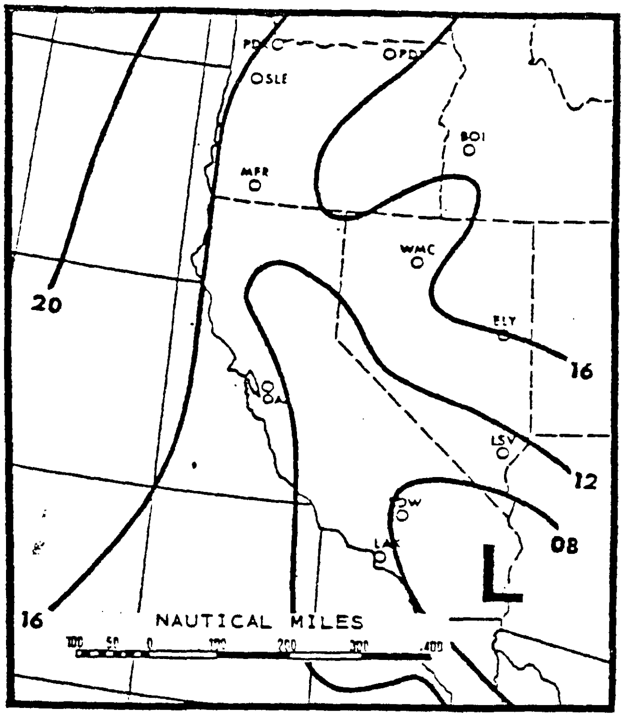
Pilot Balloon (Pibal) Sampling Locations During Summer Intensive Study
(Pibal Release Sites Labeled in Table 4-6)

5. Summer Intensive Study Results

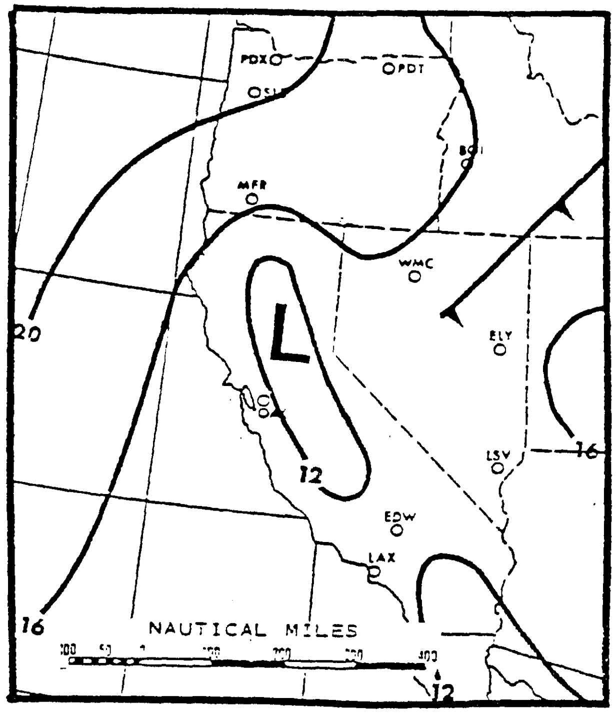
5.1 Synoptic Summary

The general large scale synoptic weather features and resultant local characteristics which affected the California Delta region during the Summer Field Program of 1976 are described below. Synoptic surface weather maps taken from published National Weather Service (NWS) analyses are included in Figures 5-1 and 5-2. The charts presented show pressure configuration in the form of isobars drawn for every 4 millibars, and associated high or low pressure centers. In addition, surface frontal systems are depicted using the standard graphical representations. The time for each map corresponds as closely as possible to the period during which tracer tests were being run. The entire 17 day period itself is broken down into short two or three day periods containing similar characteristics. The basic "marine layer" structure and 850 mb temperature characteristics are based on radiosonde data taken twice daily (0500 PDT and 1700 PDT) by the NWS at Oakland. Additional "mixing layer" information was incorporated when possible from sources such as the daily morning (0700 PDT) Cal Trans aircraft soundings at Sacramento, the MRI aircraft soundings in the Delta area taken on the 10th, 13th, and 15th, and pilot balloon data obtained during tracer test periods. Local sky weather and surface temperature conditions were obtained from hourly surface weather observations taken at NWS sites such as Stockton. Pressure tendency characteristics were derived using sea level pressure readings at NWS stations at San Francisco International Airport, Sacramento Executive Airport, Red Bluff, Reno, and Castle Air Force Base near Merced.

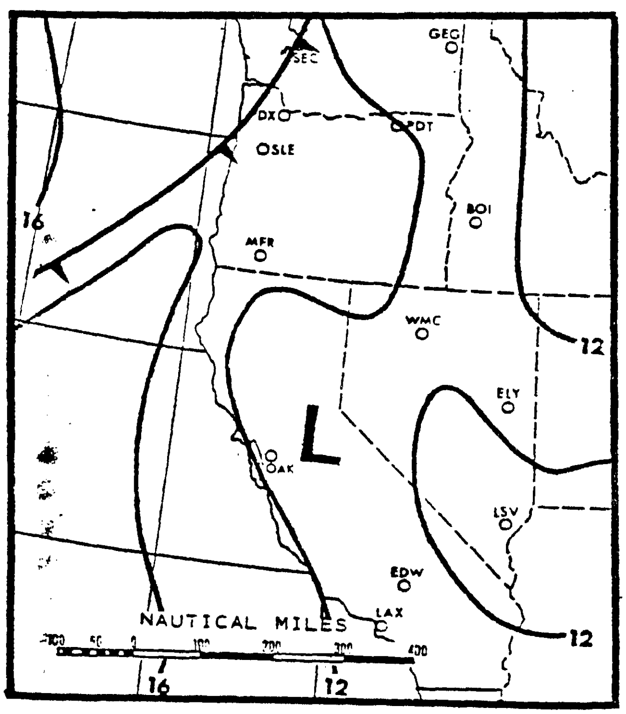
30, 31 August 1976: The surface weather map during this period was characterized by an extension of high pressure across the Pacific Northwest into Idaho and southward toward Wyoming and Colorado. At the same time, thermally-induced low pressure in Southern California encouraged a pressure gradient in the Delta area which favored air movement down the Central Valley yielding northerly winds in Sacramento and the Delta. There was considerable warm air aloft in the area as evidenced by very high 850 mb temperature readings. The "marine layer" remained very shallow while extreme surface heating caused the mixing layer in the Valley to break through the marine inversion during the afternoon of the 31st. Surface temperatures ranged from the mid-sixties (°F) during the early mornings to over 100°F during the afternoons. Skies remained cloudless during both days.



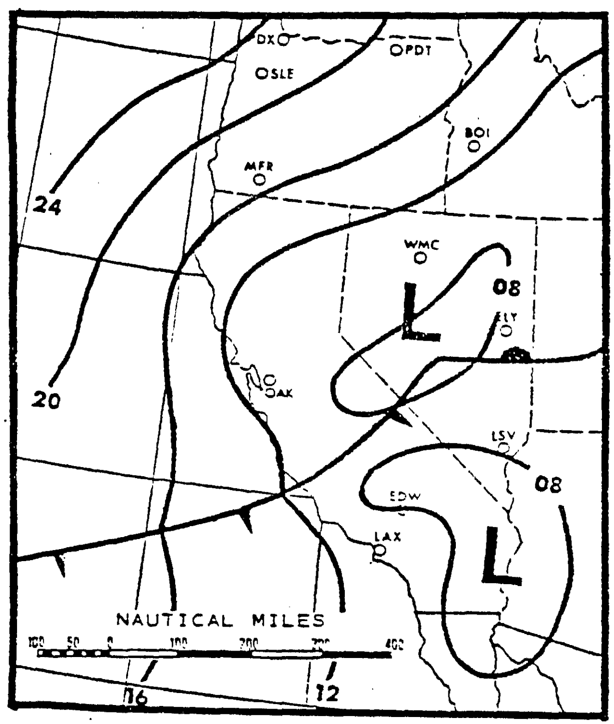
31 August 1976/1700 PDT



2 September 1976/1100 PDT



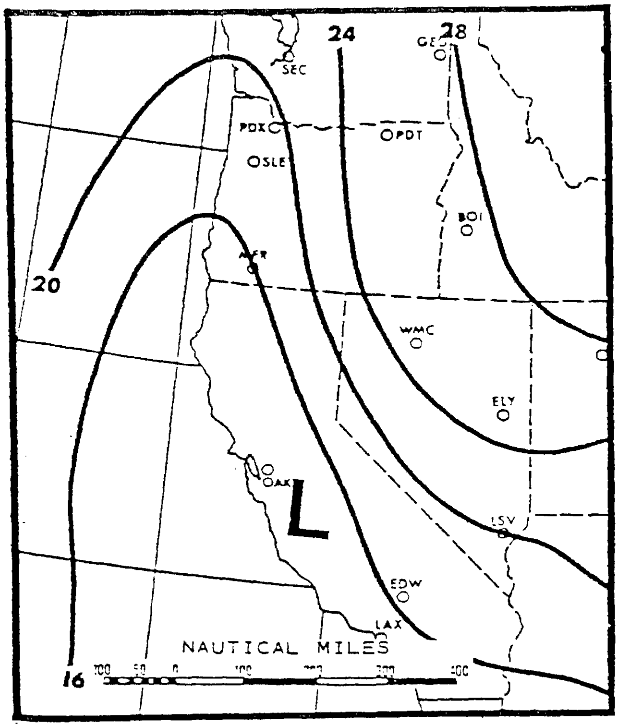
5 September 1976/0500 PDT



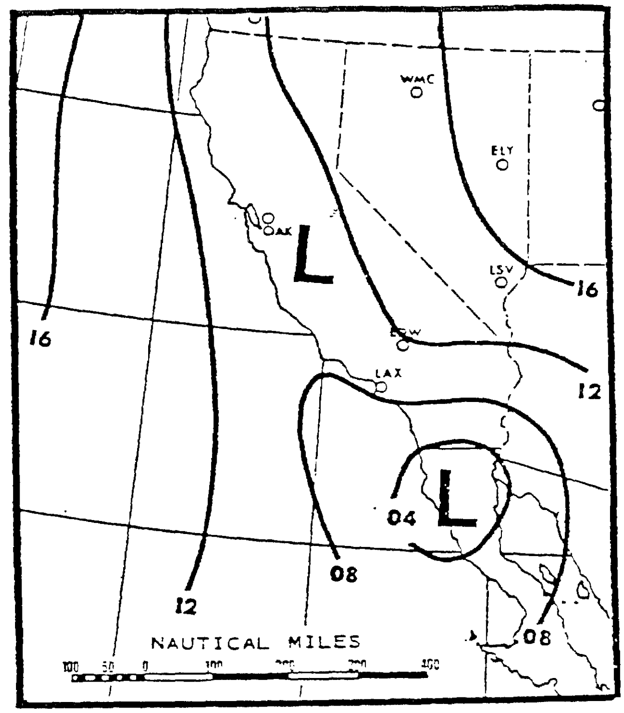
6 September 1976/1700 PDT

Figure 5-1

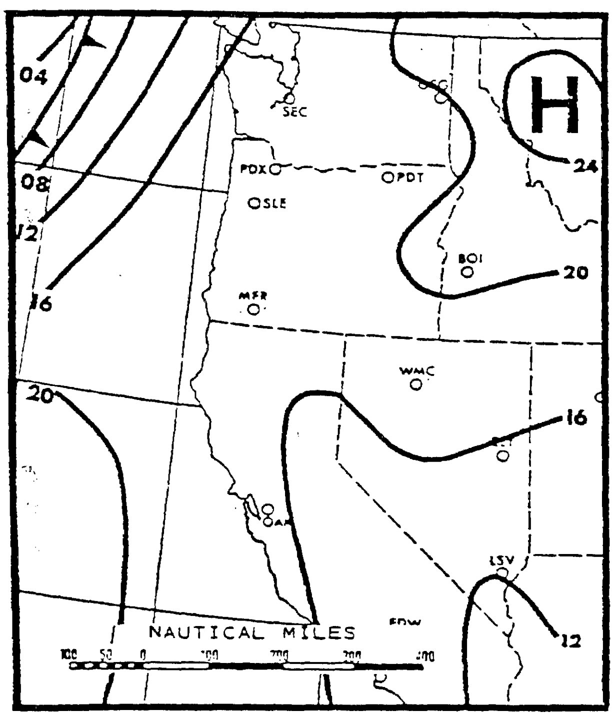
Synoptic Features During First Four
Tracer Studies - Summer Intensive Study



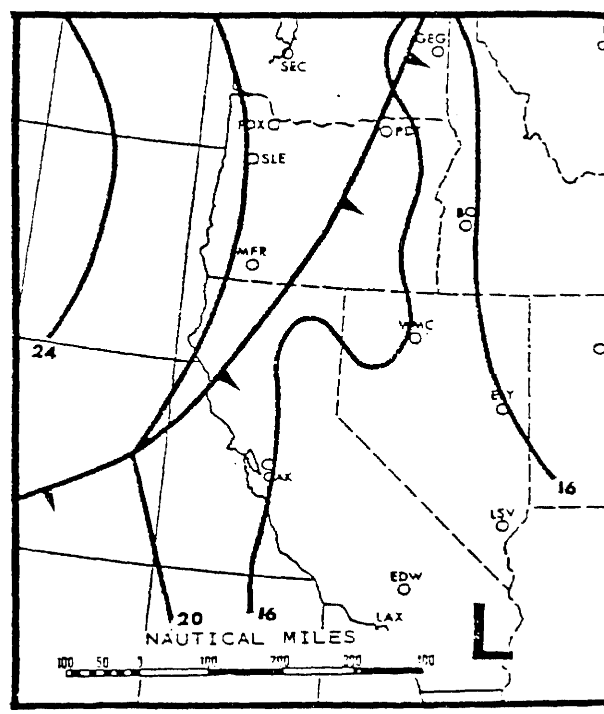
9 September 1976/1100 PDT



10 September 1976/0800 PDT



13 September 1976/0500 PDT



14 September 1976/1100 PDT

Figure 5-2

Synoptic Features During Last Four
Tracer Studies - Summer Intensive Study

1, 2, 3, 4 September 1976: During this four day period, surface low pressure spread northward and deepened slightly through most of the Central Valley while the high pressure occupying the Intermountain Region to the east weakened and spread eastward. The Eastern Pacific high pressure ridge aloft which had been dominating the west coast during the previous days continued to influence the general synoptic situation; however, it too was slowly weakening and drifting eastward during the period. Surface pressure tendencies increasingly favored onshore flow into the Delta area and slight down-valley movement because of the persistent lower pressures in Southern California. The "marine layer" slowly deepened during the period while slightly lower 850 mb temperatures indicated less stable conditions aloft. However, because of a reduction in surface heating during the afternoons in the Delta, (due to the deeper layer of "cooler" marine air) the afternoon mixing layer did not break through the inversion until the situation aloft became less stable on the 3rd and 4th. Skies remained clear through the 3rd while scattered to broken middle and high cloudiness predominated by late morning on the 4th. Surface temperatures ranged from the low 60's (°F) in the early mornings to the mid to low 90's (°F) in the afternoon.

5, 6, September 1976: The weakening and continued eastward movement across the Rockies into the Central Continent of the ridge aloft allowed the rapid development of a long wave trough aloft along the Pacific Coast during this period. As a result, a surface frontal system advanced rapidly southeastward across the Pacific Northwest into California during the 5th. The frontal system passed through the Delta area during the morning of the 6th. The pressure tendency during the period favored increasingly strong onshore flow with the tendency of air movement to be slightly from the south up the Central Valley as the weak, cold front approached from the north. After the front moved through the area, a building ridge of surface high pressure in the Pacific Northwest encouraged onshore but down-valley pressure tendency during the afternoon and evening of the 6th. The "marine layer" continued to deepen through most of the period, reaching its peak on the morning of the 6th before the frontal passage. The 850 mb temperature continued to fall during both days. The "mixing layer" broke through the lower inversion during both afternoons. No precipitation accompanied the frontal system but broken to scattered high cloudiness did persist in the area through most of the 5th. A general clearing trend characterized conditions on the 6th. Temperatures ranged from early morning readings in the low 60's or upper 50's (°F) to afternoon readings in the upper 80's to low 90's (°F).

7, 8, 9, 10 September 1976: Between the 7th and 10th of September, the eastern Pacific high pressure ridge aloft reasserted itself into extreme western U.S. from Central California to Central British Columbia. As a result, surface high pressure once again built and spread southeastward across the Pacific Northwest and the Intermountain Region. At the same time, pressure remained low in Southern California partly from thermal considerations and partially because of the persistence of a rather well-defined low aloft. That situation eventually led to the appearance of Hurricane Kathleen off the Central Baja coast on the 10th. Pressure tendencies in the Delta area became increasingly offshore and down the Valley through most of the period. Surface winds blew strongly from the north on the 8th and 9th in very hot and dry weather. The "marine layer" was quite shallow as increasing 850 mb temperatures indicated the strengthening of the lower inversion. Increased surface heating in the Delta and Valley areas was sufficient to cause the "mixing layer" to break through the inversion during the afternoons. Skies were clear through the 8th while some scattered high cloudiness increased during the 9th. Increasing moisture supplies began moving into the area by late on the ninth as a result of the tropical storm activity taking place in Southern California and northern Mexico. By the morning of the tenth, skies in the Delta area had become broken to overcast with middle and high cloudiness with some light rain recorded late that night. Temperatures during the period ranged from the upper 60's to low 70's (°F) during the early mornings to the upper 90's (°F) to 100°F in the afternoons.

11, 12 September 1976: Surface pressure continued to fall in the Delta area as tropical low pressure spread northward from Baja through Southern California on the 9th and 10th to the Central Valley on the 11th and 12th. At the same time, the long wave trough aloft spread across the Pacific Coast and drifted slowly eastward. As a result, moisture supplies were drawn northward for long distances during the period while surface pressures remained low inland. Rain fell over much of the area on the 11th. Pressure tendencies in the Delta area favored onshore flow from west to east during the 11th becoming slight down-the-valley on the 12th as the pressure to the north slowly increased. The "marine layer" was deeper than the previous four day period and reduced surface heating prevented the "mixing layer" from breaking through the inversion during the afternoons despite the fact that a large decrease in the 850 mb temperature indicated the inversion was much weaker. Skies remained overcast until midday on the 12th when clouds began to dissipate. Scattered to clear conditions prevailed by late that afternoon. Temperatures ranged from the low 60's (°F) in the early mornings to near 80°F in the afternoon.

