2A METEOROLOGY

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FINAL REPORT

SACRAMENTO MUNICIPAL UTILITY DISTRICT (SMUD) METEOROLOGICAL INVESTIGATION

Prepared for

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SUMMARY

The Sacramento Municipal Utilities District (SMUD) has proposed construction of a nuclear power plant near Clay, California about 23 miles southeast of Sacramento and 27 miles north-northeast of Stockton. This report is a study of the meteorology and climatology of the proposed site, Rancho Seco, based upon long-term data available primarily from Stockton, Sacramento and Mather AFB. In order to determine the applicability of these data to Rancho Seco, meteorological measurements were made at Rancho Seco for a six-weeks period and compared with the other sites for the same period.

The six-weeks study at Rancho Seco included the measurement of wind speed and horizontal and vertical wind direction at 53 feet above the ground, the temperature at 6 feet and the temperature difference between 6 and 53 feet, and the humidity at the 6-foot level. In addition to continuous records of these parameters during the period, two field trials were held to define the wind trajectory and associated meteorological conditions throughout the Stockton, Sacramento, Rancho Seco area. These trials included pibals (balloon wind measurements) within 2000-3000 feet of the ground at several sites within 10-15 miles of Rancho Seco for midday and nighttime conditions.

The climate of Rancho Seco is generally that of the Great Central Valley of California. Summers are hot and cloudless while winters are mild. The rainy season occurs between October and May and heavy radiational fog often exists in December and January. Tornadoes and thunderstorms are infrequent. Tornadoes occurred only 22 times in California between 1953 and 1962. Thunderstorms occurred an average of three times each year at Stockton and five times at Sacramento. Similar occurrences would be expected at Rancho Seco.

The winds at Rancho Seco have two major dynamic controls - the thermally-driven "marine" flow in the summer and the synoptic pressure gradient systems of mid-winter. Spring and fall are largely controlled by thermal gradients.

072

The Central Valley warms greatly during the day resulting in a marked thermal contrast between the Valley and the air over the Pacific. The Coast Range separates the marine air from warm valley air except for a gap through the range formed by Sacramento-San Joaquin Rivers. The heavy marine air flows through this gap and splits into a northerly flow into the San Joaquin Valley and a southerly flow into the Sacramento Valley. The divergence zone between the two flows usually lies between Stockton and Sacramento near Rancho Seco. The divergence zone is usually north of Rancho Seco during the day resulting in west to northwest winds. The cool marine air usually arrives around 1800 PST. As the air in the Valley cools, the flow decreases and calms may set in. If the drainage from the Sierra Nevada is sufficient, the winds may shift to southeasterly and again increase in speed at Rancho Seco. During the hottest mid-summer months, the light westerly winds may persist all night. During the winter, the synoptic gradients prevail much of the time and the wind trajectories over the Sacramento-Stockton-Rancho Seco area are reasonably uniform.

Sacramento and Stockton extreme wind speeds have been in good agreement for the periods of record. The maximum observed at Sacramento (longest period of record) has been 70 mph. Since these winds are associated with synoptic gradients, Rancho Seco can be expected to be similar.

No precipitation data are available for the Rancho Seco site. Since the precipitation is associated with synoptic scale gradients, Stockton, Sacramento and Rancho Seco should have similar characteristics. The yearly normal rainfall for Sacramento is 16.29 inches and 13.37 inches for Stockton with maximum 24-hour amounts of 5.59 and 3.01 inches respectively. At Sacramento precipitation occurs with south to southeasterly winds 65 per cent of the time. Frozen precipitation is extremely rare and of very small quantities.

The surface temperatures at Rancho Seco were found to agree on the average with Stockton and Sacramento. Temperature inversions at the ground can be expected every night during the summer, usually modified by the marine airflow in the evening which results in the top of the inversion being at several hundreds of feet. During the winter, shallow (a few hundred feet) but intense surface inversions can be expected at night during light wind conditions. When they are associated with fog, they may persist throughout the day, occasionally for several days at a time.

On an average, relative humidities at Stockton, Sacramento and Rancho Seco were found to agree well with each other.

From an analysis of long-term climatological statistics from Sacramento and Stockton, an F condition with a wind speed of 2.4 m/sec is recommended for use in the zero to two-hour dosage model.

Turbulence measurements made at the site were used to calculate cloud widths (σ_y) for comparison with existing diffusion classification systems. The Fuquay method of using ($\sigma_\theta \bar{u}$) to estimate cloud widths was used to calculate expected values of σ_y for releases of 10 minutes and one-hour duration. It was found that the cloud widths calculated from on-site observations agreed well with the Pasquill system for categories A through E. For categories F and G the observed cloud widths for one-hour releases were considerably larger due to the meandering of the wind under these stable conditions. It is recommended that the Pasquill system be used for the Rancho Seco site but with new F and G curves to provide more realistic cloud widths under stable conditions. A slight modification in the σ_z curves is also recommended to adapt the calculations to the occurrence of an average nocturnal inversion base height of 200 m as determined from Oakland data.

074

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

076

LIST OF TABLES

077

I. INTRODUCTION

The Sacramento Municipal Utilities District (SMUD) has proposed construction of a nuclear power plant at a site about two miles east of Clay. The proposed site (Rancho Seco) is about 23 miles southeast of Sacramento and 27 miles north-northeast of Stockton in the lower Sacramento Valley of California.

This report includes the results of a six-weeks meteorological study at the proposed site and a comparison of the meteorology of that site with available meteorological data from nearby locations. Having established this comparison, the long-term data for the nearby locations have been processed and utilized in developing climatological descriptions of the site. These descriptions have included the dispersion and wind trajectory characteristics of the site.

II. SCOPE

The six-weeks on-site study included the provision and installation by MRI and operation by SMUD personnel of wind and temperature measuring equipment at the site. The recorded measurements included the horizontal and vertical wind direction and wind speed at the 53-foot level and the temperature at the 6-foot level with the temperature difference between the 6 and 53-foot levels. In addition, a hygrothermograph recording temperature and humidity was operated within a thermoscreen at the bottom level. All data were removed from the recorders and returned to MRI weekly for reduction and analysis.

In addition, two field programs were carried out to obtain information on the air-flow trajectories within 10-15 miles of the proposed site. These consisted primarily of a series of pibal (pilot balloon) observations of the winds within the lower 2000-3000 feet taken at about a dozen locations around the site (see Site Climatology). A set of these observations was taken for midday and nighttime conditions on each of two days for each of the field programs. Surface temperature and wet-bulb temperature were measured concurrently at each location. Aircraft temperature soundings were made occasionally over the Rancho Seco site during the pibal observation period. The first of the two field programs (20-23 April) occurred during a period of thunderstorm and rain shower activity associated with a large-scale synoptic flow pattern. The second field program (12-14 June) was held during a more typical spring through fall mesoscale flow pattern to be described in the section on Site Climatology.

Meteorological data from nearby locations were obtained during the on-site program for comparison with the Rancho Seco site data. Long-term meteorological data from the nearby locations were obtained and processed to develop the climatology of the site utilizing comparative results of the six-weeks study. The availability of these and long-term climatological data are listed in more detail in the following section.

079

III. DATA SOURCES

A. Off-Site

Meteorological data are available for past years from government weather observation stations. These data generally include hourly observations of wind direction and speed, temperature, dew point, cloud conditions, precipitation, and weather. Various climatological summaries are also available for some sites. Data utilized in this report include:

Sacramento (USWB at Municipal Airport)

1. Hourly Observations, 1963, 1965
   15 April-15 June 1967 (microfilm or copy)
2. Hourly Observations, January 1949-December 1955
   (magnetic tape)
3. Summary of Hourly Observations, 1951-1960
   (printed material)
4. Local Climatological Data, 1965, 1966
   (printed material) including normals, means and extremes for the period of record.

Stockton

1. Hourly Observations, 1963, 1965
   15 April-15 June 1967 (microfilm or copy)
2. Hourly Observations, January 1949-December 1954
   (magnetic tape)
3. Local Climatological Data, 1965, 1966
   (printed material) including normals, means and extremes for the period of record.