13, 14, 15 September 1976: Weak surface high pressure once again built across the entire western U.S. on the 13th, including a weak version of the eastern Pacific ridge off Central and Southern California. However, another long wave trough aloft was pushing southeastward from the Gulf of Alaska into the Pacific Northwest. By the 14th, an associated surface frontal system moved down the west coast into northern California. On the 15th, the front had developed into a surface cyclonic system in central Nevada. Pressure tendencies indicated onshore gradients throughout the period with weak down-valley movement on the 13th and strong cross to slightly up-valley tendencies on the 14th and 15th. The "marine layer" was shallow on the 13th but slowly deepened on the 14th and 15th. The 850 mb temperature rose during the 13th but started falling again by late on the 14th. The "mixing layer" did not break through entirely during the 13th and 14th but several layers of air were evident on the 13th. Skies were clear until mid morning on the 14th when some high, thin cirrus began to appear. Scattered to broken cloudiness prevailed on the 15th. Temperatures ranged from the low 60's (°F) in the early mornings to near 90°F in the afternoons.

5.2 Airflow Summary

As a basis for documenting the airflow characteristics of the Bay area/Delta/Central Valley, surface winds for available stations in the principal study area were plotted for every three hours of the 17-day field program. 136 maps of 3-hourly winds from the 33 stations shown in Figure 5-3 were constructed and streamlines drawn over the entire area of data availability. Streamline patterns were classified according to windfield behavior both in the Bay area and in the Delta region.

In order to provide a basis for comparison with a longer period record, the classification scheme followed the same procedures as previously used by the ARB in classifying San Francisco airflow types. Since the ARB summaries contained two years of streamline classification, some comparison between the summer intensive study and its relationship to the overall dispersion regime could be established.

The seven basic types of flow recognized by the ARB meteorologists are shown in Figure 5-4. Although these patterns were intended to define Bay area flowfields, these patterns also fit the Delta windfield very well. The summer program pattern description could have been applied equally well to the Smalley (1957) scheme or a simplified set of Smalley patterns developed by Basso, et al. (1976). However, the simplicity of the ARB scheme and its apparent applicability to the Delta as well dictated its selection.

Because of the excellent data density of the wind network, some subgrouping of the seven basic flow types was performed. These subgroups were established to distinguish differing dispersion characteristics within the same basic flow regime. Given the dominance of westerly and southwesterly winds, subgroups within those prevailing directions were more

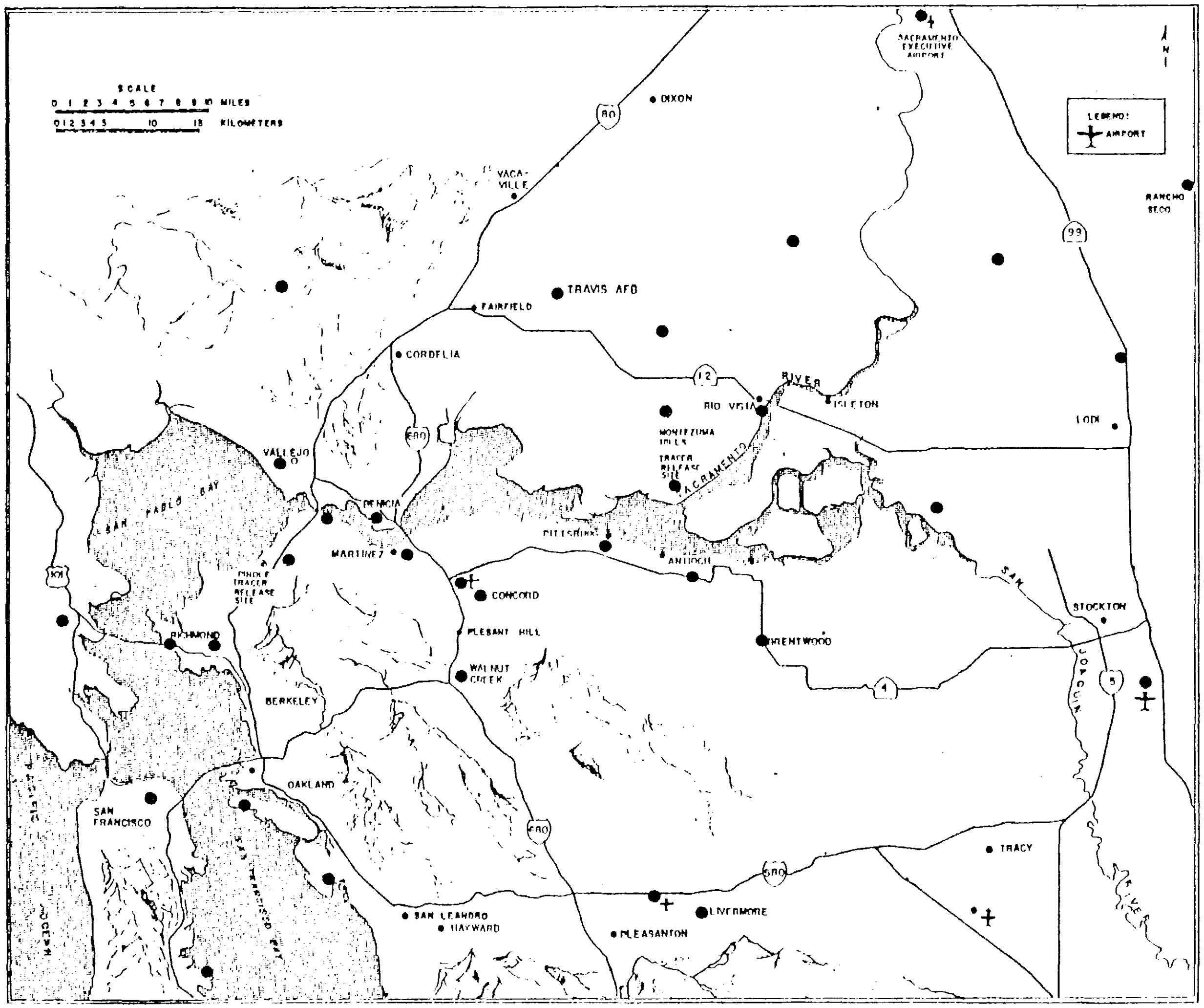


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Figure 5-3

Station Locations Used to Construct Study Area Surface Streamline Patterns

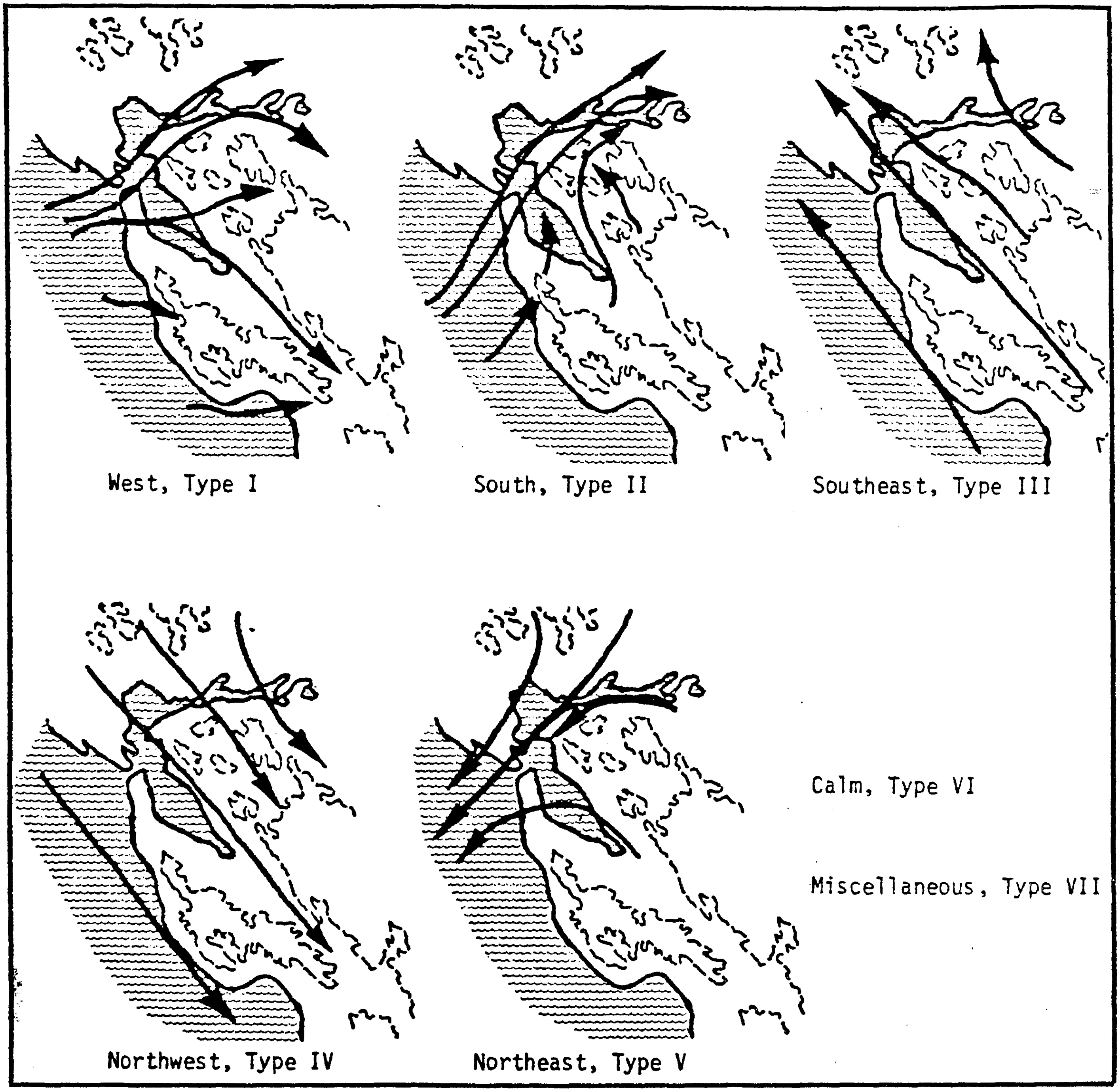

Figure 5-4

San Francisco Bay Area Airflow Types
Defined by ARB Meteorologists

obvious. During other seasons when Types III, IV, and V are more prevalent, finer detail would probably also be apparent within those classifications.

Table 5-1 shows the breakdown that was used to classify the 136 streamline maps. The comparison between the summer of 1976 and the ARB breakdown in 1974-75 are shown in Table 5-2. Except for differences in classification, i.e., the ARB distinguishes only between westerly and southerly, whereas, MRI's regime 2 is really southwesterly, the two sets of characterizations are almost identical. Within a broad definition of "representative" it can be said that the summer intensive study was representative of typical summer Bay area - Central Valley flow regimes.

The important question is not what kind of flowfield occurred, but rather its implication on the transport of background emissions out of the Bay area source region and the dispersion of emissions from the Montezuma Hills. The prevalence of Types 1A and 1B (Figures 5-5 and 5-6) implies that the summer background source region for air in the Delta is the northern Bay area. Streamlines over the Montezuma Hills originate over Richmond or San Pablo Bay. The northerly branches into Sacramento originate in nearly the same area as the southerly branches into the San Joaquin Valley. The northerly branches, however, should be somewhat less polluted because they pass over much of Marin County and San Pablo Bay rather than the more industrialized areas of Contra Costa County.

Figure 5-6 also illustrates a unique flow feature that results from the rapid deceleration of winds beyond the Montezuma Hills and the effects of the Black Hills/Mt. Diablo topography on the seabreeze. A very sharp bend in the streamline along the south side of the Sacramento River beyond Pittsburg and Antioch is necessary to account for the northeasterly winds that formed at Brentwood on many afternoons. The Brentwood winds indicate that a strong eddy forms in the lee of hills which transports material against the onshore gradient toward Danville and San Ramon. The "Brentwood Eddy" breaks down when the late afternoon seabreeze finally overcomes the eddy flow. Westerlies through the canyons west of Brentwood recycle the air which had been in Brentwood earlier in the day. In particular, the eddy may force ozone into protected elevated layers over the San Ramon Valley which can descend during the flow reversal. In this way, the Brentwood area may (and does) experience late evening ozone peaks due to pollutant recirculation.

Other summer flow types that have significant implications on the dispersal pattern from the Montezuma Hills are shown in Figures 5-7 through 5-18. Type 1C (Figure 5-7) and Type 4A (Figure 5-14) are important in terms of the potential synergism between emissions from the Contra Costa County complex of refineries, heavy industry, and power

Table 5-1

FLOW CLASSIFICATION SCHEME FOR THE BAY AREA AND DELTA

Classification	Flow Characterization
1A	Westerly throughout
1B	Westerly around the Bay and Hills but forking into two streams inland
1C	Westerly around the Bay and Hills but turning northwesterly inland
1D	Westerly around the coast or Strait but drainage pattern dominant inland
1E	Westerly near the coast, Bay or Strait turning southwesterly inland
1F	Westerly around the Bay turning northerly inland
2A	Southwesterly throughout
2B	Southwesterly around the coast, Bay or Strait but turning westerly
2C	Southwesterly around the Bay or Strait but turning westerly
2C	Southwesterly around the Bay or Strait but drainage pattern inland
3	Southeasterly flow
4	Northwesterly flow throughout
5	Northeasterly flow with outflow into Bay area from Central Valley
6A	Drainage pattern throughout
6B	Drainage pattern around the Bay but northwesterly inland
6C	Light and variable around the Bay but northerly inland
7A	Westerly around the Bay but northeasterly inland
7B	Westerly around the Bay or Strait but light and variable inland
7C	Other miscellaneous flow types

Table 5-2

BREAKDOWN OF SUMMER 1976 FLOW REGIMES VERSUS CLIMATOLOGICAL EXPECTATIONS

Regime*	Number of Occurrences	Percentage	ARB Data (%)
1A	22		
1B	37		
1C	15		
1D	9		
1E	6		
1F	5		
Total Regime 1	94	69	89
2A	9		
2B	13		
2C	5		
Total Regime 2	27	20	2
Total Regime 3	0	0	0
Total Regime 4	2	1	2
Total Regime 5	0	0	0
6A	9		
6B	2		
6C	1		
Total Regime 6	12	9	2
7A	1		
7B	1		
Total Regime 7	2	1	6

* 1 July-September 1974-75 data

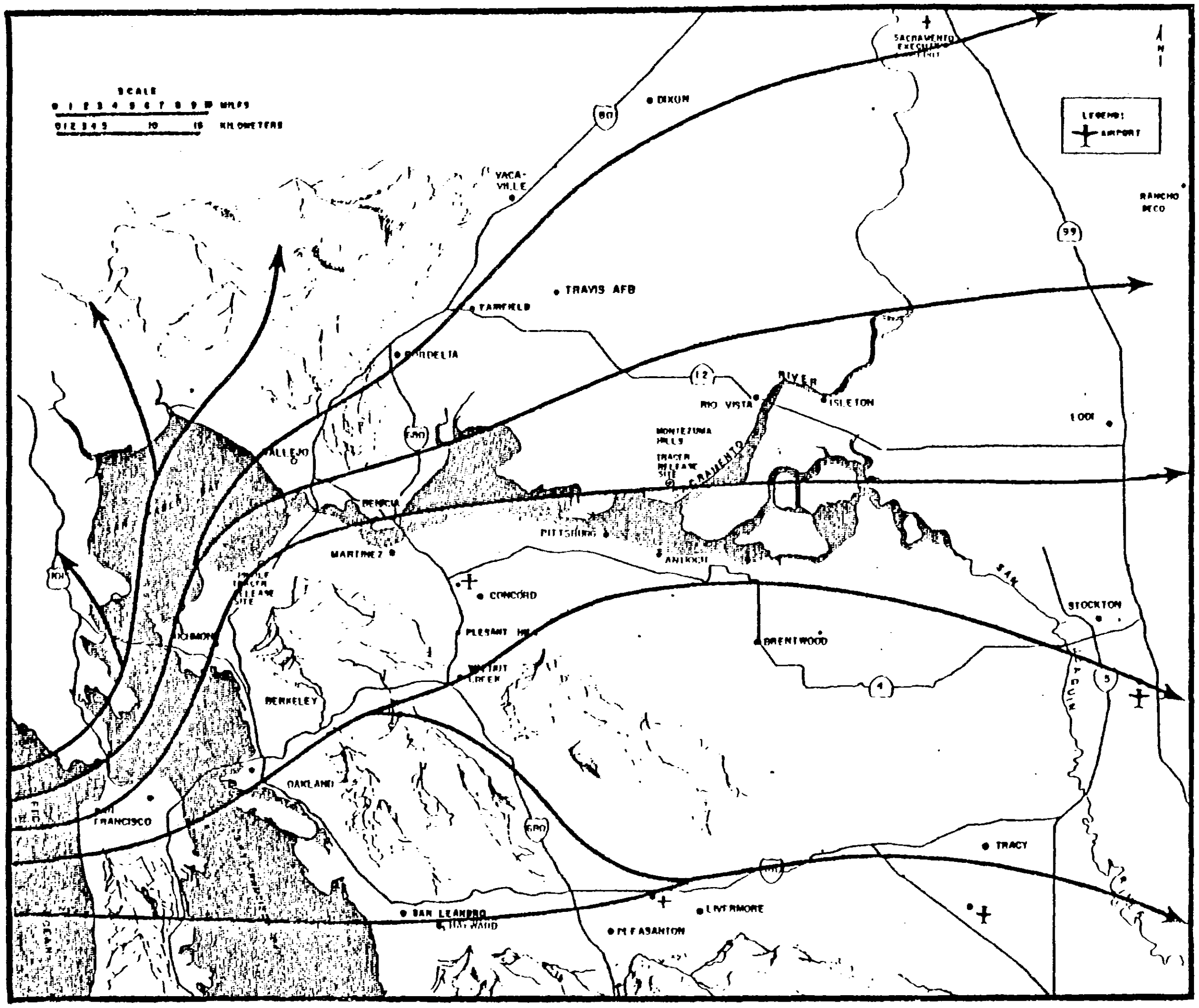

Figure 5-5

Representative Streamline Patterns - Type 1A
(Strong Westerly)