Mather AFB

1. Hourly Observations, 1963, 1965
   15 April-15 June 1967 (microfilm or copy)
2. Uniform Summary of Surface Weather Observations - Part C (Flying Weather Wind Roses) 1952-1961, Part E (Psychrometric Summary) 1952-1961.

In addition to the standard weather observation stations, wind data have been collected at several sites between Sacramento and Stockton for various periods in conjunction with agricultural studies being made by H. B. Schultz of the University of California at Davis. These include:

1. Terminous - April through September for 1958 through 1963
2. "Galt" (several miles from the town) - April through present 1967
3. Walnut Creek - TV Tower

The "Galt" data appear to be inconsistent and were not utilized. Unfortunately, the Walnut Creek data are not yet available. It is hoped that data from these sites will be available for later usage.

All data sites are shown on Fig. 1. It should be noted that no data sources have been found east of the proposed site.

B. On-Site

The primary source of data from the proposed site is the meteorological instrumentation operated on site from 22 April through 15 June 1967 with a more limited system operating through the present time. The initial meteorological measurements included:

1. MRI VectorVane measuring and recording continuously (analog) the horizontal and vertical wind direction and speed at the top of a telephone pole (53 feet).
2. Fast response (thermistor) temperature measuring system with a cycled (5 minutes each) recording of the temperature at the 6-foot level and the difference in temperature between the 6 and 53-foot levels.
3. Hygrothermograph recording temperature and humidity near the base of the pole (in thermoscreen) - see Figs. 2 and 3.

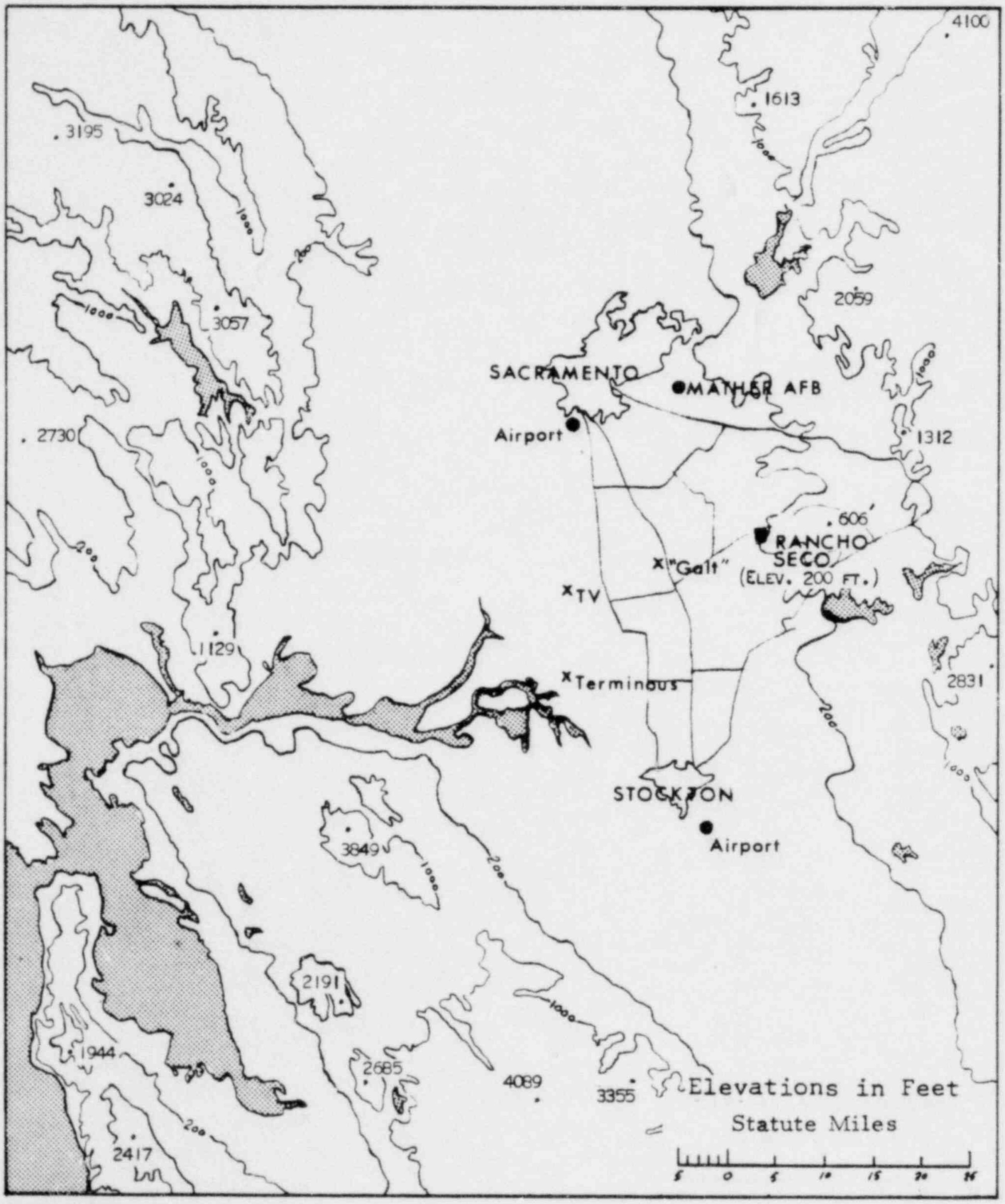


Fig. 1. PROPOSED SITE AREA

082

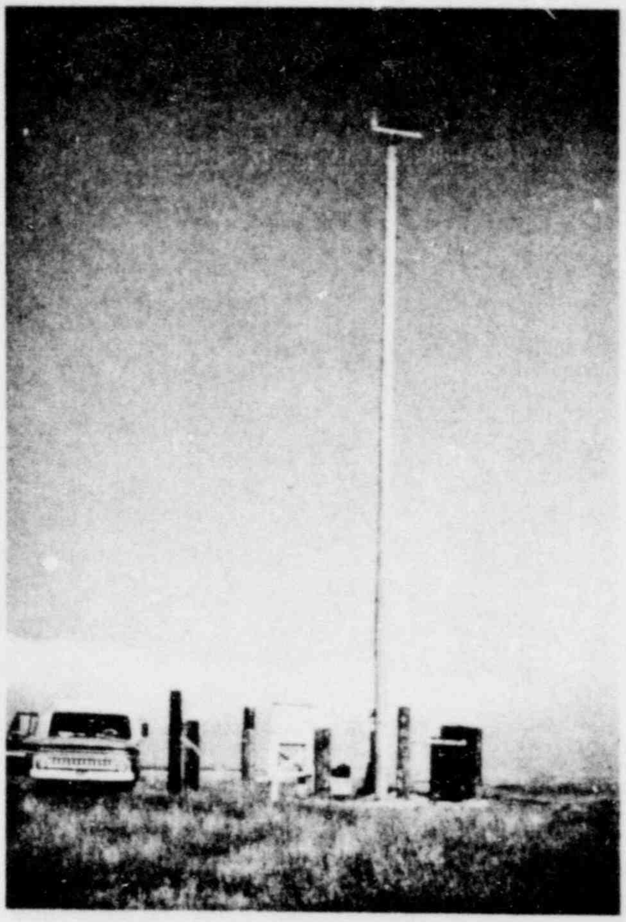


Fig. 2. METEOROLOGICAL INSTRUMENTATION

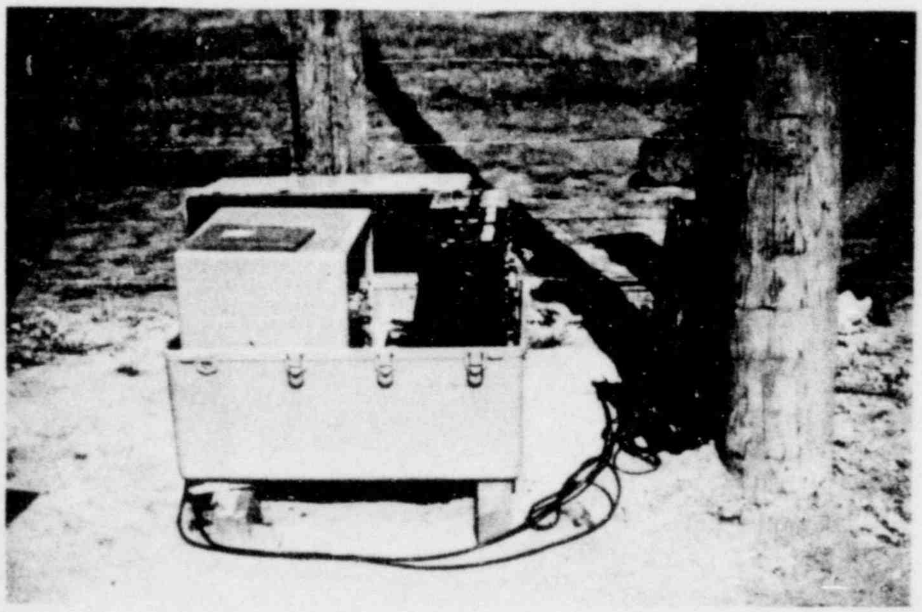


Fig. 3. METEOROLOGICAL ELECTRONICS AND RECORDERS

083

About 15 June, the wind and temperature systems were replaced with a unit at the top of the pole measuring wind direction and speed. The period from 15 June to 10 July has been reduced and is utilized in the report. The hygrothermograph remains at the surface location.

During the field programs the instrumentation system above was supplemented with pibal observations at the site and within 10-15 miles of the site to determine the wind trajectories in the area. These data were reduced at MRI to wind directions and speeds at given levels based upon the standard ascent rate of the balloons. At the time of the balloon release, temperature and dew point readings were taken. In addition, temperature soundings were taken by a light aircraft over Rancho Seco to define the stability conditions.

IV. SITE CHARACTERISTICS

A. Terrain

The San Joaquin-Sacramento Valleys are oriented in a northwest-southeast direction between the Sierra Nevada to the east and the Coast Range along the Pacific Ocean to the west. Sacramento and Stockton are east of the gap in the Coast Range associated with the Sacramento and San Joaquin Rivers. The Sacramento and Stockton Airports are at 17 and 22 feet MSL, respectively. The terrain rises steadily to 200 feet at the proposed Rancho Seco site. East of the site the land becomes more rolling, rising to an elevation of 606 feet at 7 miles and increasing in elevation thereafter as one approaches the foothills of the Sierra Nevada which rise to over 10,000 feet 65 miles east of Rancho Seco.

The Rancho Seco site is located in an area of flat to lightly rolling terrain. The land is used primarily for agriculture and generally lacks tree cover except in isolated patches along the streams.

B. Reservoirs

The closest reservoir at present is the Camanche Reservoir about 10 miles southeast of Ranch Seco. Two additional reservoirs have been recommended in the "Southeast Area Plan" by the Sacramento County Planning Department and adopted by the Sacramento County Board of Supervisors. One of these is about 4 miles southeast of the site and the other 8 miles to the northwest. Both new dams would be used for irrigation and flood control.

085

V. SITE CLIMATOLOGY

A. General

The climatology of the Rancho Seco site is similar to other locations in the Great Central Valley of California. Cloudless skies prevail during the summer and much of the spring and fall. The rainy season is in the winter (December through March) when more than two-thirds of the annual rainfall can be expected. Heavy radiational fogs occur in mid-winter, primarily in December and January and may last for several days.

The most important controlling geographical influence on the climate results from the mountains which surround the Valley to the west, north and east. During the winter, storms which pass through the area are moderated by the mountains which collect much of the precipitation. The rains that occur in the Valley are usually accompanied by south to southeast winds. The cold north and northwest winds pass over mountains to the north where the air is warmed dynamically by descent into the Valley resulting in comparatively warm, dry winds. A similar condition occurs infrequently in the summer when a steep northerly pressure gradient develops, producing a pronounced heat wave.

In the summer, the synoptic pressure patterns weaken and a thermal gradient develops between the heated Valley and cool marine air along the Pacific Ocean. The Coast Range blocks the marine air except at the break in the range associated with the San Joaquin-Sacramento River. The resulting westerly flow of marine air enters the Valley and splits into a southerly flow into the Sacramento Valley and a northerly flow into the San Joaquin Valley. The resulting divergence zone is usually located between Stockton and Sacramento. The effect of this divergence zone upon the climate at Rancho Seco is discussed in detail in the following sections.

086

The possibility of severe storms in the area can be limited to tornadoes and thunderstorms. According to the U. S. Weather Bureau, 22 tornadoes occurred in California during the 1953-1962 period. Using the methods described by Thom (1963), the probability of occurrence of a tornado in the state of California can be calculated to be 4×10^{-5} per year. The mean recurrent interval of a tornado would be 23,200 years.

Thunderstorms occur infrequently in the area. The mean number of days during which thunderstorms occurred over an 18-year interval for Sacramento and a 19-year interval for Stockton are listed in the following table. The + indicates less than one-half day.

TABLE I

MEAN NUMBER OF DAYS OF THUNDERSTORMS

	Stockton	Sacramento		Stockton	Sacramento
Jan	+	+	July	+	+
Feb	+	+	Aug	+	+
Mar	+	1	Sept	1	1
Apr	+	1	Oct	+	+
May	+	1	Nov	+	+
June	+	+	Dec	+	+
			Year	3	5

B. Winds

1. Wind Roses and Trajectories

The wind roses for January, April, July and October for Mather AFB, Sacramento and Stockton are included in Fig. 4. The January roses show a general similarity between the three sites with a slightly larger occurrence of westerly winds at Stockton. For the other three months, Stockton shows a dominant west to northwest flow with the other two sites showing south to southwest.