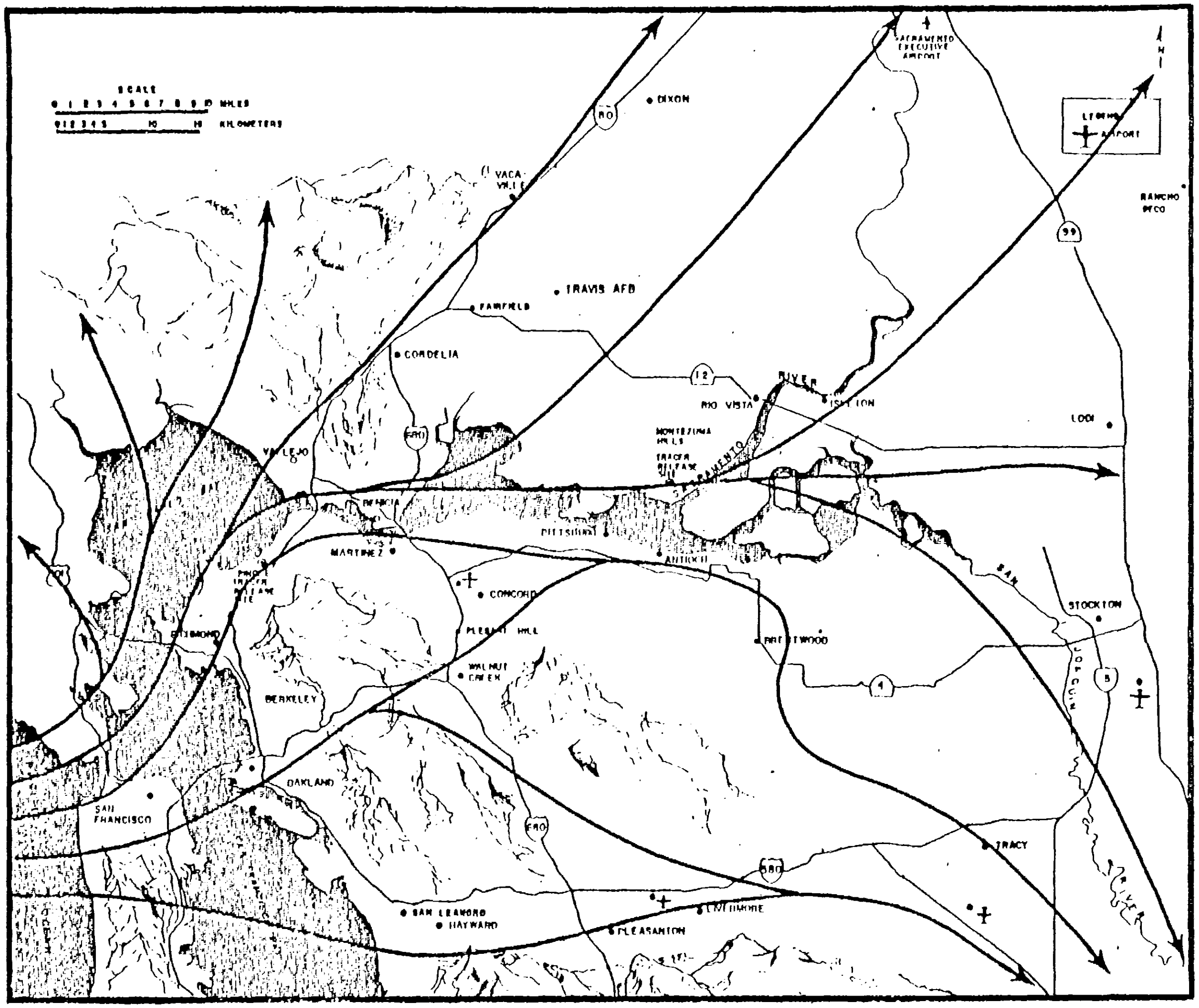

Figure 5-6

Representative Streamline Patterns - Type 1B
(West and Split)

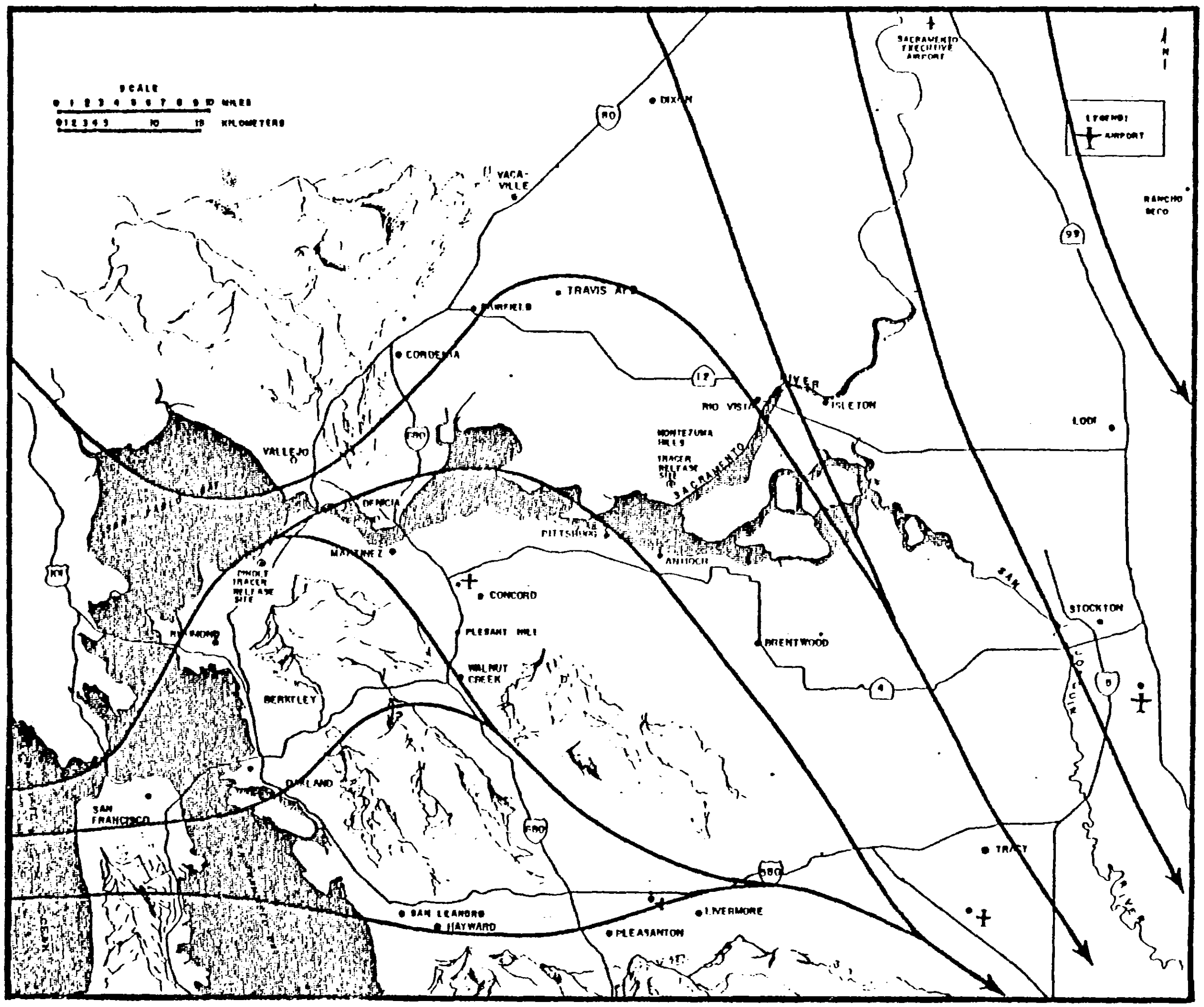

Figure 5-7

Representative Streamline Patterns - Type 1C
(West-Northwest)

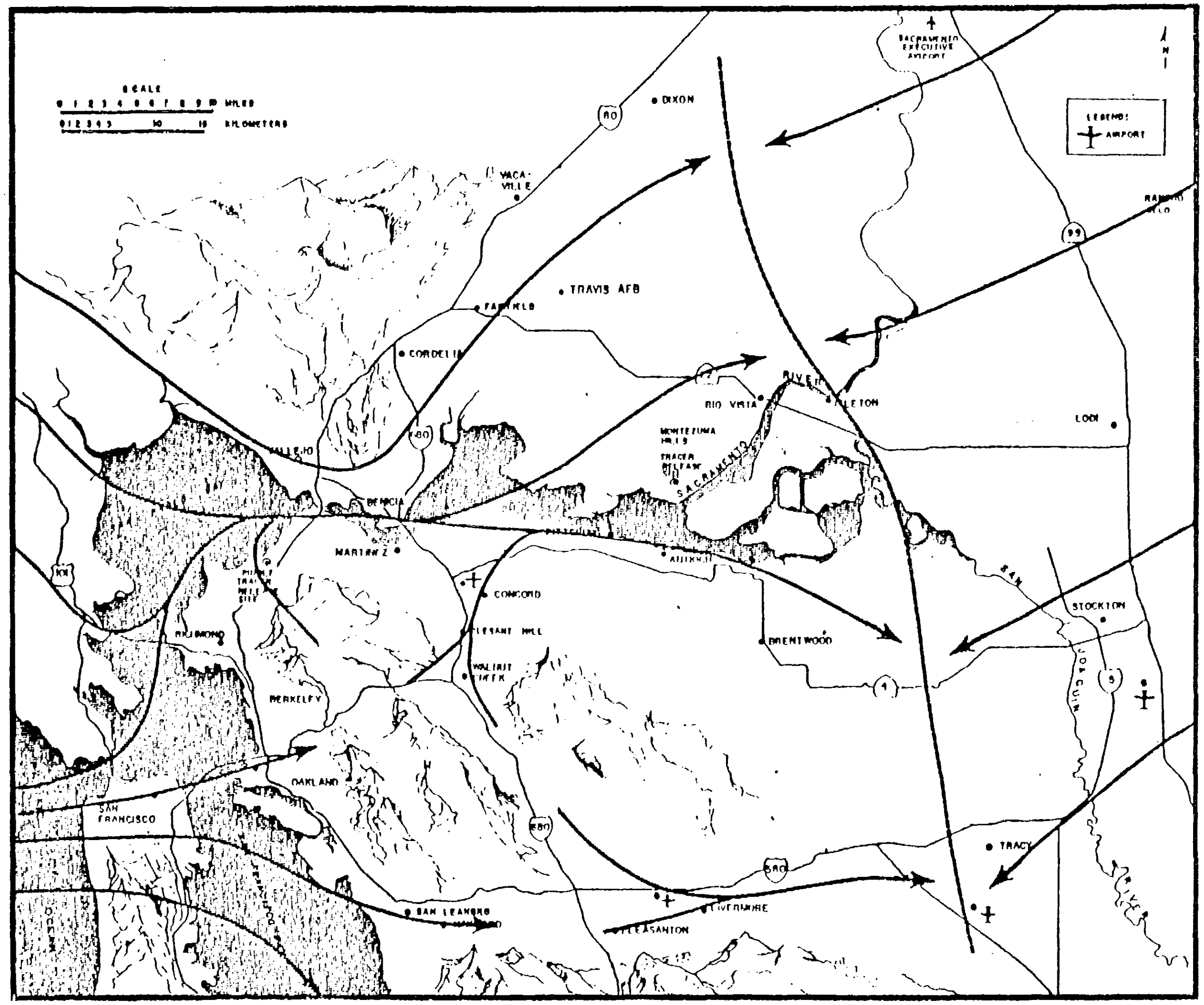

Figure 5-8

Representative Streamline Patterns - Type 1D
(West and Drainage)

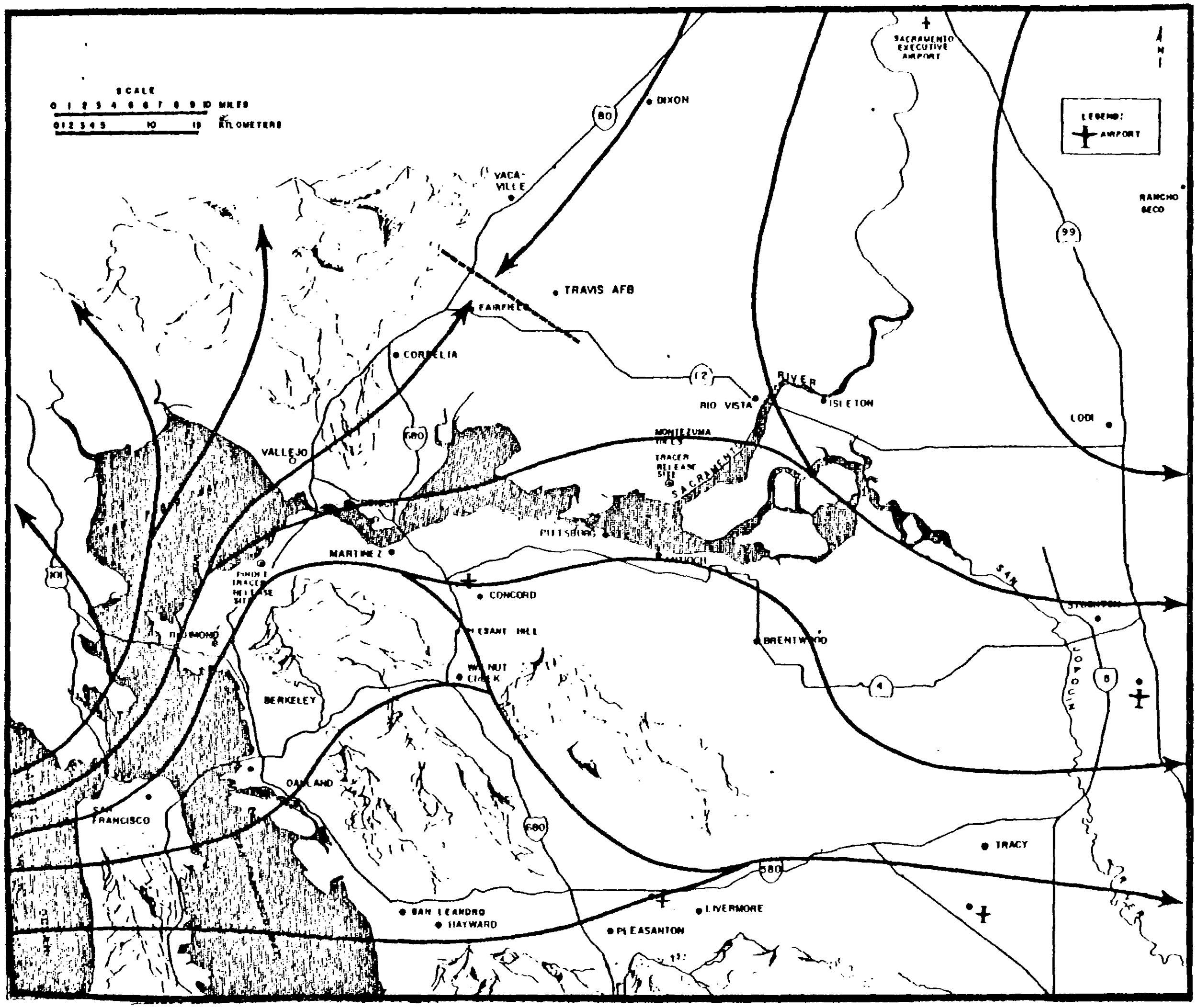

Figure 5-9

Representative Streamline Patterns - Type 1E
(West, with North over SAC)

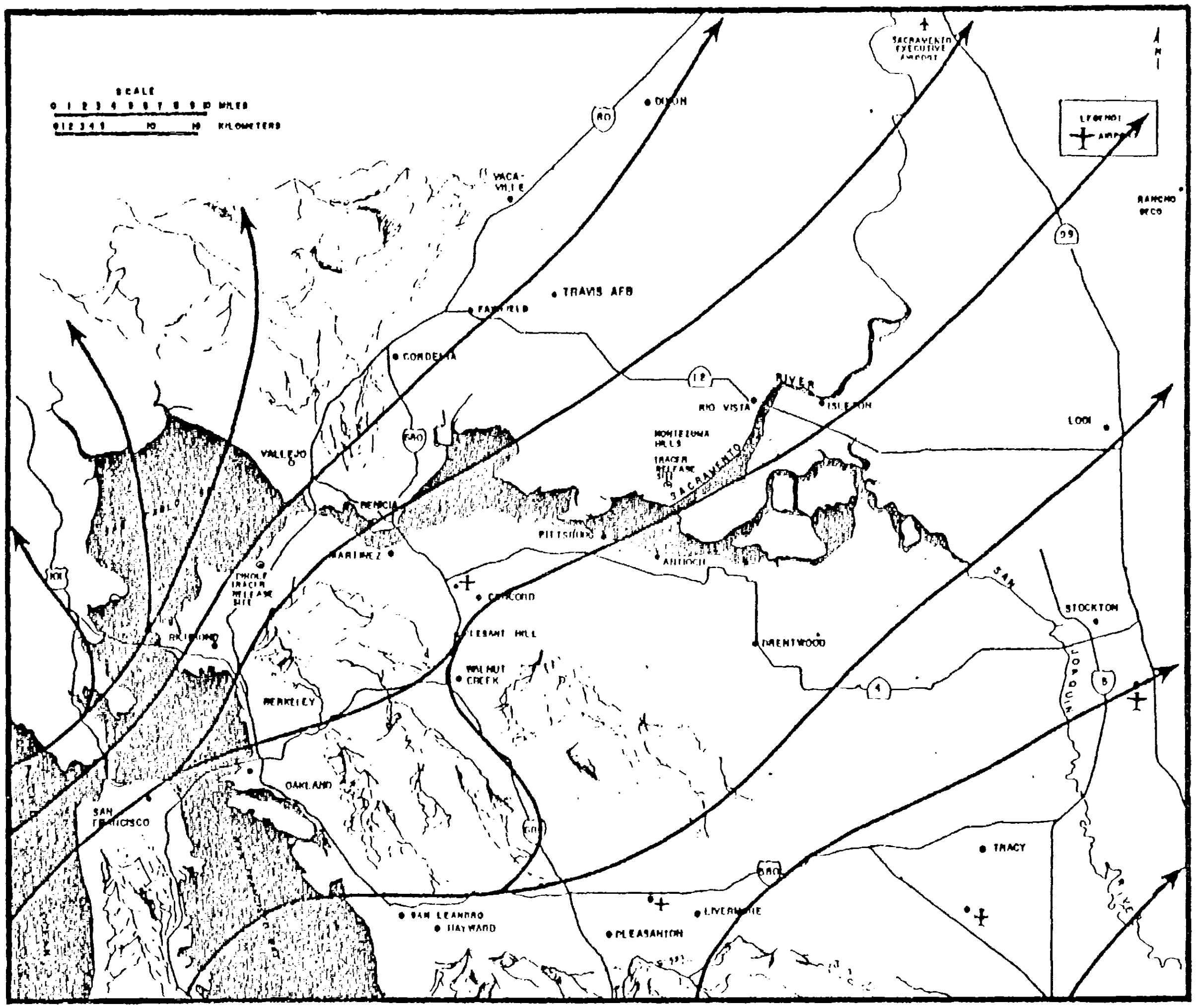

Figure 5-10

Representative Streamline Patterns - Type 2A
(Southwest)

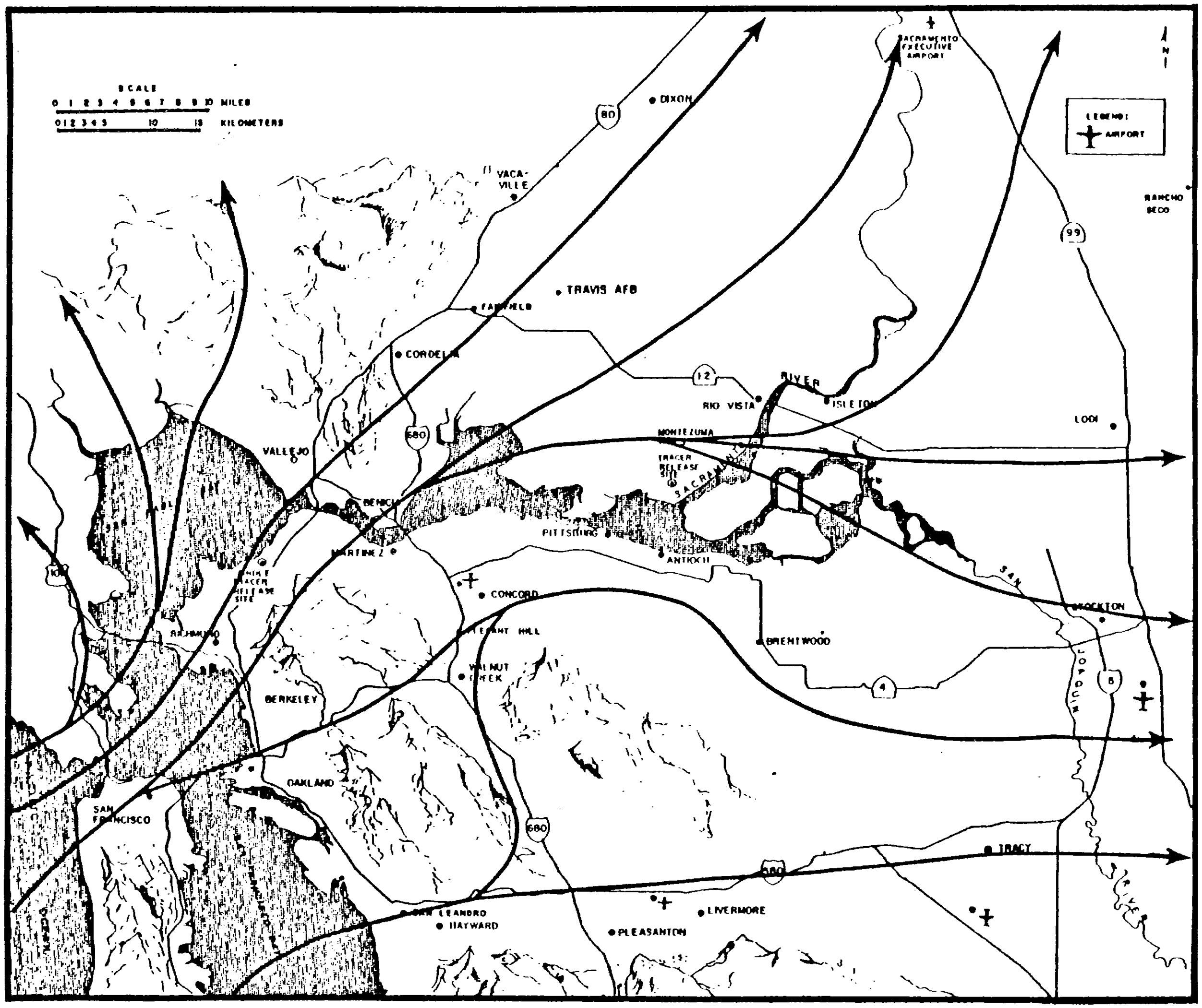

Figure 5-11

Representative Streamline Patterns - Type 2B
(Southwest and West)

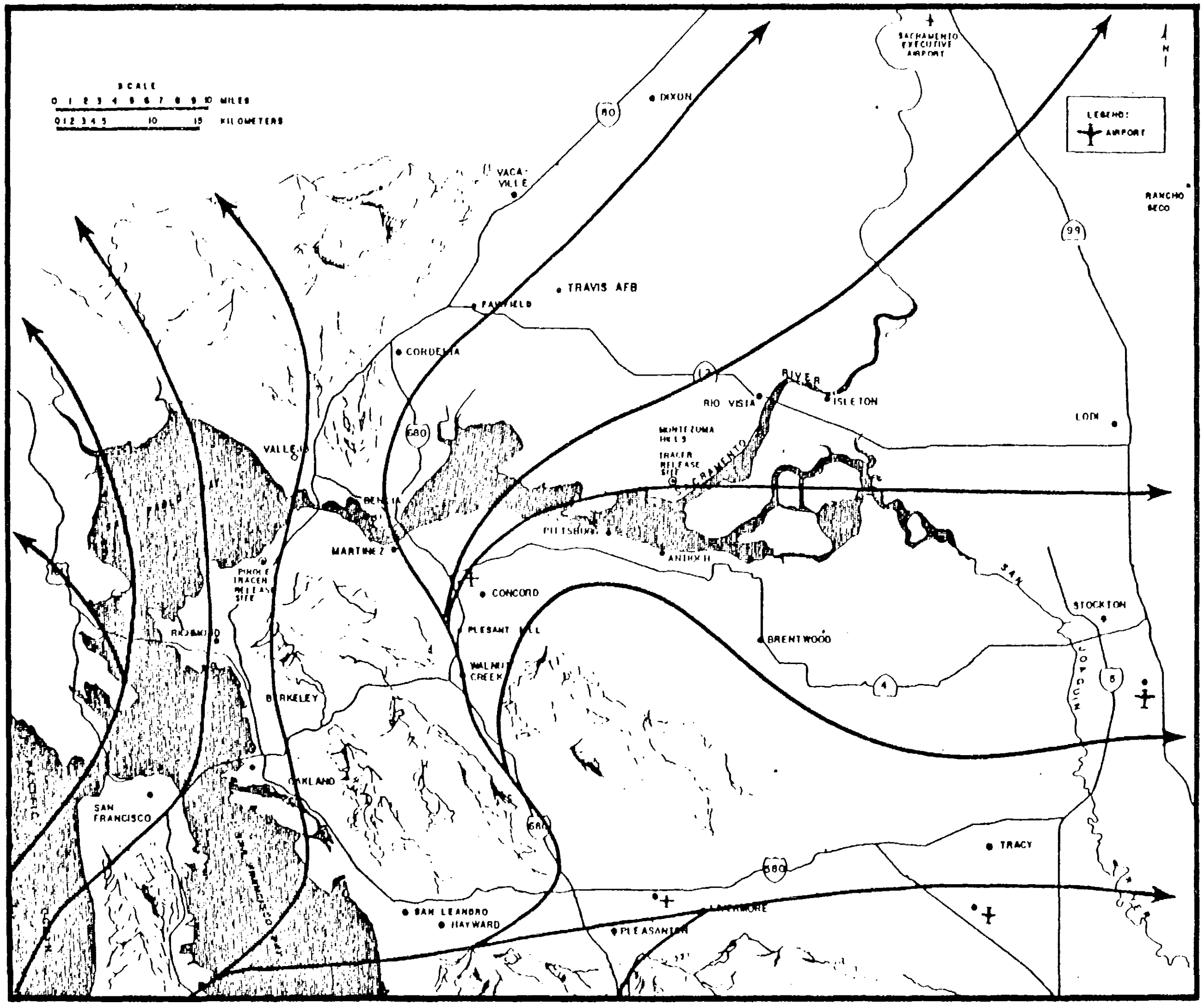

Figure 5-12

Representative Streamline Patterns - Type 2C
(South, Southwest, and West)

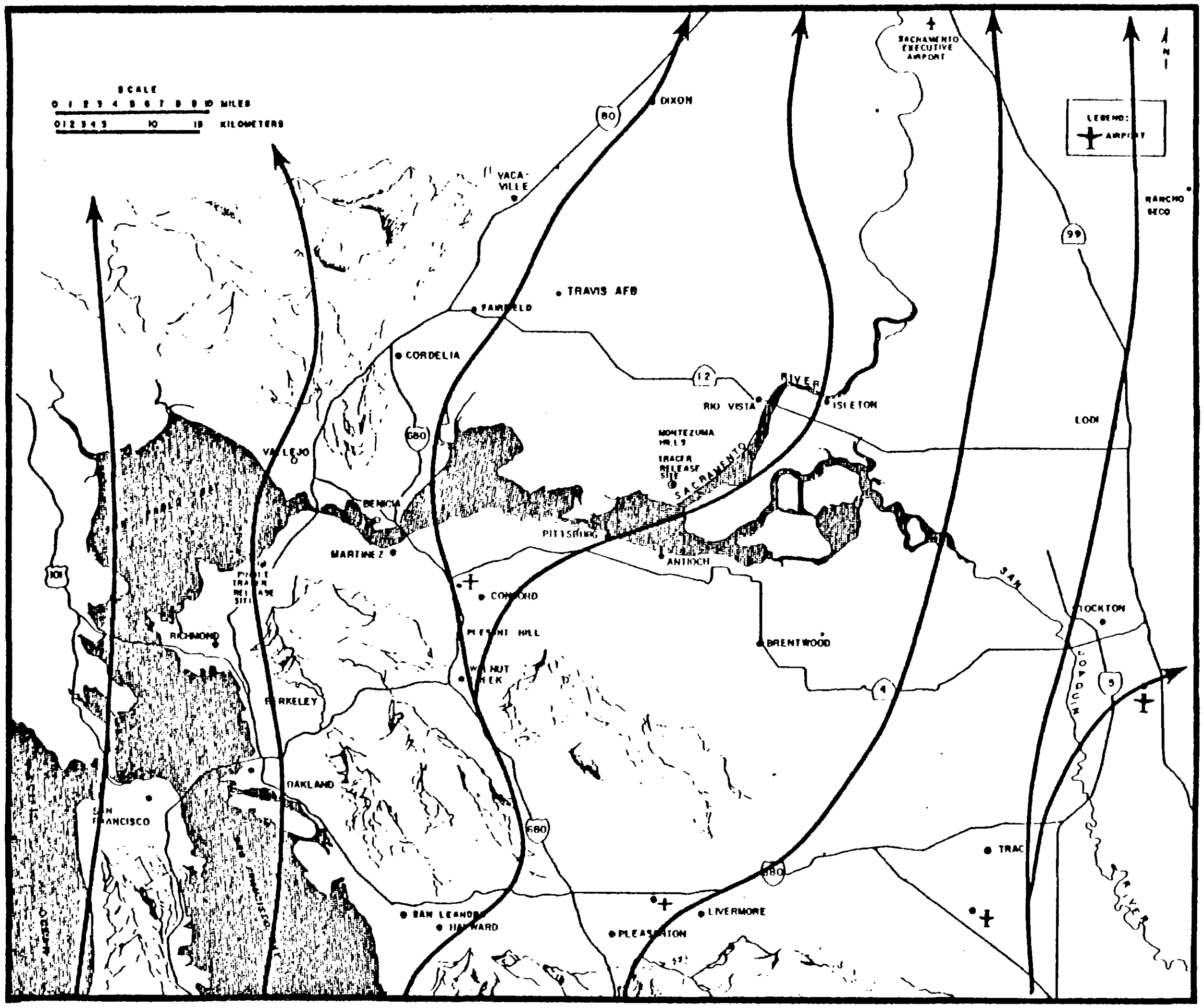

Figure 5-13

Representative Streamline Patterns - Type 3
(South)

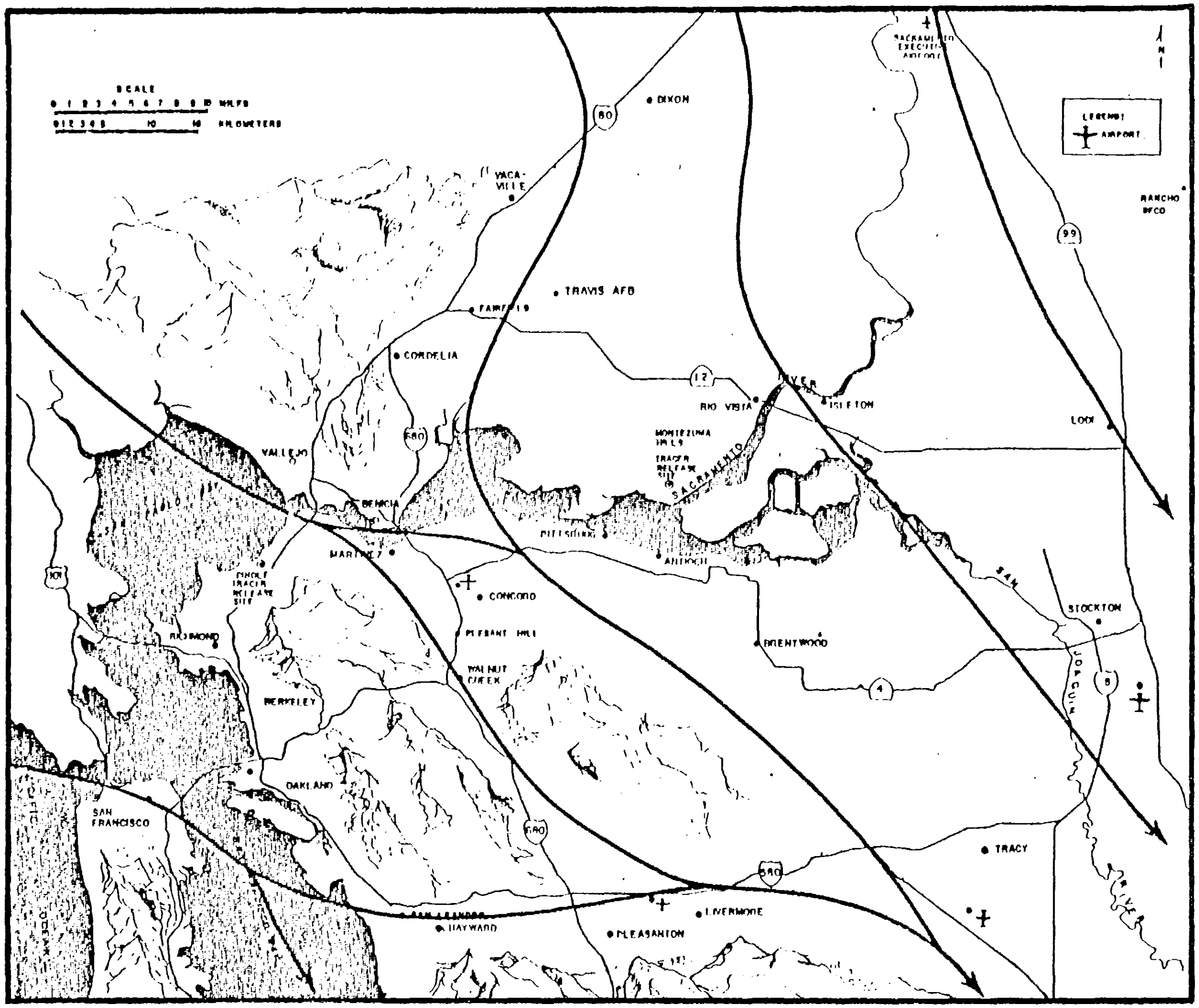

Figure 5-14

Representative Streamline Patterns - Type 4A
(Northwest)