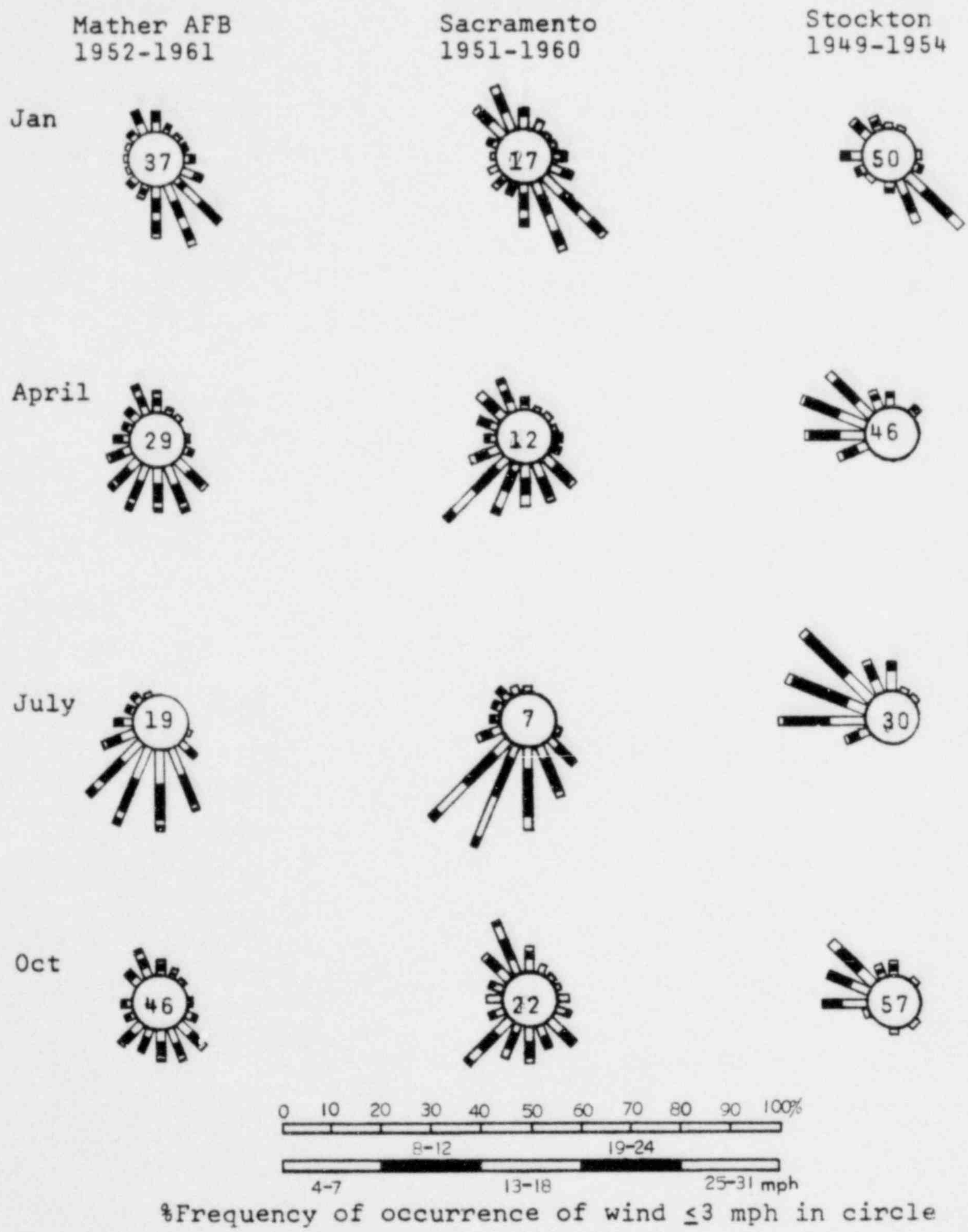


Fig. 4. WIND ROSES

088

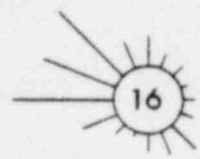
The dominance of the synoptic scale pressure pattern in winter results in a general agreement between the three sites during this season. Heating at midday may result in some thermal gradient between the ocean air and the Valley but the average maximum of 53°F at Sacramento in January is not much more than the ocean temperature, allowing the stronger winter synoptic pressure gradients to prevail.

In summer, the synoptic scale pressure gradients weaken and the thermal gradient increases. The resulting flow of air through the break in the Coast Range at the Sacramento-San Joaquin River pours into the Valley from the west, diverging into a northwest flow into the San Joaquin Valley and a southeast flow into the Sacramento Valley.

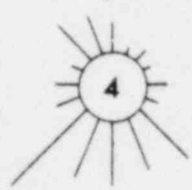
The southwest flow at Sacramento and west to northwest flow at Stockton are the dominant features on the yearly wind roses presented in Fig. 5. The southeast flow seen in January at both sites is also discernible.

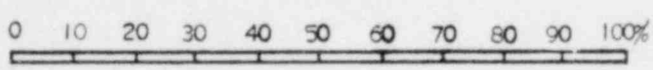
The Rancho Seco site lies near the divergence zone which is usually centered to the north of the site in mid-afternoon and to the south during the nighttime hours. The resulting wind trajectories can be clearly seen in Figs. 6 and 7 which are streamlines of the most frequent wind directions for 0300 and 0600 PST and for 1500 and 1800 PST, respectively, for the month of May 1967. These trajectories will vary from day to day. The wind direction for the lowest level (0-480 foot average direction) of the pibals taken during the June on-site study, along with some surface winds, were plotted as arrows in Figs. 8 and 9. The wind streamlines based on those arrows were then drawn and are presented in the figures. These trajectories illustrate some of the variations possible due to the movement of the location

Stockton
(6 years)



Sacramento
(7 years)





% frequency of winds <0.5 mph in circle

090

Fig. 5. YEARLY WIND ROSES

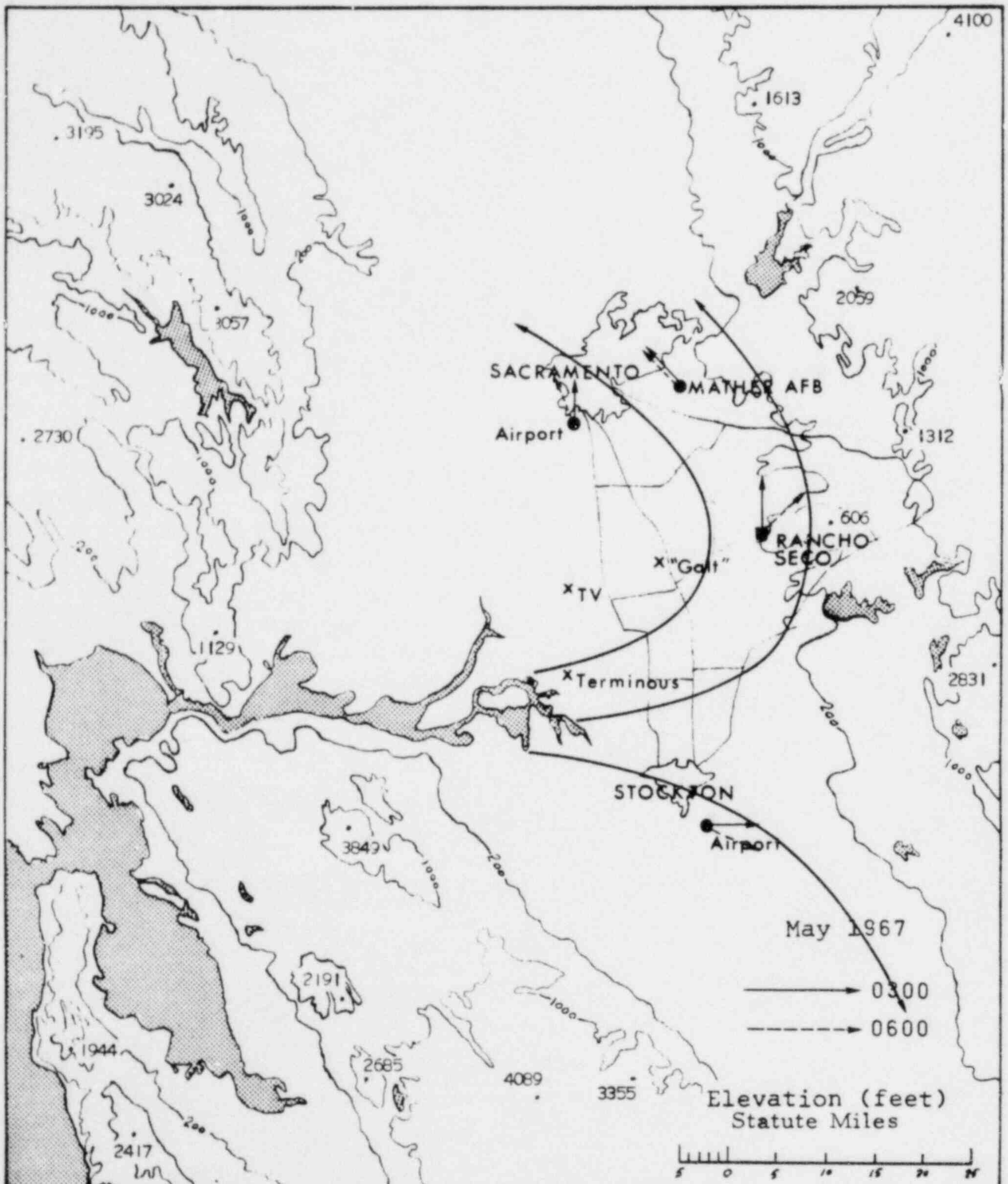


Fig. 6. MOST FREQUENT WIND DIRECTIONS

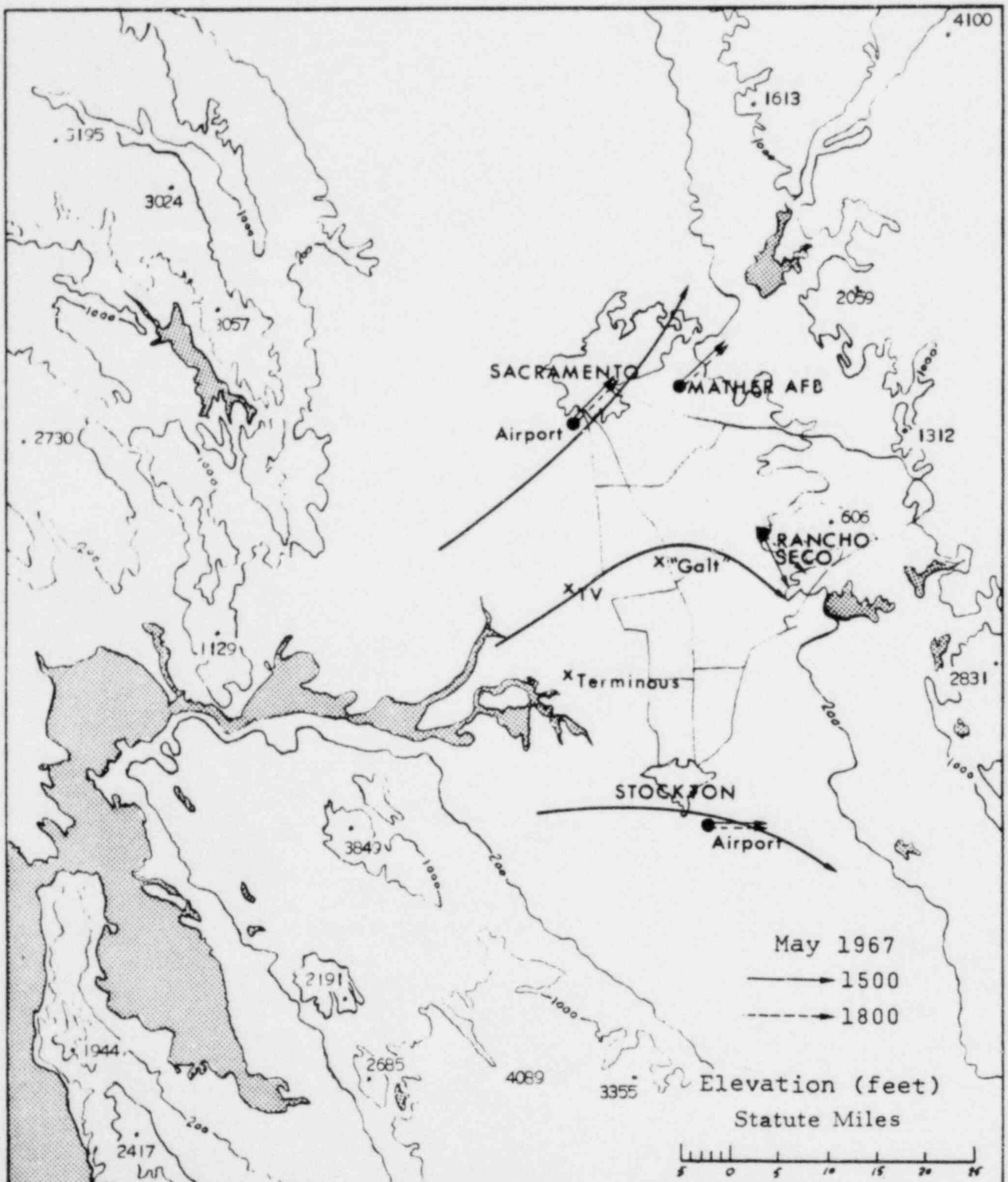


Fig. 7. MOST FREQUENT WIND DIRECTIONS

092

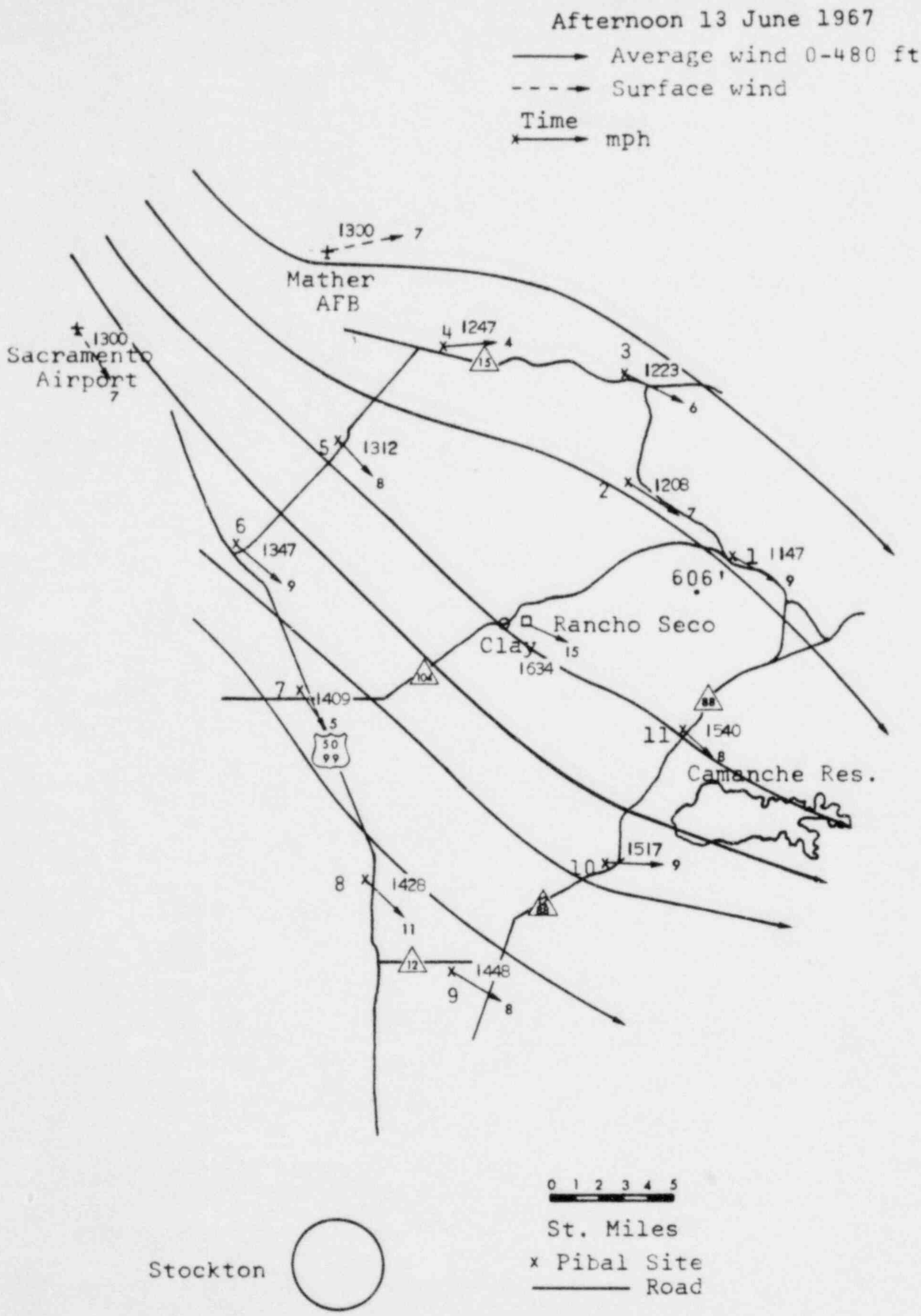
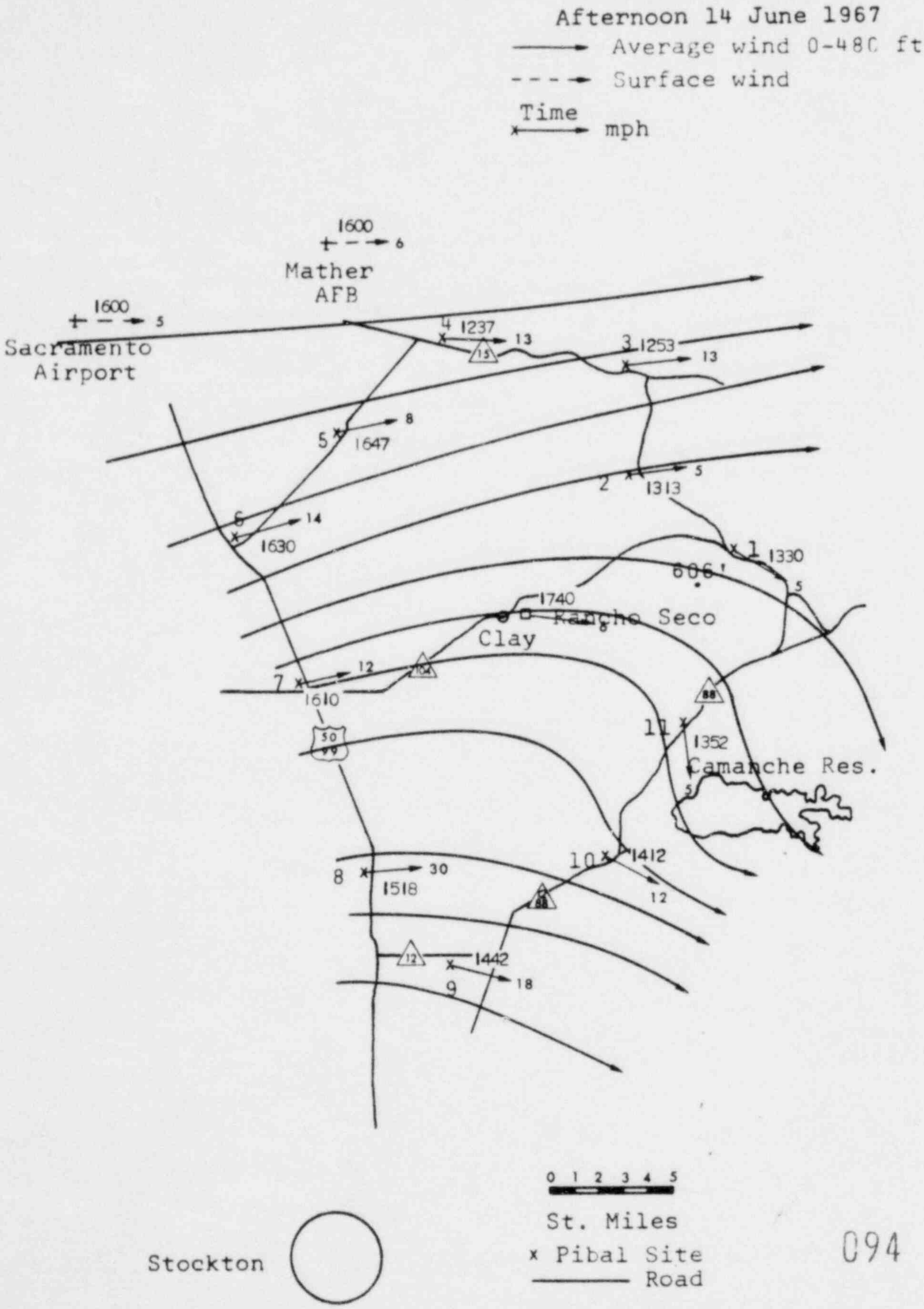