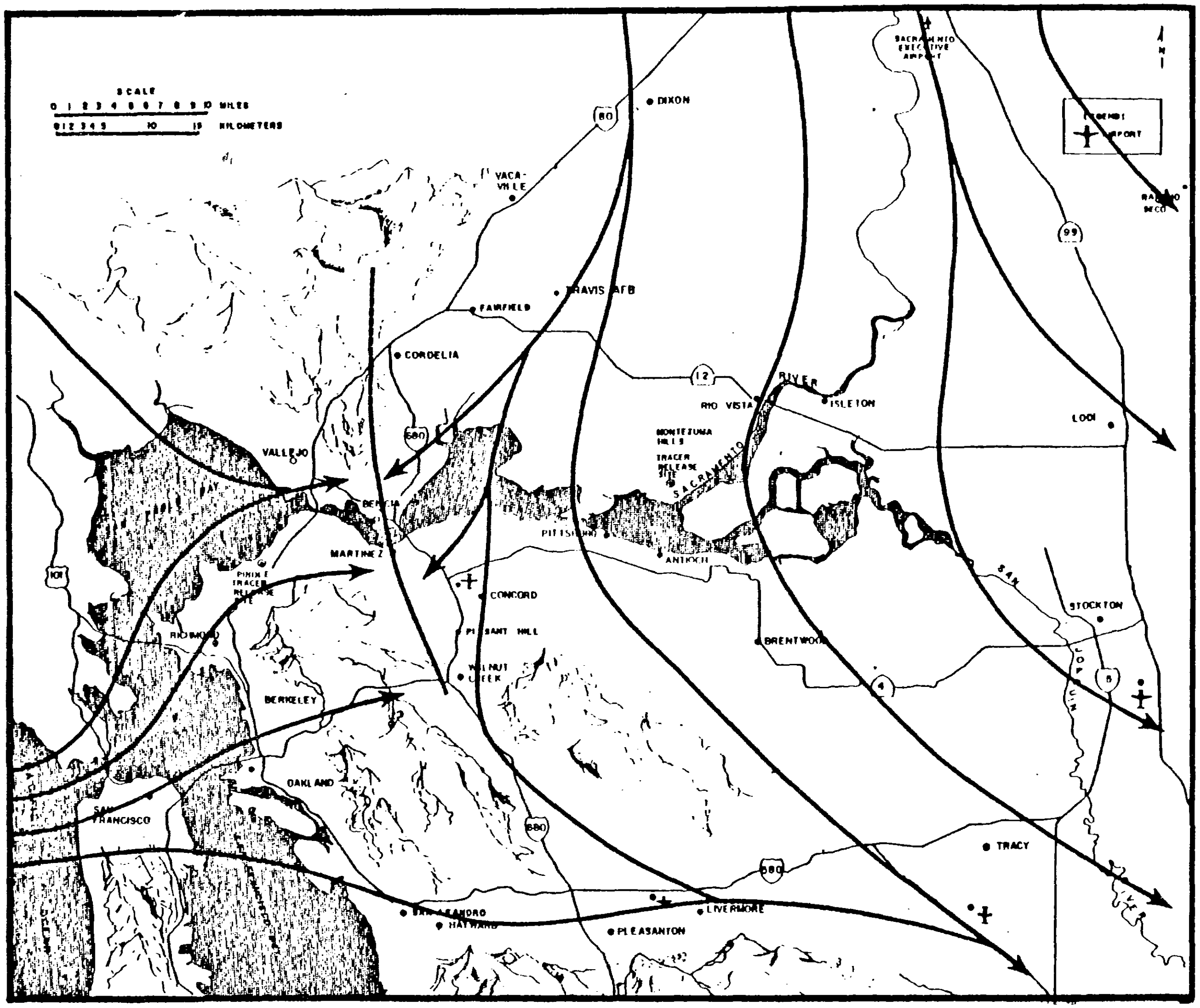

Figure 5-15

Representative Streamline Patterns - Type 4B
(North-Northwest and West)

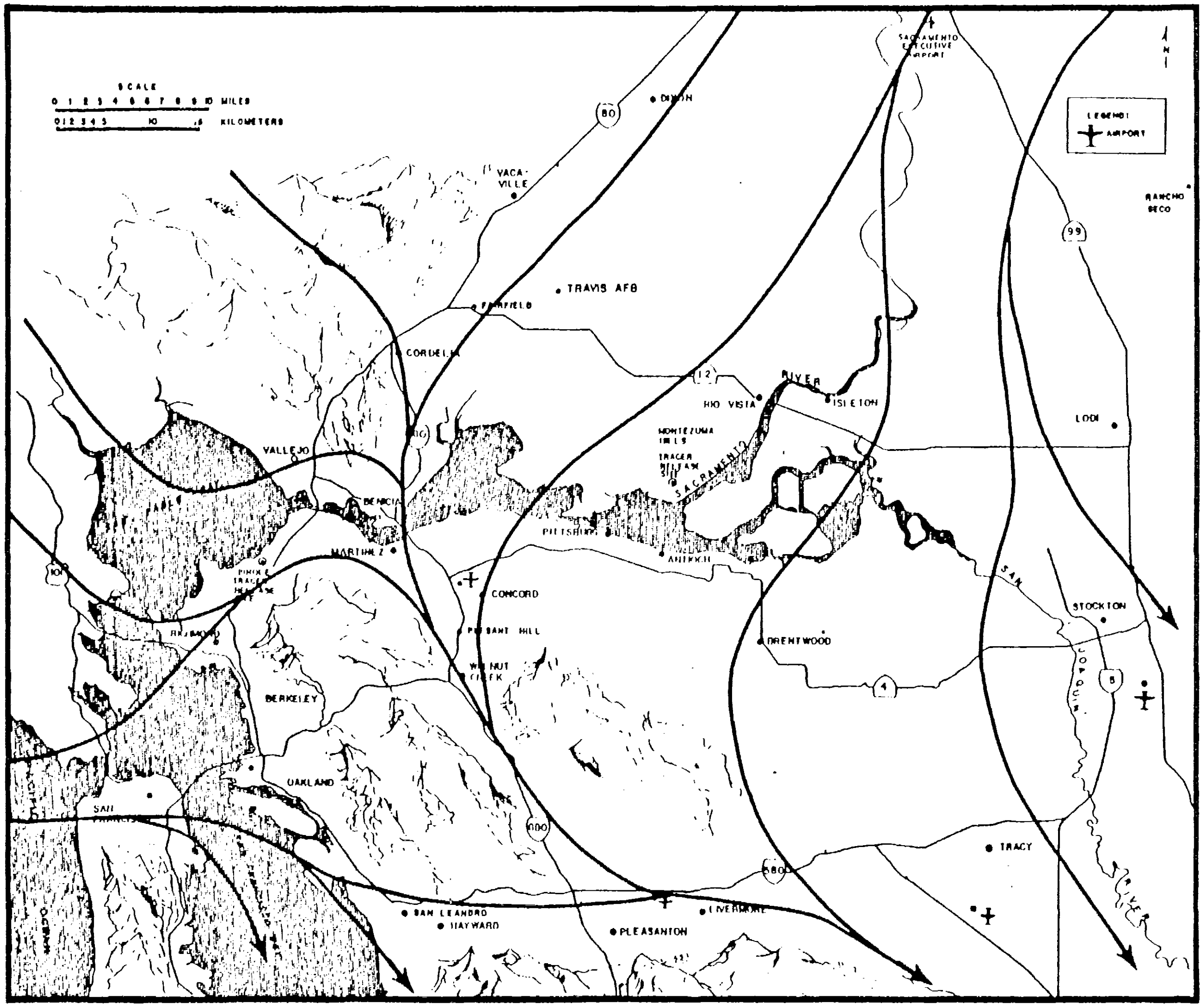

Figure 5-16

Representative Streamline Patterns - Type 5
(West and Northeast)

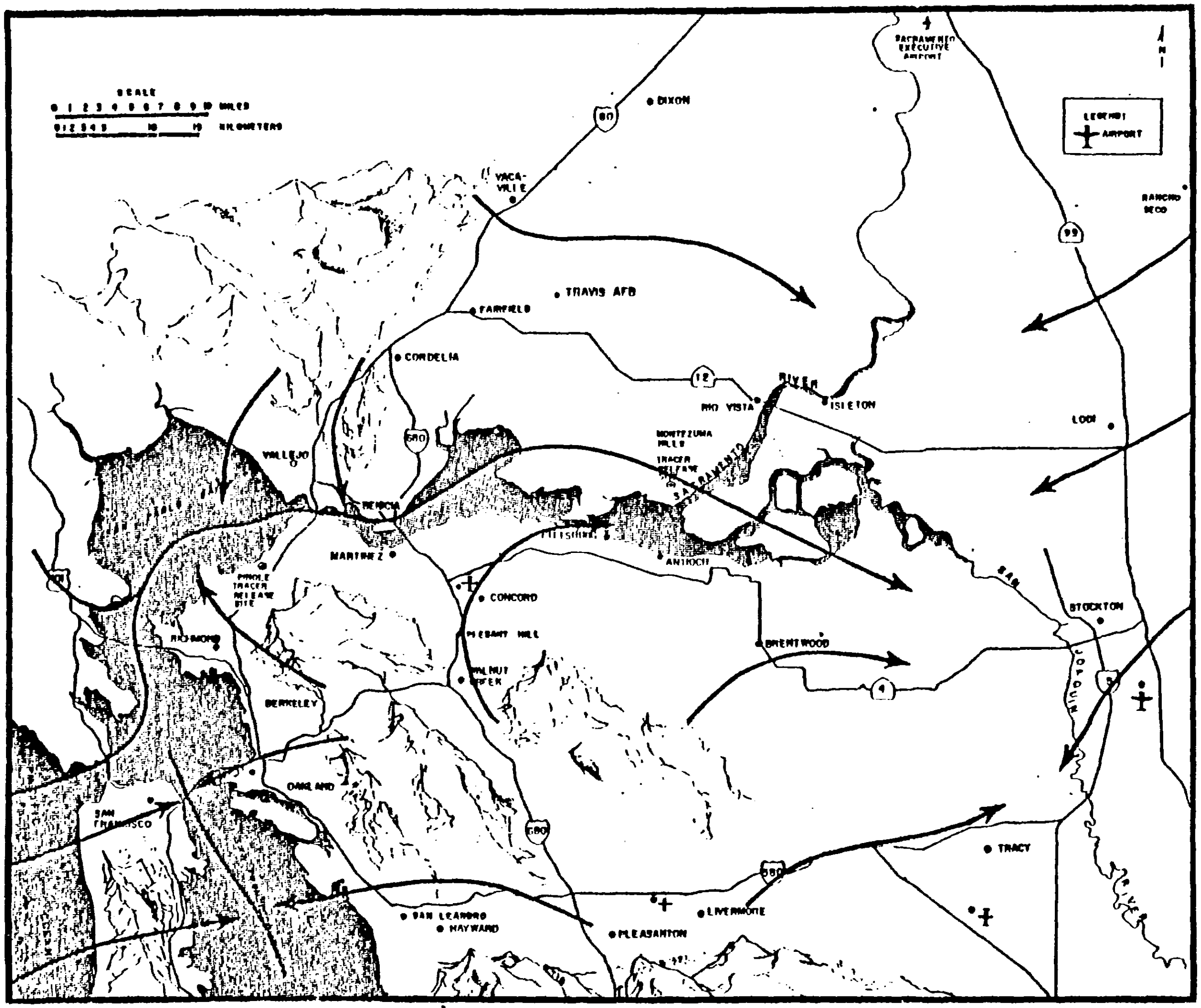

Figure 5-17

Representative Streamline Patterns - Type 6A
(Random Pattern, Drainage Dominant)

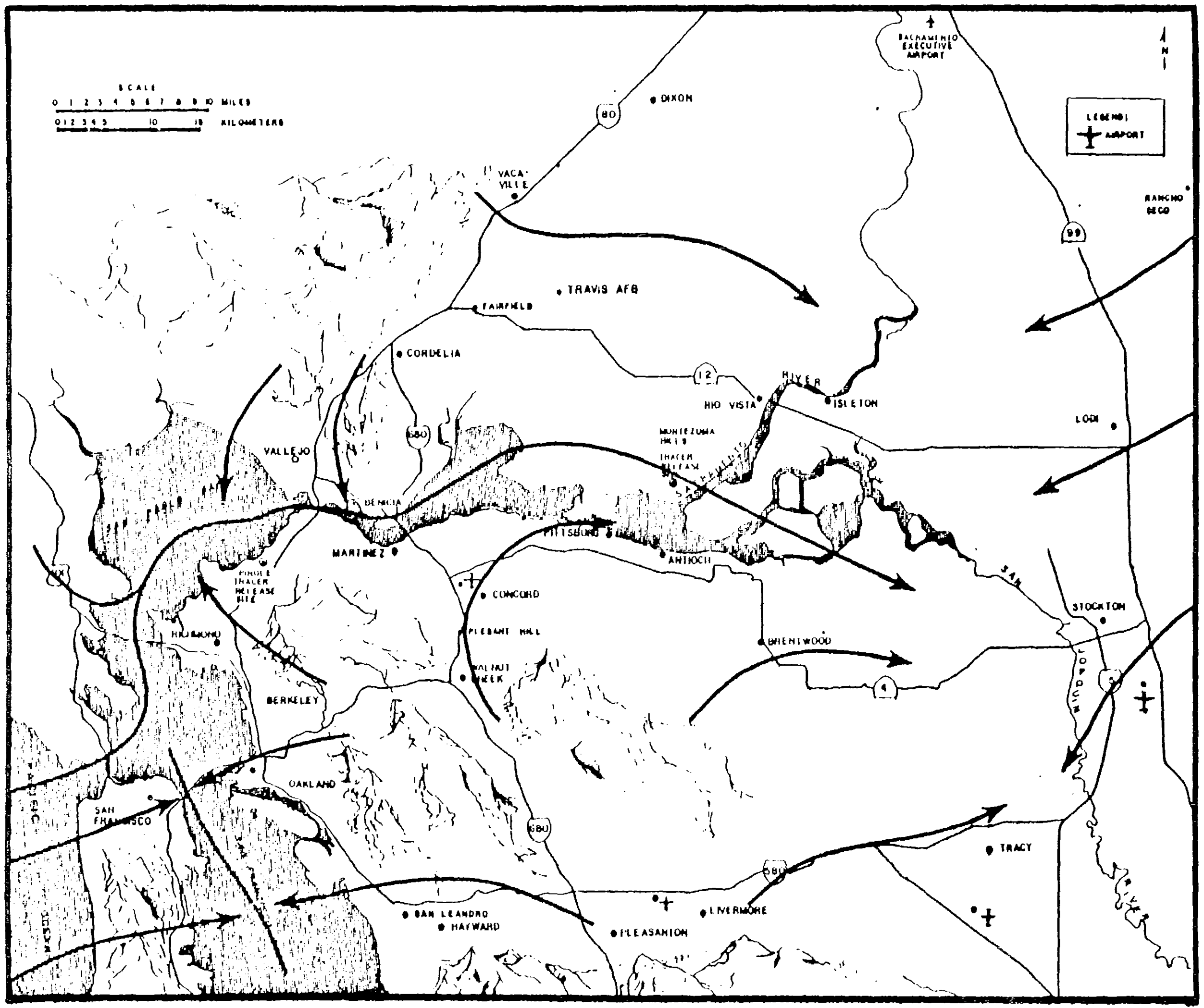

Figure 5-18

Representative Streamline Patterns - Type 6 and 6D
(Random Pattern, Drainage Dominant)

plants and potential emissions from industrialization of the Montezuma Hills. During strong westerly conditions, emissions from the Hills and along the river are diluted by a fanning out of the flowfield. Under northwesterly down-valley conditions, the winds across the Hills may develop a complete northerly or slightly northeasterly orientation such that emissions from the Hills mix with the air originating between Martinez and Antioch.

Another potential meteorological problem regime is shown in Type 1D (Figure 5-8) and Type 6A (Figure 5-17). The formation of a convergence zone or "front" between oceanic inflow and Sierra drainage at night may cause the Montezuma Hills emissions to go aloft over the colder drainage winds. This may be significant for two reasons. First, if the emissions continue toward the east aloft, they may be introduced into the mountainous areas east of Stockton in the El Dorado and Stanislaus National Forests where they can mix down to the ground during the next day's heating cycle. Secondly, if the Central Valley summer night-jet (Willis and Williams, 1972) has not dissipated when these emissions are injected above the valley floor, they could be carried some distance down the valley to participate in Central Valley photochemical processes quite far from their original source in the Hills.

The final summer flow regime important to the dispersion of potential pollutants from an industrialized Delta area is the southwest pattern seen in Figure 5-10. Southwest winds flow from the major stationary source areas and the proposed Montezuma Hills development will carry pollutants northeastward toward Lodi, Rancho Seco, and Sacramento. Since Sacramento already generates sufficient ozone precursors locally as discussed in Section 3-2, additional background burdens may further hinder the attainment of ambient air quality standards in the Sacramento area.

The frequency of the various weather types for the past several years is given in Table 5-3. For the purpose of this table, the flow patterns were grouped into westerly (Type 1), southwesterly (Type 2), light and variable (Type 6) and northerly (Types 4 and 5). The table indicates the predominance of westerly and southwesterly patterns and suggests that the test period was anomalous only to the extent that the frequency of northerly patterns was higher than previous years and the frequency of southwesterly types was somewhat less.