Fig. 8. WIND TRAJECTORY

093



094

Fig. 9. WIND TRAJECTORY

of the divergence zone. The trajectory in Fig. 10 for the night of 13-14 June 1967 is almost a duplicate of Fig. 6.

The diurnal variations of the wind directions at Rancho Seco and their relationship with Stockton, Sacramento and Mather AFB during May 1967 can be seen in the wind roses in Figs. 11, 12 and 13. During the daytime hours (0900-1800), Stockton and Rancho Seco are similar but Rancho Seco is more nearly represented by Sacramento at night, particularly at 0000 and 0300. The westerly flow persisted at Stockton during the entire day for this particular month which was warmer than normal. Mather appears to have more southeasterly flow at night and more calms during the day.

Wind data were reduced for Rancho Seco through 10 July to determine if the sequence of the variation of the wind direction observed during May persisted into the hot summer months. The three-hourly wind roses for 1 June through 10 July are shown in Figs. 14 and 15. Two features stand out. First, the west-northwest afternoon flow became dominant during the first 10 days of July. Indeed, the westerly flow appears to have become evident during some of the nights. The second feature is the lack of calms during the daytime hours from 0900-1800 but their increase at night. The data suggest that during the summer heating months, the westerly flow is strong enough and consistent enough to generate substantial airflow each day.

2. Extremes

The fastest one-minute average wind (mph) for Sacramento for 18 years is presented in Table II. The data are from the "Annual Summary of Comparative Data, 1966" of the "Local Climatological Data" for Sacramento. The Stockton data are not available for a comparatively long period.