The occurrence of the various types was plotted against the concurrent pressure gradients (San Francisco-Red Bluff and San Francisco-Stockton). The resulting pattern in shown in Figure 5-19. The division between westerly and southwesterly types appears to depend mainly on the

Table 5-3

FREQUENCY OF WEATHER PATTERNS

Date	W (%)	SW (%)	Light Variable (%)	N (%)	Period
1976	27.3	40.9	18.2	13.6	Aug - Sept 15
1975	45.9	45.9	19.7	4.9	Aug - Sept
1974	57.4	26.2	11.5	4.9	Aug - Sept
1973	44.3	37.7	8.2	9.8	Aug - Sept
Field 1976	47.1	23.5	17.6	11.8	Aug 30 - Sept 15

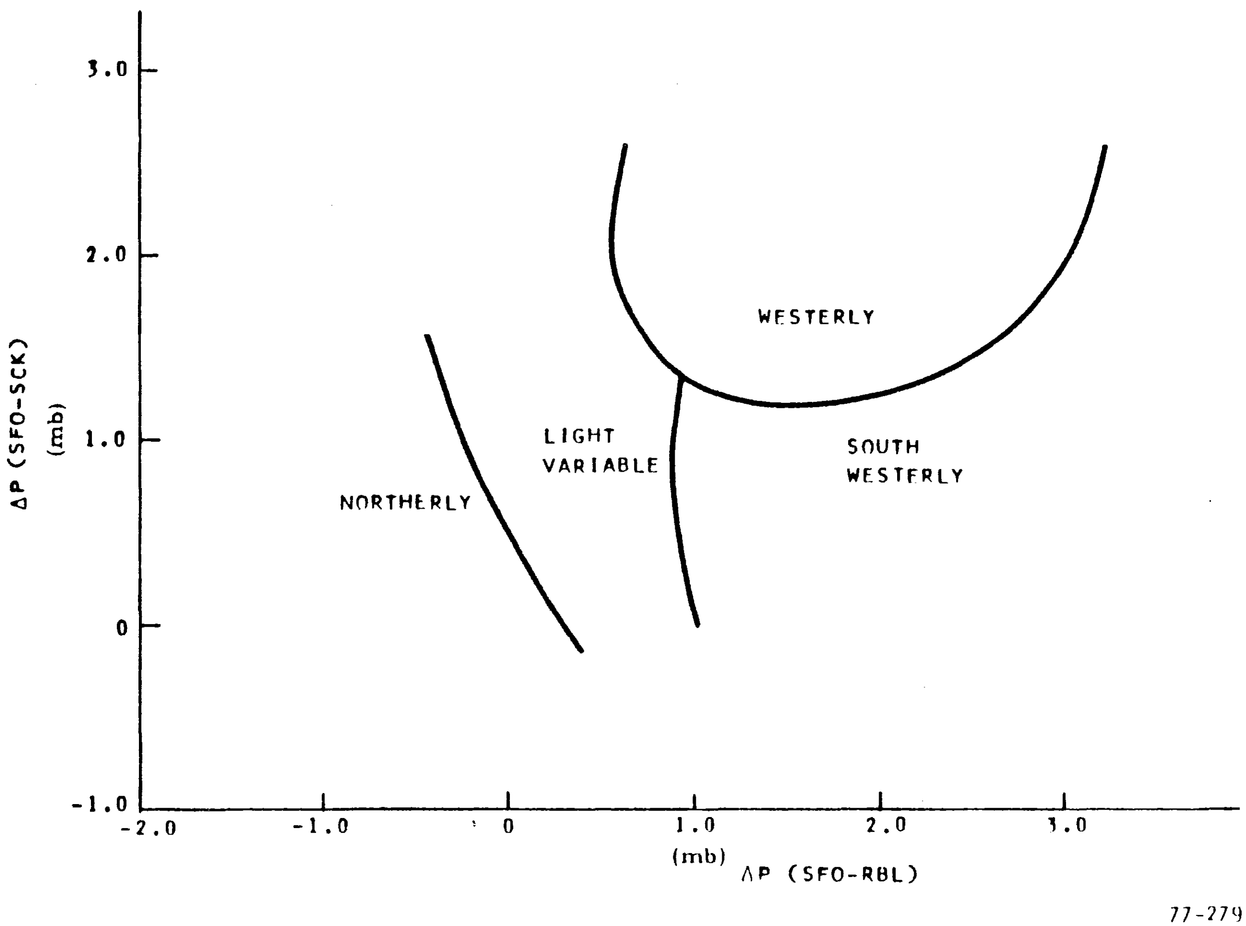

Figure 5-19

Relation of Streamline Patterns to Pressure Gradients strength of the San Francisco-Stockton gradient. Northerly types appear generally with negative San Francisco-Red Bluff gradients but with a range of San Francisco-Stockton gradients.

The San Francisco-Stockton pressure gradient is also the prime factor controlling the wind speed at Montezuma Hills. Wind speed data obtained at the Dow Tower site during the test period were plotted against the concurrent San Francisco-Stockton pressure gradient in Figure 5-20. A best-fit estimate was drawn through these points. The best-fit line was then used to estimate the climatological frequency of various wind speed categories at the Montezuma Hills site. These estimates are given in Table 5-4. The predominance of 15-25 mph winds during the August-September period is clearly evident. The table does show, however, that there has been a steady trend toward decreasing high wind speeds over the past four years. Presumably, this trend is a reflection of significant shifts in the major pressure centers affecting the central California area. The table indicates that the 1976 period was characterized by a somewhat lower frequency of high wind speeds in the Montezuma Hills area than has occurred in the recent past.

5.3 Vertical Structure Summary

Two key indices generally used for determining the degree of ventilation and its associated air pollution potential are the 850 mb temperature and the strength of the onshore pressure gradient. The 850 mb temperature is an important measure of the depth of the mixing layer, i.e., a high temperature aloft supports a strong low-level marine inversion which will prevent afternoon inversion burn-off in the Delta and Central Valley and will trap pollutants in the lower layers during the periods of maximum oxidant formation and transport. A list of 850 mb temperatures for the period is shown in Table 5-5.

The pressure gradient determines the driving force controlling the acceleration and velocity through the Carquinez Strait region into the Valley. A plot of the August and September, 1976, Oakland 850 mb temperature and the gradient between San Francisco International Airport and Red Bluff, Sacramento and Stockton is shown in Figure 5-21. In general terms, the beginning of the study period was characterized by the highest 850 mb temperature of August and September (the entire summer, for that matter) with gradually diminishing temperatures aloft due to a succession of cooler troughs passing through portions of California. The onshore gradient lagged the temperature profile by a few days such that the maximum gradient did not occur until temperatures aloft were beginning to decrease. The period of increasing temperatures aloft beginning about August 28 was marked with

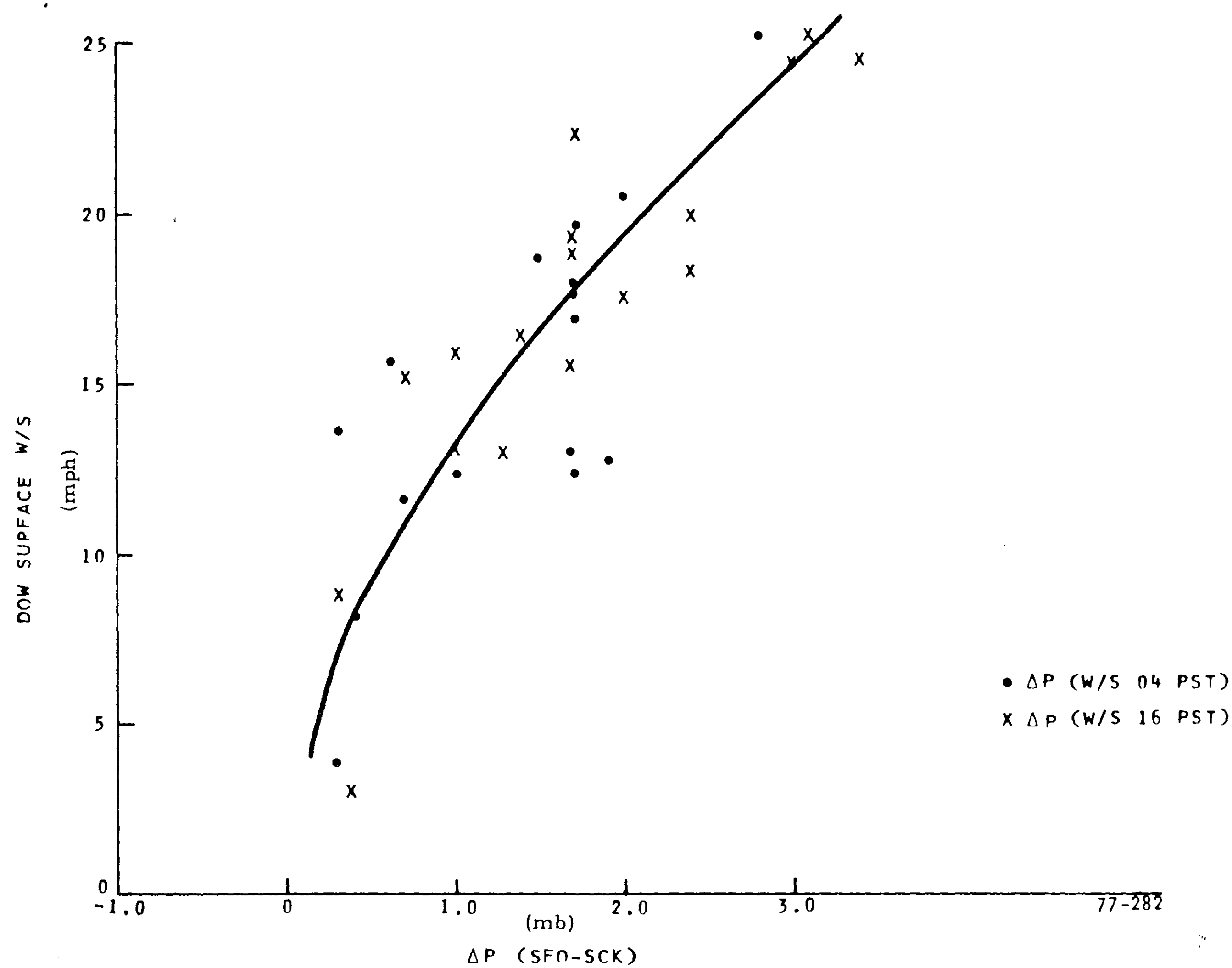

Figure 5-20

Wind Speed Relationship at Montezuma Hills

Table 5-4

FREQUENCY OF 04 PST WIND SPEEDS
MONTEZUMA HILLS
(Derived from ΔP SFO-SCK)
(August - September)

Wind Speed (mph)	1973 (%)	1974 (%)	1975 (%)	1976 (%)
0-5	3.3	-	1.6	8.7
5-10	3.3	1.6	8.2	17.4
10-15	13.1	23.0	34.4	32.6
15-20	23.0	37.7	36.1	32.6
20-25	50.8	37.7	19.7	8.7
25-30	6.5			

Table 5-5

OAKLAND SOUNDING SUMMARY

Date	Time (PDT)	Temperature (°C)	Dew Point (°C)	Wind Direction (degree)	Wind Speed (m sec $^{-1}$)
August					
30	0400	22.2	< - 8	160	07
30	1600	25.2	< - 5	205	09
31	0400	27.8	< - 2	300	10
31	1600	25.8	< - 4	310	10
September					
1	0400	25.4	< - 5	M*	M
1	1600	25.8	< - 4	330	04
2	0400	26.4	< - 4	320	08
2	1600	26.0	M	M	M
3	0400	23.8	< - 6	290	03
3	1600	24.0	< - 6	260	03
4	0400	23.4	< - 6	280	04
4	1600	22.0	1.0	225	12
5	0400	22.8	< - 7	230	10
5	1600	21.8	M	250	13
6	0400	18.0	< -12	295	19
6	1600	18.0	< -12	245	07
7	0400	18.0	-2.0	M	M
7	1600	18.8	< -11	145	06
8	0400	20.0	< -10	200	04
8	1600	20.4	< -10	200	03
9	0400	21.6	< - 8	210	07
9	1600	21.8	-0.2	270	06
10	0400	20.8	< -10	320	03
10	1600	18.2	-3.8	345	13
11	0400	10.6	9.4	250	15
11	1600	13.0	-9.0	165	06
12	0400	14.6	< -15	205	01
12	1600	14.6	-7.0	360	03
13	0400	14.6	-7.0	360	03
13	1600	M	M	M	M
14	0400	17.4	< -13		

*M - missing

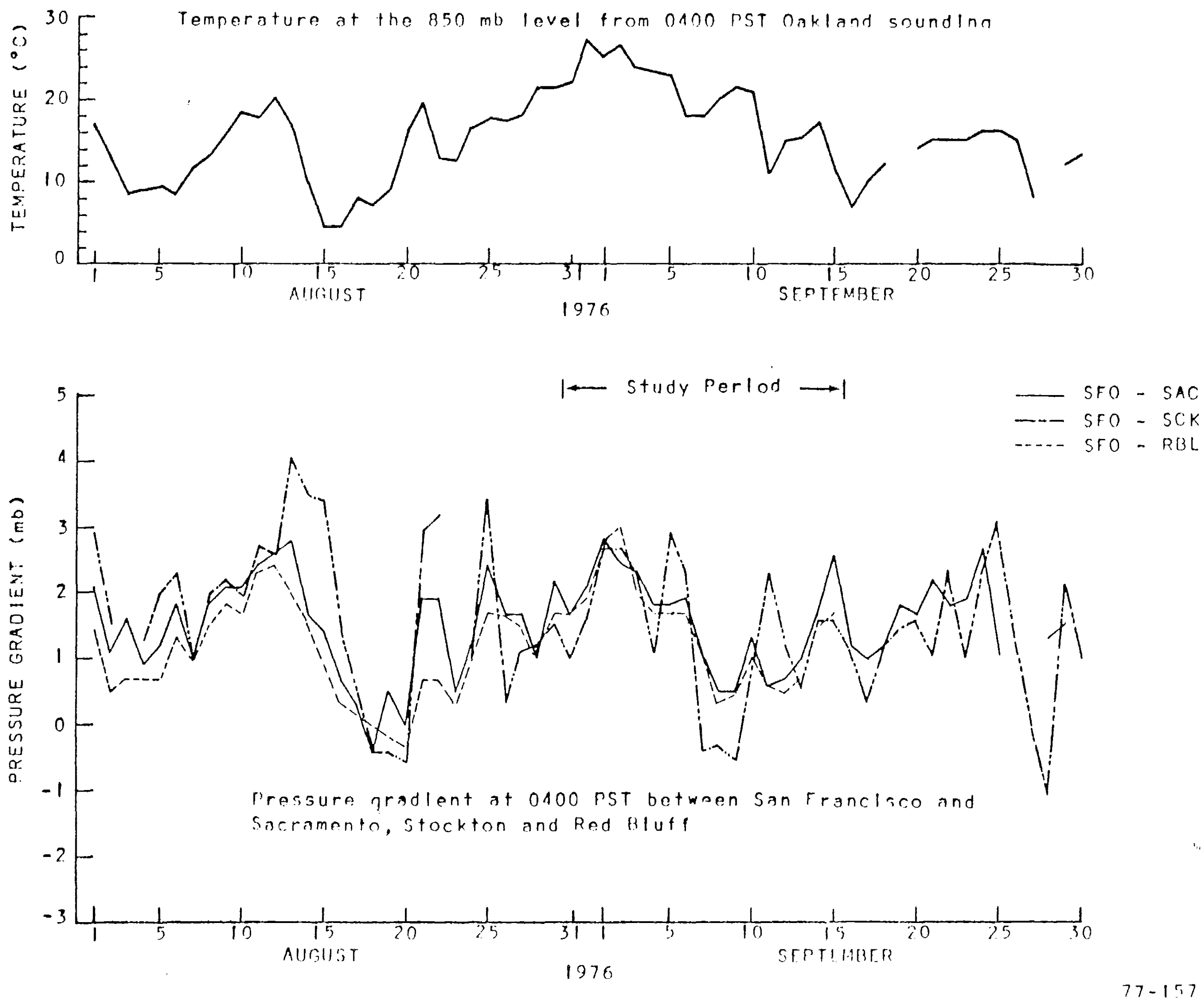

Figure 5-21

850 mb Temperature and San Francisco-Inland Pressure Gradient During August and September, 1976

a fairly weak onshore flow until the strength of the ventilation began to become dominant on September 1. The period from August 29-31 was remarkable for unusually high oxidants in the Delta inflow area. Such maximum ozone readings are consistent with the large-scale meteorology as indicated by temperatures aloft.

Although the 850 mb temperature is a good relative indicator of the strength of the capping inversion, the mixing depth is actually the critical parameter that determines the probable pollution levels associated with a given meteorological regime. Temperatures aloft and mixing depth are generally directly correlated, but not necessarily completely equivalent. In particular, high temperatures aloft lead to high surface temperatures such that a strong inversion may be "broken" by intense surface heating while a weaker inversion may persist on cooler days. In addition to the temperature data, the winds aloft are good indicators of the mixing depth.

The low-level inflow into the Delta remains shallow until surface heating and convective motions erode the inversion strength. When the inversion breaks, a dramatic deepening of the mixing depth is evidenced by a strong surge of fresh marine air throughout the mixed layer. If the inversion persists, however, then the deepening of the marine air is very gradual.

Figures 5-22 and 5-23 show the sudden transition from a low morning mixing depth to the deeper afternoon layer within one or two hours. The mixing depth over the Strait may remain at 300-400 meters while rising to 2000 meters or more inland over the Delta. Although not all days showed such a sharp transition, the depth of the mixed layer was generally readily discernible from the wind data. By combining the information from the Oakland radiosonde, the Sacramento sounding, and the pilot balloon data at the various wind measurement sites, a general picture of the mixing layer structure can be synthesized. Table 5-6 shows the variations in the depth of this layer over the Montezuma Hills during the various tracer releases at the beginning, midpoint, and end of each release. Additional modifications to account for terrain influences are necessary to infer the layer structure in other areas, but the estimates in Table 5-6 are indicative of the transition zone from the predominantly marine climate of the Bay area to the continental regime of the Valley.