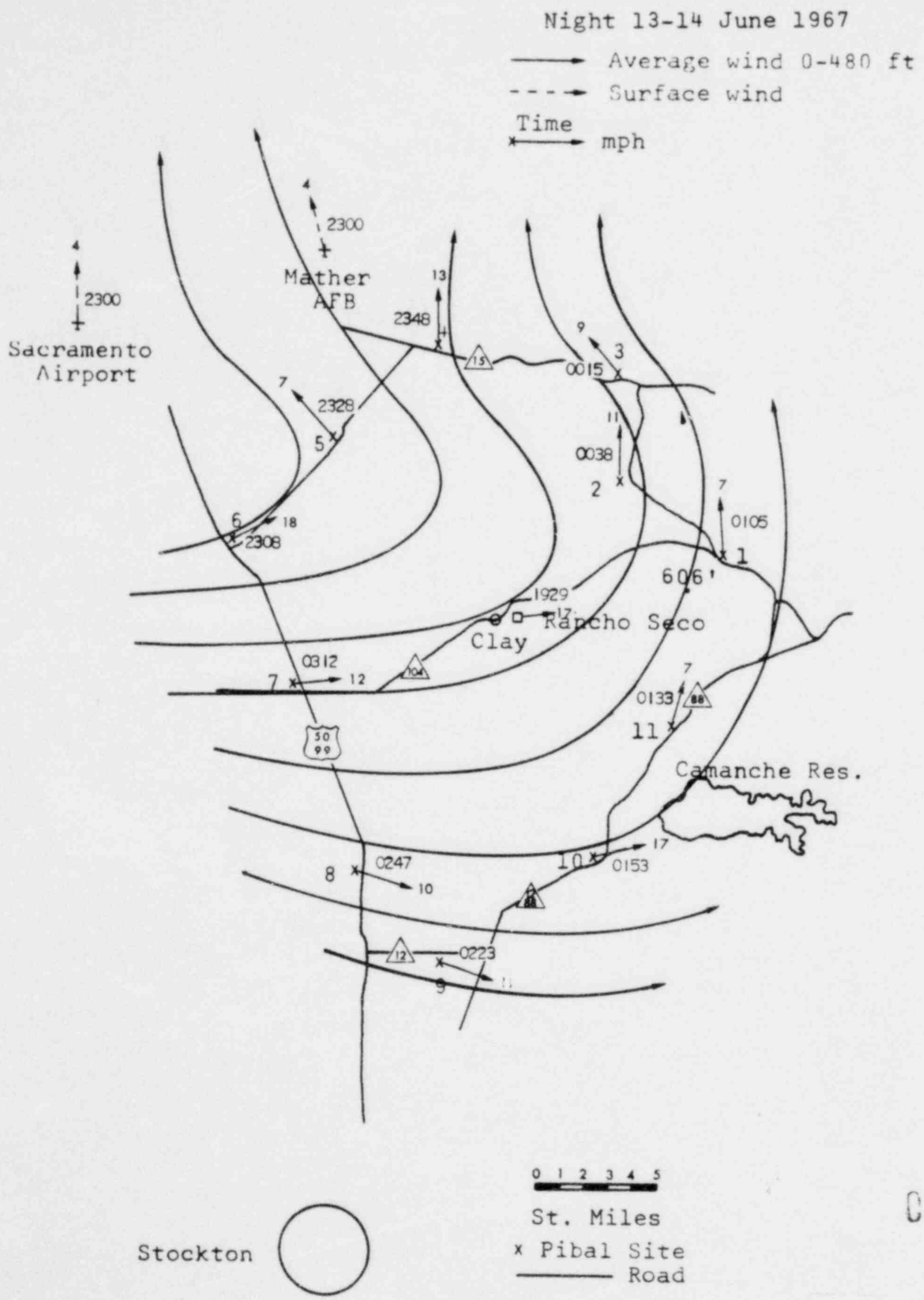
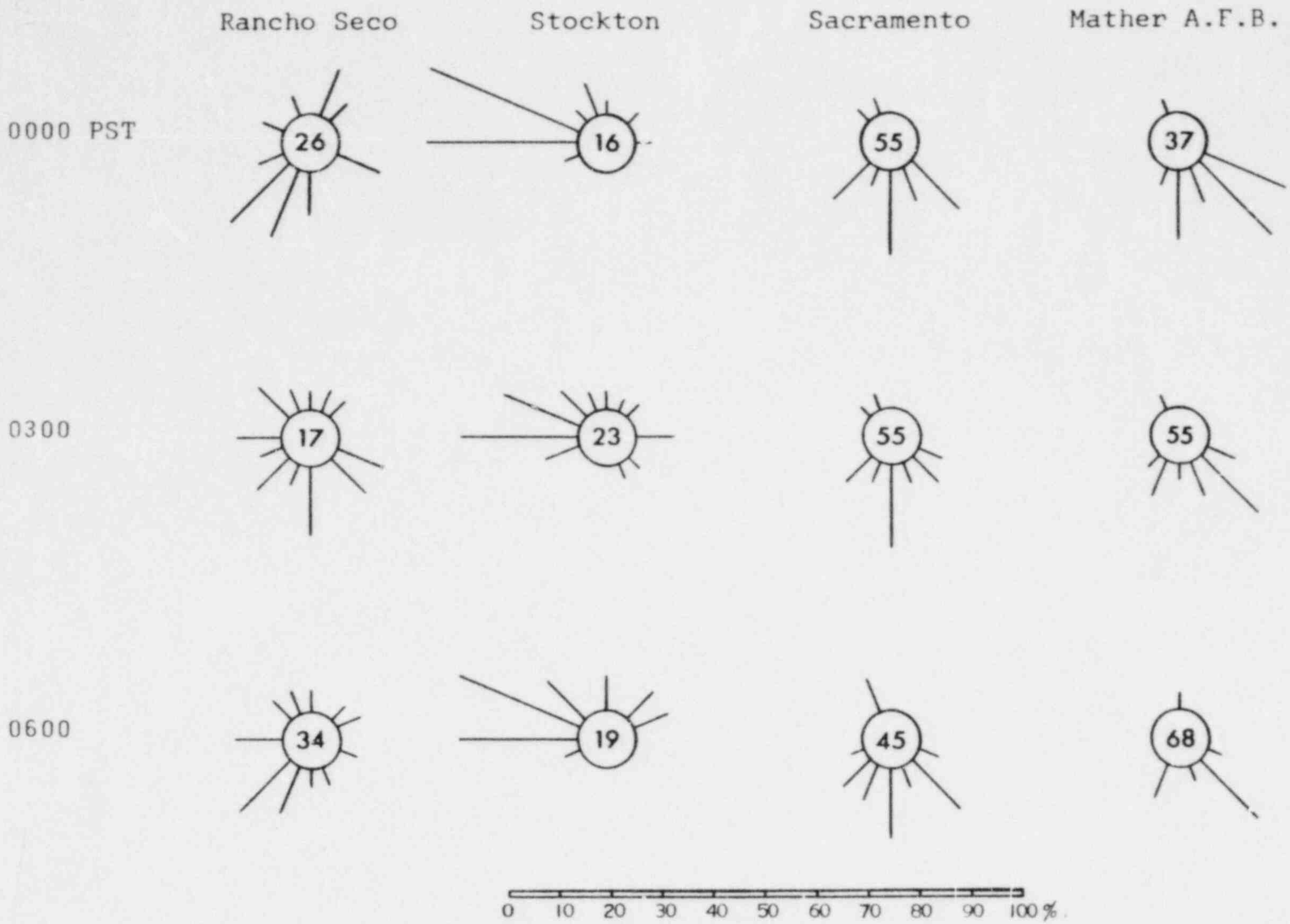