5.4 Air Quality Summary

Air quality during the intensive study period was characterized by two unique air quality phenomena which are characteristic of the meteorology/air quality relationships of the Bay area/Delta/Central Valley. Both sets of conditions are typical of the weather patterns that tend to

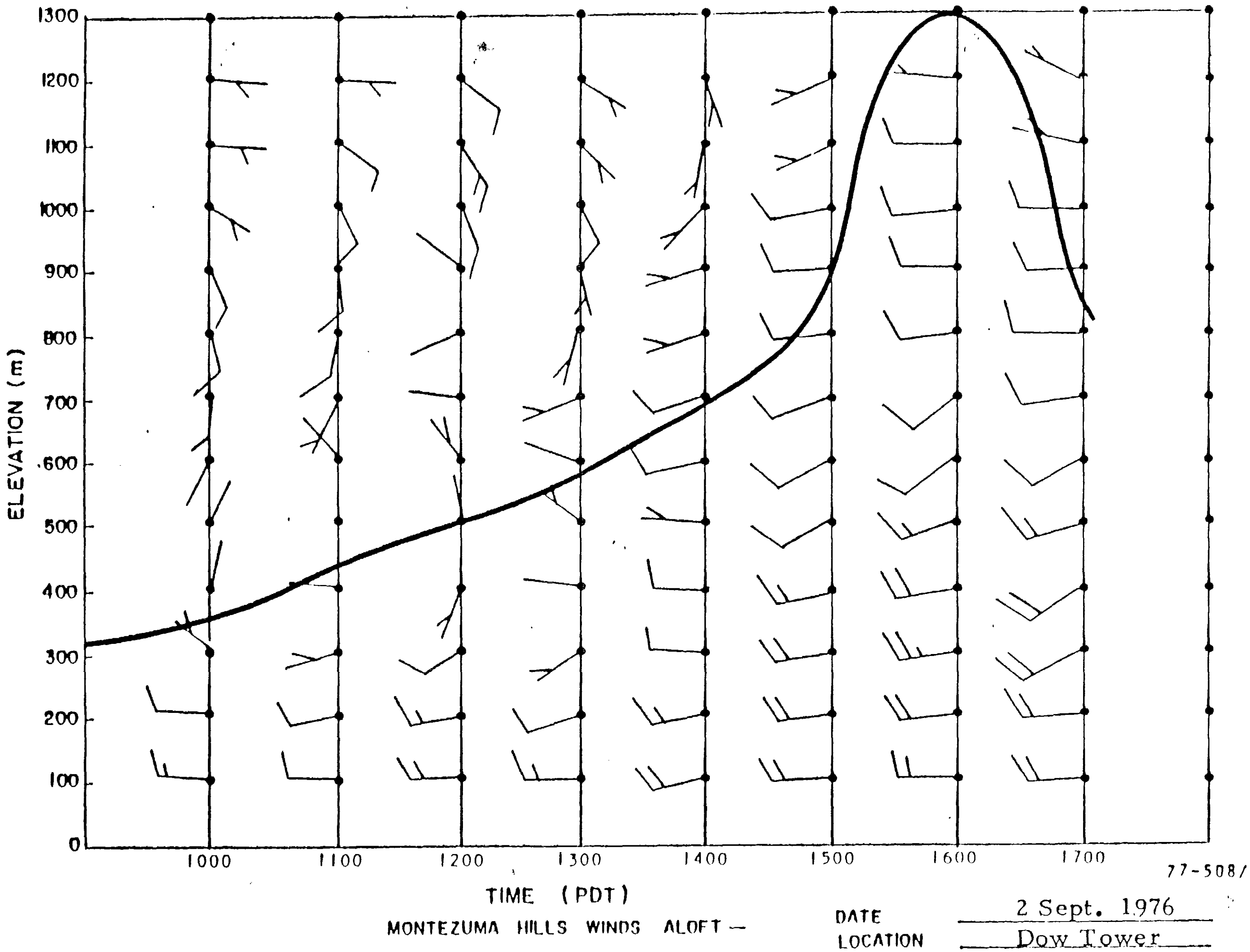

Figure 5-22

Approximate Mixing Depth (Marine Layer) Over Montezuma Hills

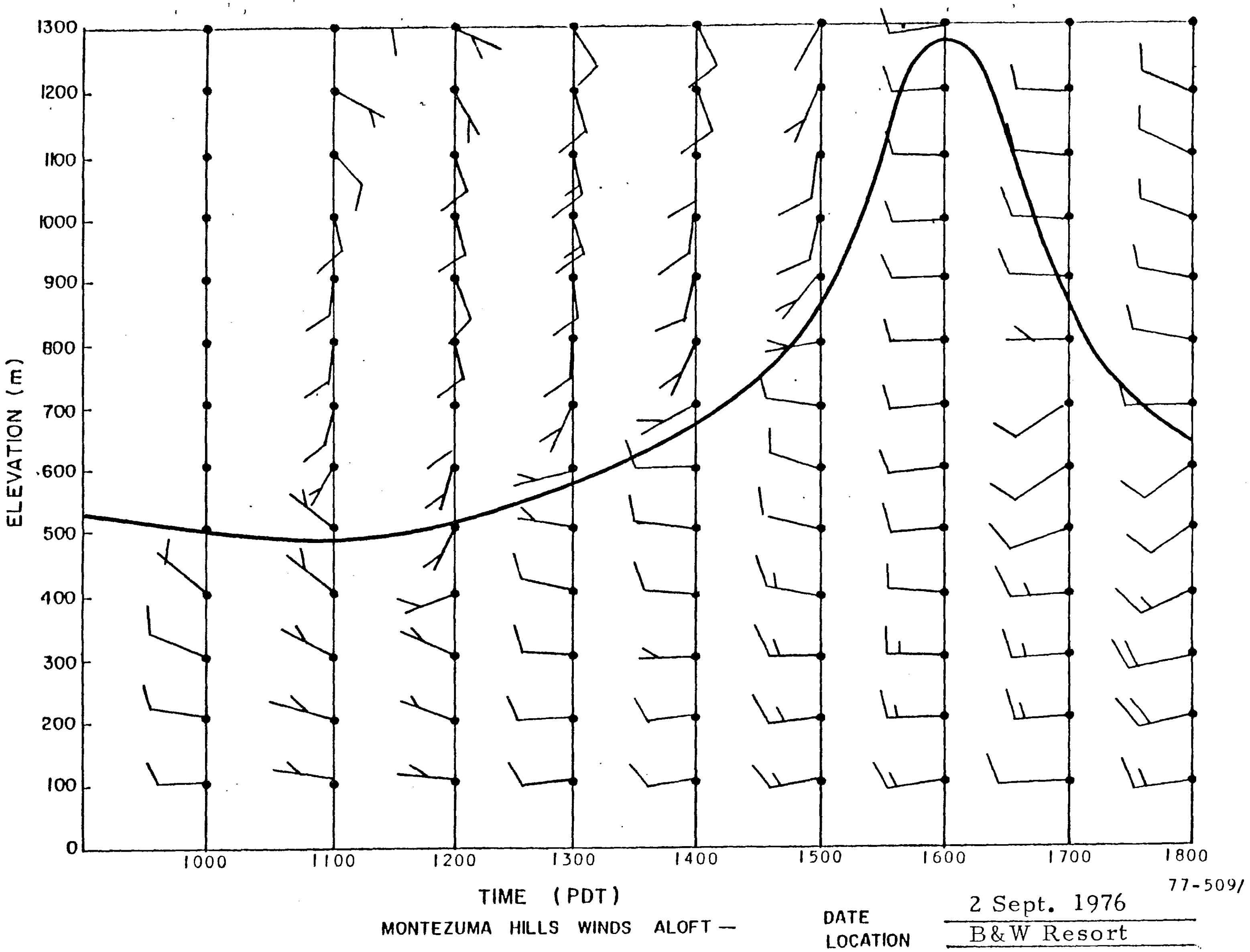

Figure 5-23

Approximate Mixing Depth (Marine Layer) Over Montezuma Hills

Table 5-6

MIXING LAYER DEPTH OVER THE MONTEZUMA HILLS
SUMMER INTENSIVE STUDY

Test Number	Date (1976)	Time (PDT)	Time During Test		
			Beginning (m)	Mid-Point (m)	End (m)
1	08/31	1200-1700	500	600	2300
2	09/02	1100-1600	500	600	1300
3	09/05	0000-0500	300	300	300
4	09/06	1800-2300	500	400	400
5	09/09	1130-1330	-	1000	1400
6	09/10	0600-1100	500	500	500
7	09/13	0600-1500	300	400	500
8	09/14	0730-1300	300	400	600

maximize the impact of the Bay area on downwind receptor locations. Although the highest 1976 air quality concentrations (in terms of oxidant/ozone) at all study area stations were not necessarily recorded during this intensive study, the two sets of conditions can serve as prototype meteorological inputs around which a definition of worst-case conditions can be constructed.

The two conditions encountered between August 30 and September 15 were (1) a very strong and low inversion accompanied by onshore winds and (2) a light offshore gradient with high pressure inland. The former situation leads to limited vertical dispersion with a maximum Bay area impact on downwind locations such as the Delta, Central Valley, or the Hayward Gap. The latter situation creates significant air quality deterioration within the Bay area itself because the horizontal advective ventilation mechanism is almost completely suppressed. High ozone values during the offshore circulation pattern have been well-documented by the BAAPCD, but the low inversion effect on the Delta has previously not been closely analyzed.

A better understanding of the meteorological events from August 28-30 at the start of the summer study is extremely important because of the high ozone values reported at the Brentwood air quality station during this period. The true magnitude of the Brentwood ozone values may be somewhat in doubt because of calibration questions but the trends in the data were consistent with meterorological expectations and corresponding data at the Montezuma Hills site.

Hourly average ozone values at Montezuma Hills, Brentwood, Sacramento, and Stockton for the study period are shown in Figures 5-24 through 5-27. Considering only September 1-15, 1976, it should be noted that the Montezuma Hills and Brentwood sites typically experience higher ozone values than do either Sacramento, Stockton, or even the ARB trailer in downtown Rio Vista. Given the good agreement of both the Montezuma Hills and Brentwood sensors with a reference instrument at the conclusion of the study, the apparent differences between air quality at the two project measurement sites and other surrounding stations is probably a real phenomenon. Table 5-7 illustrates the ozone maximum in the middle of the study area, surrounded by the lower ozone values at Pittsburg, Fairfield, and Rio Vista. In examining the date of occurrence of each station's maximum, the Brentwood site groups with the Valley stations on September 1-3, whereas; the Montezuma Hills and Rio Vista ARB sites are more closely related to the Bay area and Delta stations at Pittsburg and Fairfield. In order to define a worst-case background one needs to distinguish between localized phenomena where an offshore or northerly wind prevails over the Hills (September 9) and maximum Central

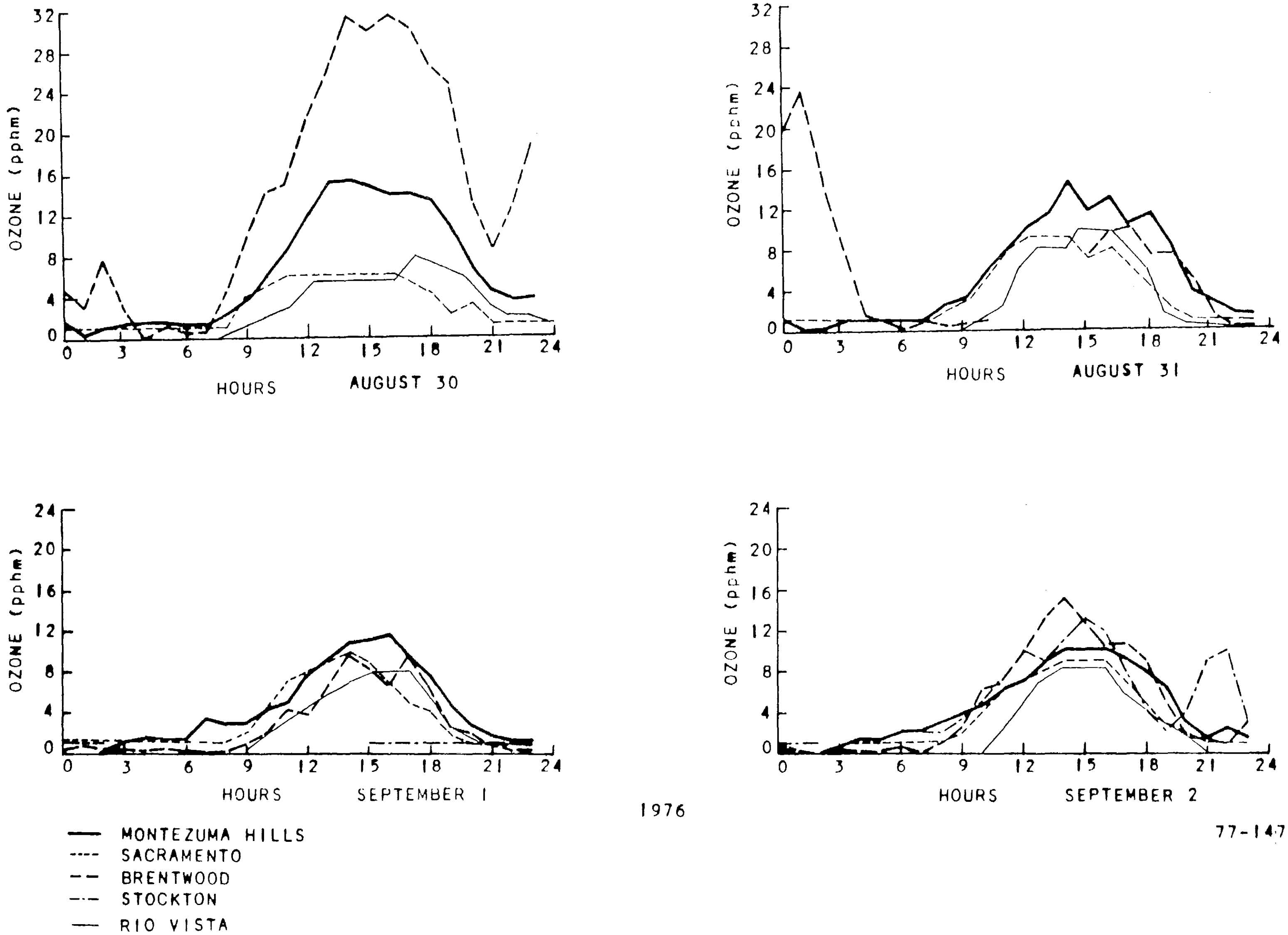

Figure 5-24

Diurnal Variation in Ozone
(August 30-September 2)

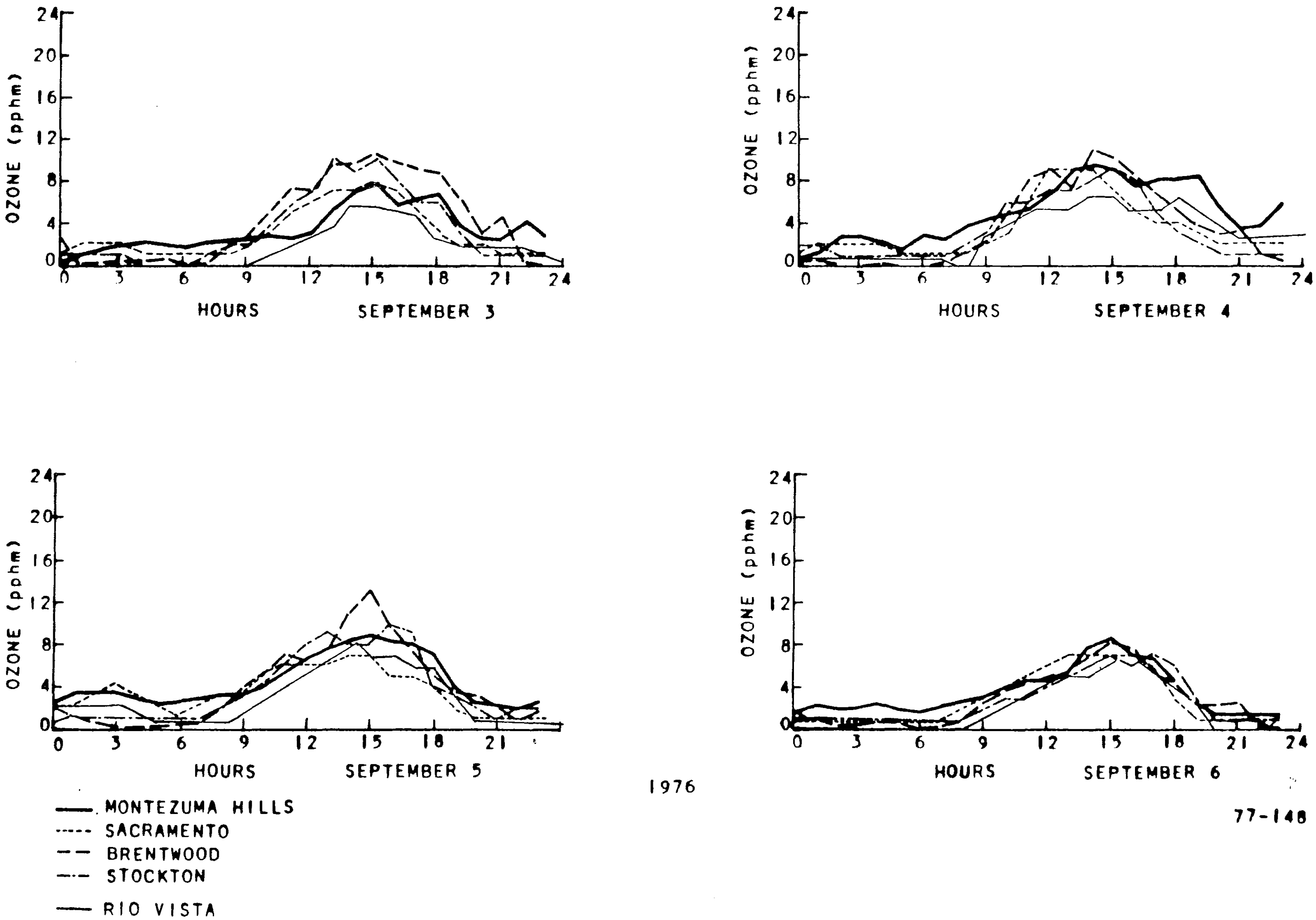

Figure 5-25

Diurnal Variation in Ozone
(September 3-September 6)

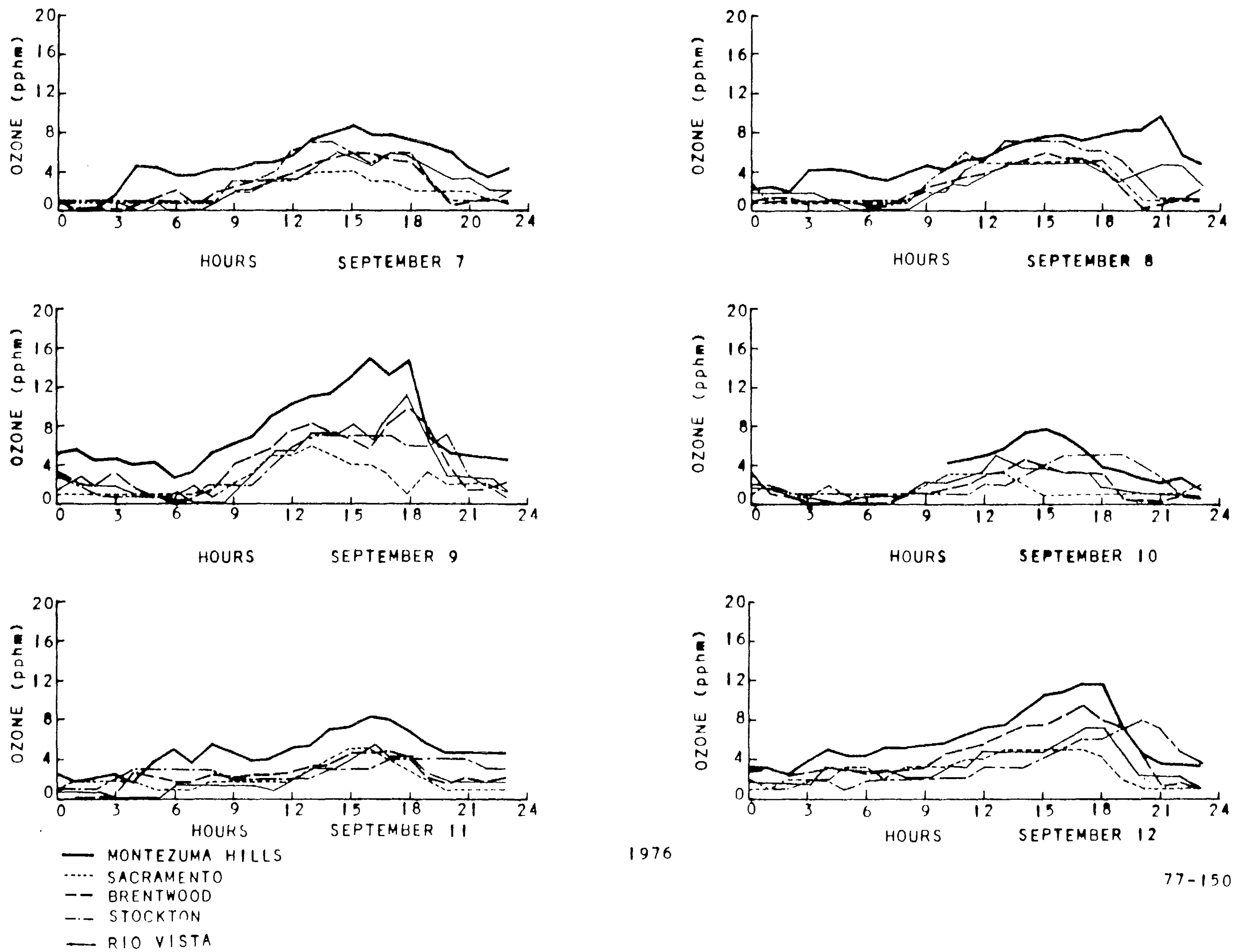

Figure 5-26

Diurnal Variation in Ozone
(September 7-September 12)

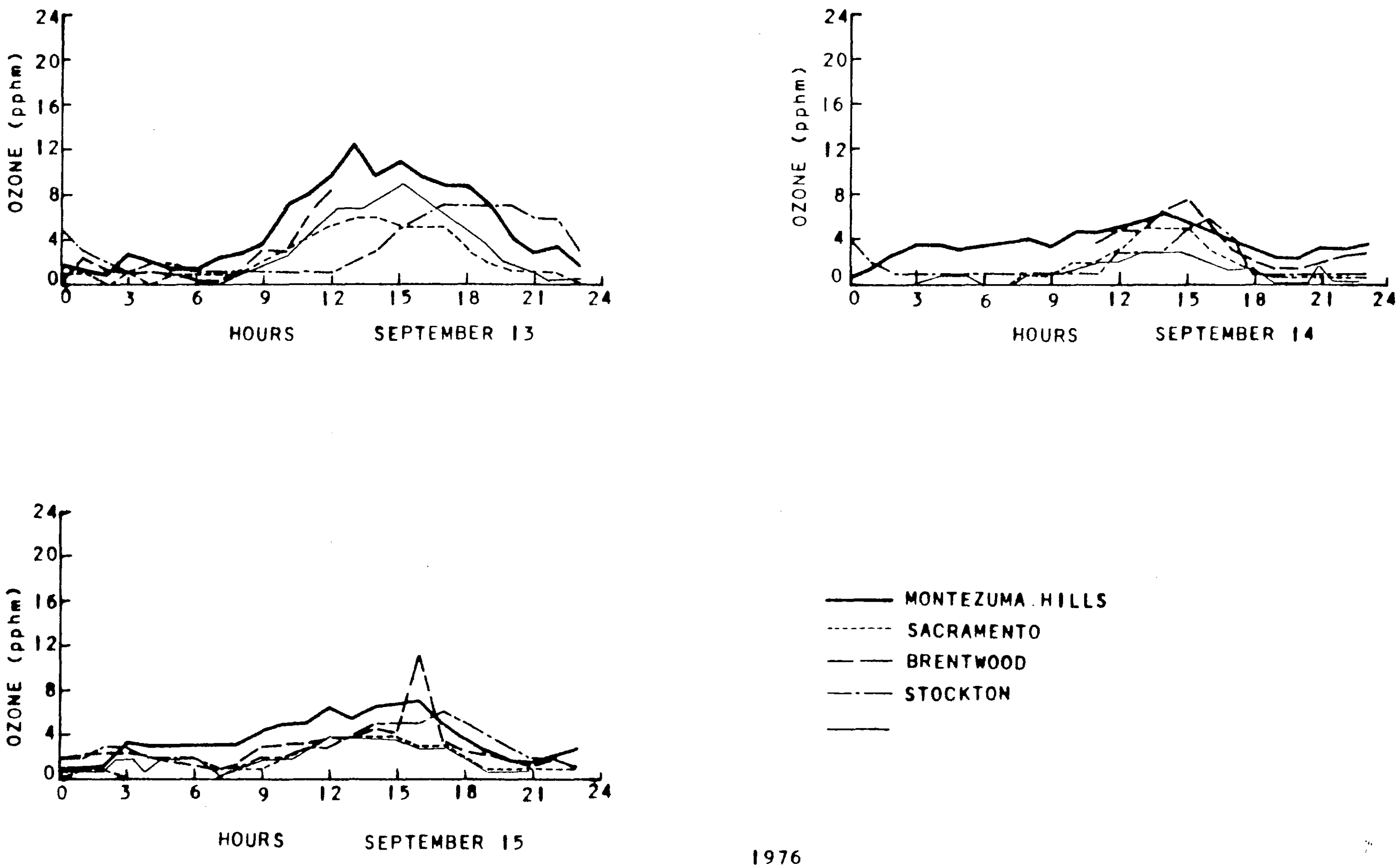

Figure 5-27

Diurnal Variation in Ozone
(September 13-September 15)

Table 5-7

OZONE MAXIMA CHARACTERISTICS

AUGUST 31-SEPTEMBER 14, 1976

	Woodland	Sacramento	Stockton	Pittsburg	Fairfield[1]	Brentwood	Montezuma Hills	Rio Vista
Days with ozone > 0.08 ppm	3	3	4	2	1	7	8	1
Days with ozone ≥ 0.10 ppm	2	1	3	1	1	7	7	1
Maximum hourly average (ppm)[2]	0.11	0.10	0.12	0.11	0.10	0.15	0.15	0.10
Date of maximum[3]	9/2, 3	9/1	9/2	9/9	9/9	9/2	9/9	9/9
Days with highest hourly average among 8 stations considered[4]	1	0	0	0	0	4	9	0

[1] Total oxidant measured in Fairfield
[2] Clock-hour hourly maximum, i.e., 1300-1400, 1400-1500, etc.
[3] September 1 data missing at Woodland and Stockton--a fairly smoggy day in the area
[4] One additional day tied between Brentwood and Montezuma Hills

Valley impact which occurs under low inversions and a strong onshore gradient (September 13). The transition zone for maximum impact under these two conditions appears to occur a few miles east of the Montezuma Hills.

The time scale for photochemical reactions is on the order of one or more hours which allows the emissions from the proposed development to travel downwind at least ten to twenty miles. It is therefore apparent that the meteorological scenario of onshore conditions and restricted vertical mixing defines a worst-case meteorology for oxidant impact.

Having defined the meteorological phenomena conducive to maximizing the Montezuma Hills industrialization impact, one further needs to characterize the background values upon which such impact will be superimposed. Given the pronounced differences in ozone values between the Montezuma Hills site and the Rio Vista ARB site separated by only about seven miles, it becomes very difficult to define a representative value of background pollutant concentrations near the site itself, much less downwind in the development impact area.

This difficulty in defining representative background oxidant levels near the Montezuma Hills and the surrounding environment was best characterized by the events of August 27-31. The maximum one-hour average ozone readings in Brentwood reported by Rockwell International (Gemmill et al, 1977) came very close to the maximum Southern California hourly average reading for 1976 of 0.38 ppm measured in Upland on August 30. Maximum hourly averages at Brentwood, Montezuma Hills and the Rio Vista ARB site are shown in Table 5-8 along with corresponding daily peak values.

Although both the Brentwood and Montezuma Hills sites continued to show higher ozone values than the Rio Vista site throughout the entire study the disparity was not nearly as dramatic as prior to and at the beginning of the field project. In order to further access the possibility of such high values in Brentwood, a detailed case study of the events on August 30-31 was performed.

Figure 5-28 is a multiple-parameter plot of air quality and the wind direction and speed during a possible episode day. During the early morning hours of August 30, ozone values at Brentwood were near zero and the NO_x values were relatively high in response to light winds (2-4 mph), local traffic and probably the school bus traffic active from 6-8 AM. Ozone value began to rise sharply after 8 AM until the sharp rise was temporarily suppressed by the arrival of the Pittsburg/Antioch industrial and vehicular "plume." SO_2 levels increased sharply at 0900 PDT in response to a

Table 5-8

COMPARISON OF MAXIMUM HOURLY AVERAGES AND DAILY PEAKS DURING THE REPORTED BRENTWOOD OZONE MAXIMA[1]

Date/Ozone (ppm)	Brentwood Max. Hourly Average	Brentwood Daily[2] Peak	Montezuma Hills Max. Hourly Average	Montezuma Hills Daily[2] Peak	Rio Vista (ARB) Max. Hourly Average	Rio Vista (ARB) Daily Peak
Friday, August 27	0.30	M	M	M	0.07	0.08
Saturday, August 28	0.34	0.45	0.18	0.20	0.10	0.11
Sunday, August 29	0.37	0.40	0.16	0.16	0.10	0.11
Monday, August 30	0.33	0.39	0.15	0.24	0.08	0.08
Tuesday, August 31	0.24	0.28[3]	0.14	0.25	0.09	0.10

M = Data not available

[1] Some data based on preliminary Rockwell data, subsequent calibration may have adjusted values up to ± 0.02 ppm

[2] Instantaneous peak sampled at 5-minute intervals

[3] Occurred during the night of August 30-31 around 0100-0200 PDT

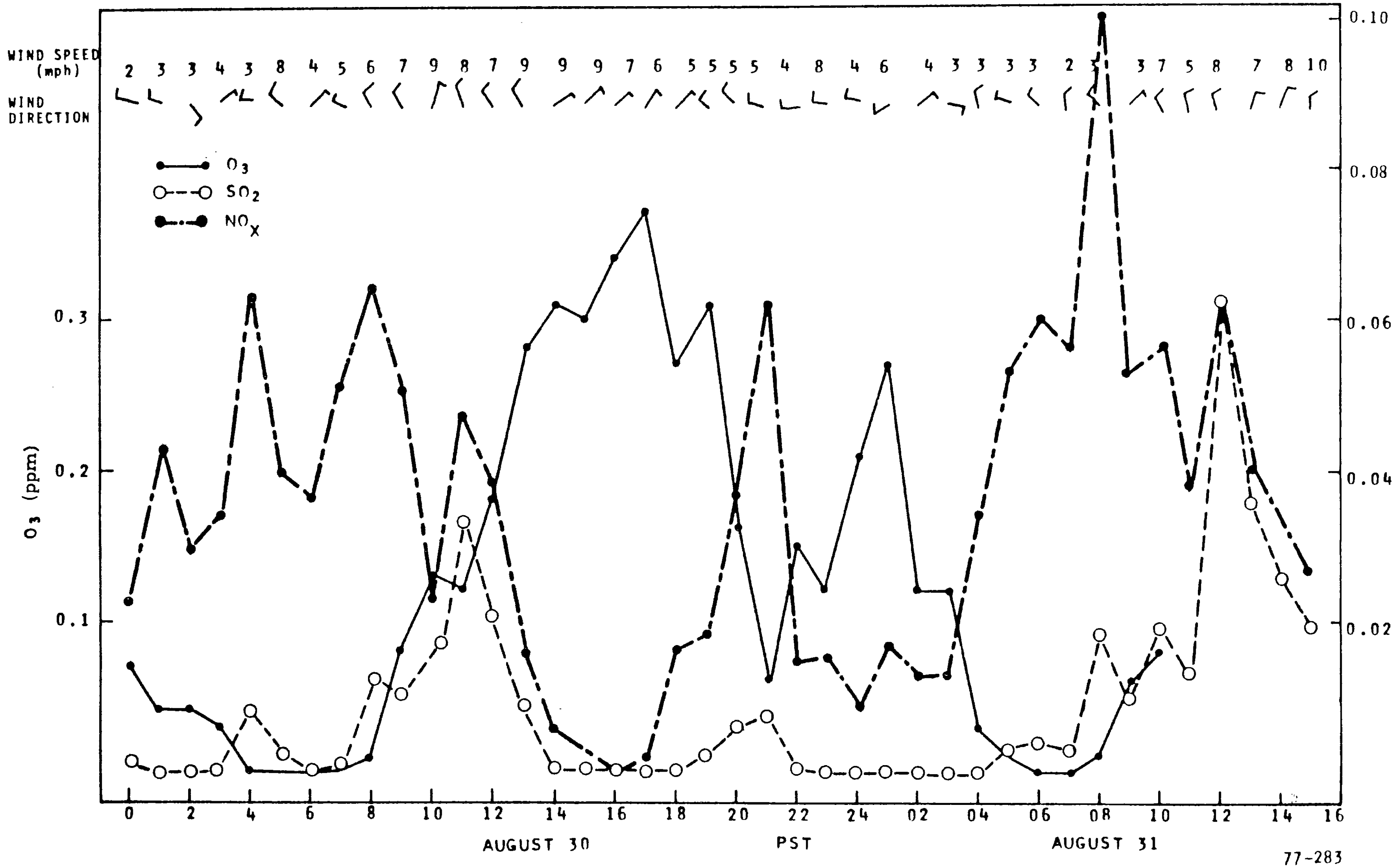

Figure 5-28

Average Hourly Values of Pollutants - Brentwood
(August 30-31, 1976)

windshift from the northwest to the north and north-northeast reaching an instantaneous maximum level of 0.67 ppm at 1055 PDT. Simultaneously, the NO_x level rose to 0.08 ppm with a little more than half NO_2 and a little less than half NO indicating a reasonably fresh source of pollutants with $NO \rightarrow NO_2$ conversion in progress. SO_2 levels continued to be slightly elevated while dropping slowly until 1355 PDT when a rapid transition from northerly to northeasterly winds brought levels to background within a few minutes. NO_x levels also continued to be slightly elevated throughout the period of northerly winds until they too dropped suddenly to background levels after the 1355 PDT windshift. By 1130 or 1200, however, NO levels had dropped to their baseline level for that day indicating little ozone scavenging was taking place by noon. Ozone levels rose quickly once the NO was depleted and stayed at 0.18 ppm or higher from 1215-1950 PDT. The ozone values appeared to be almost independent of the wind direction since little change in ozone was noted when the northeasterlies reversed quickly back to northerlies around 1800 PDT. Slight increases in SO_2 and NO_2 after the wind reversal back to the north indicated that Brentwood was again under the influence of the emissions from Pittsburg and Antioch but no real perturbation in the ozone pattern was evident. NO_x levels rose throughout the early evening hours with a corresponding decrease in ozone with a maximum NO_x concentration of 0.062 ppm at 2100 and a simultaneous ozone minimum of 0.06 ppm.

In addition to the very high ozone maxima which are difficult to understand from our dyamic/photochemical knowledge of Bay area-Central Valley interactions, the secondary ozone maximum later during the night at Brentwood also presents certain difficulties in conceiving a conceptual model of air quality and airflow over the area. Ozone values rose to a nocturnal maximum of 0.28 ppm as the winds progressively shifted from the northwest into the west and west-southwest. The penetration of a sea breeze across the hills behind Mt. Diablo suggests that ozone previously existing aloft in the San Ramon Valley may have been carried eastward to downwash into the Brentwood area. Subsequent relative secondary ozone maxima of much lower concentrations on September 3, 6, 7, 9, 10, 12, 13, and 15 implies that some mechanism for ozone recirculation does exist that leads to a small ozone increase at night when the lee-side coast range downwash may transport pollutants downward from protected layers aloft.

In summary, the behavior of NO_x and SO_2 in the Brentwood area is directly related to northerly winds that bring emissions southward into Brentwood from the source area along the industrialized south bank of the river. The existence of non-negligible ozone values in the Brentwood area as a result of emissions carried from the Bay area across the Montezuma

Hills and then turned southwestward in the "Brentwood eddy" is also easily established from the available data. The possibility of a nocturnal secondary maximum created by lee-side turbulence or downwash associated with penetration of the sea breeze from the west is also a plausible dynamic mechanism. Based upon representative ozone precursor source strengths and low-level ozone decay during the evening hours, the magnitude of the ozone values measured at Brentwood from August 27 through the early morning hours of August 31 remain questionable despite the excellent calibration agreement at the conclusion of the field test. Because of the relatively isolated occurrence of such a phenomena and the lack of precise traceability of the readings, they should be accepted as an indicator that a definite ozone problem (and possibly other critical pollutants) may exist in the Brentwood area under certain meteorological conditions.