Fig. 10. WIND TRAJECTORY

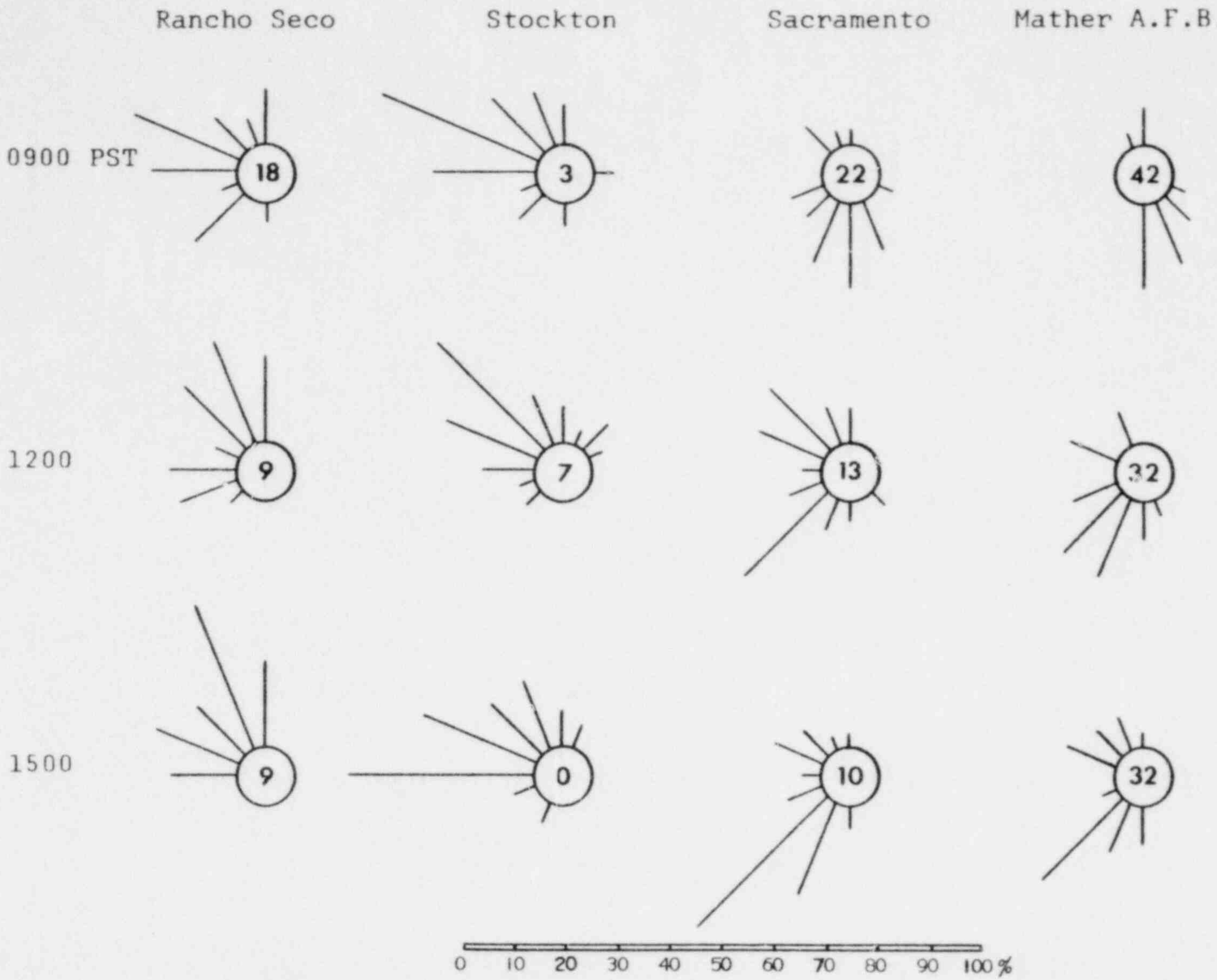
096



% Frequency of Winds ≤ 3 mph in Circle

May 1967

Fig. 11 WIND ROSES

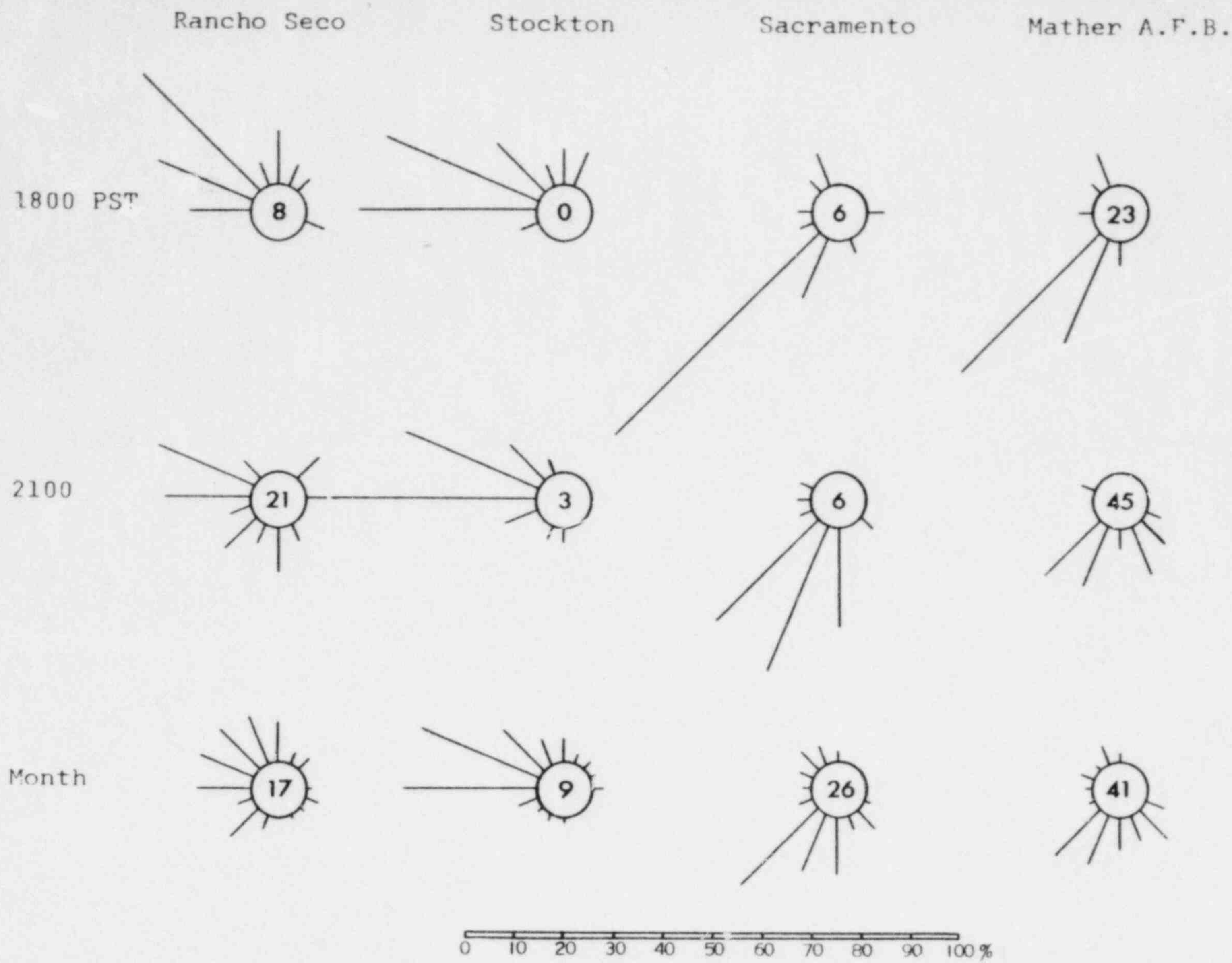


% Frequency of Winds ≤ 3 mph. in Circle

May 1967

Fig. 12 WIND ROSES

098

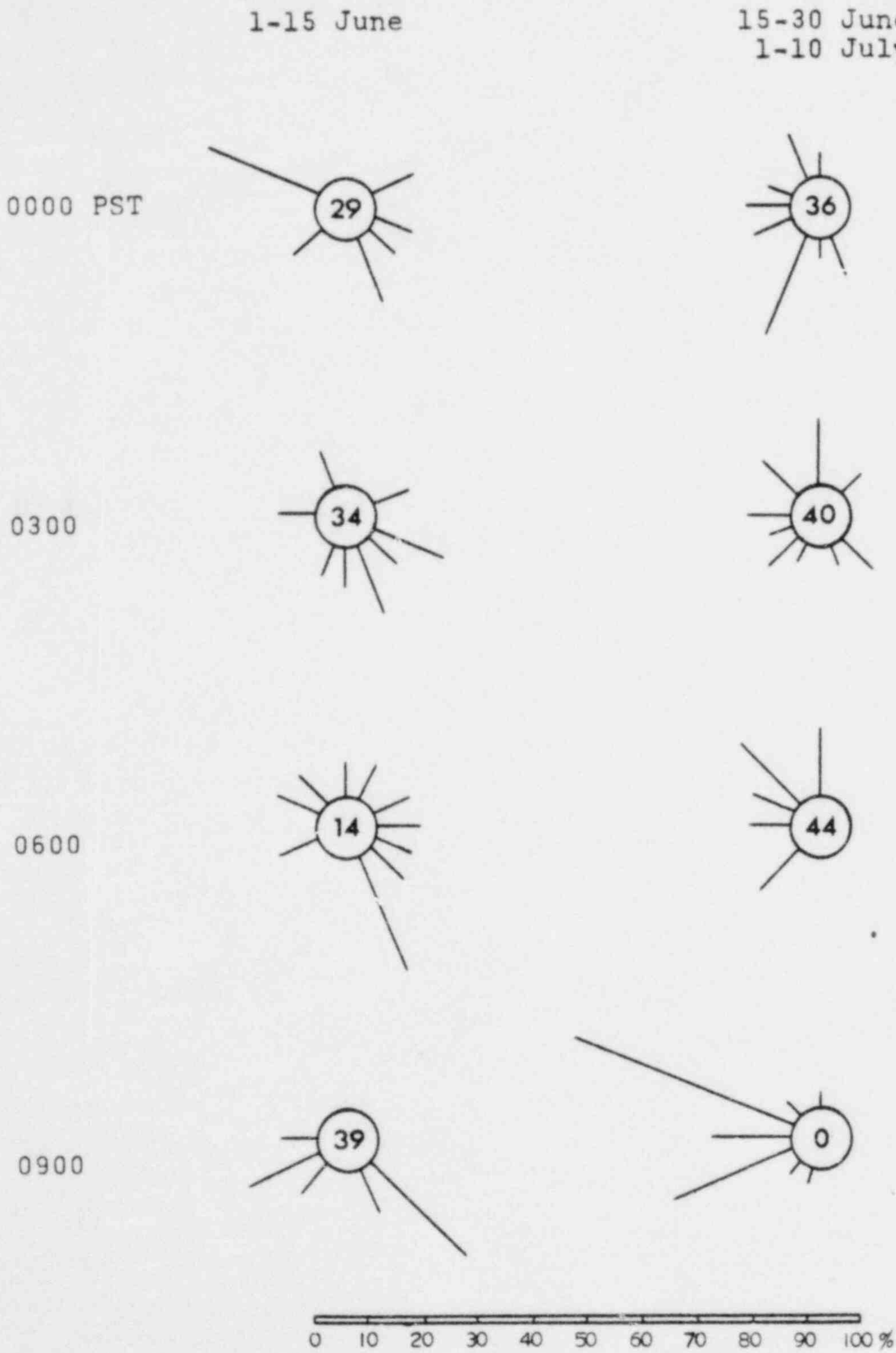


% Frequency of Winds ≤ 3 mph. in Circle

May 1967

Fig. 13 WIND ROSES

Rancho Seco



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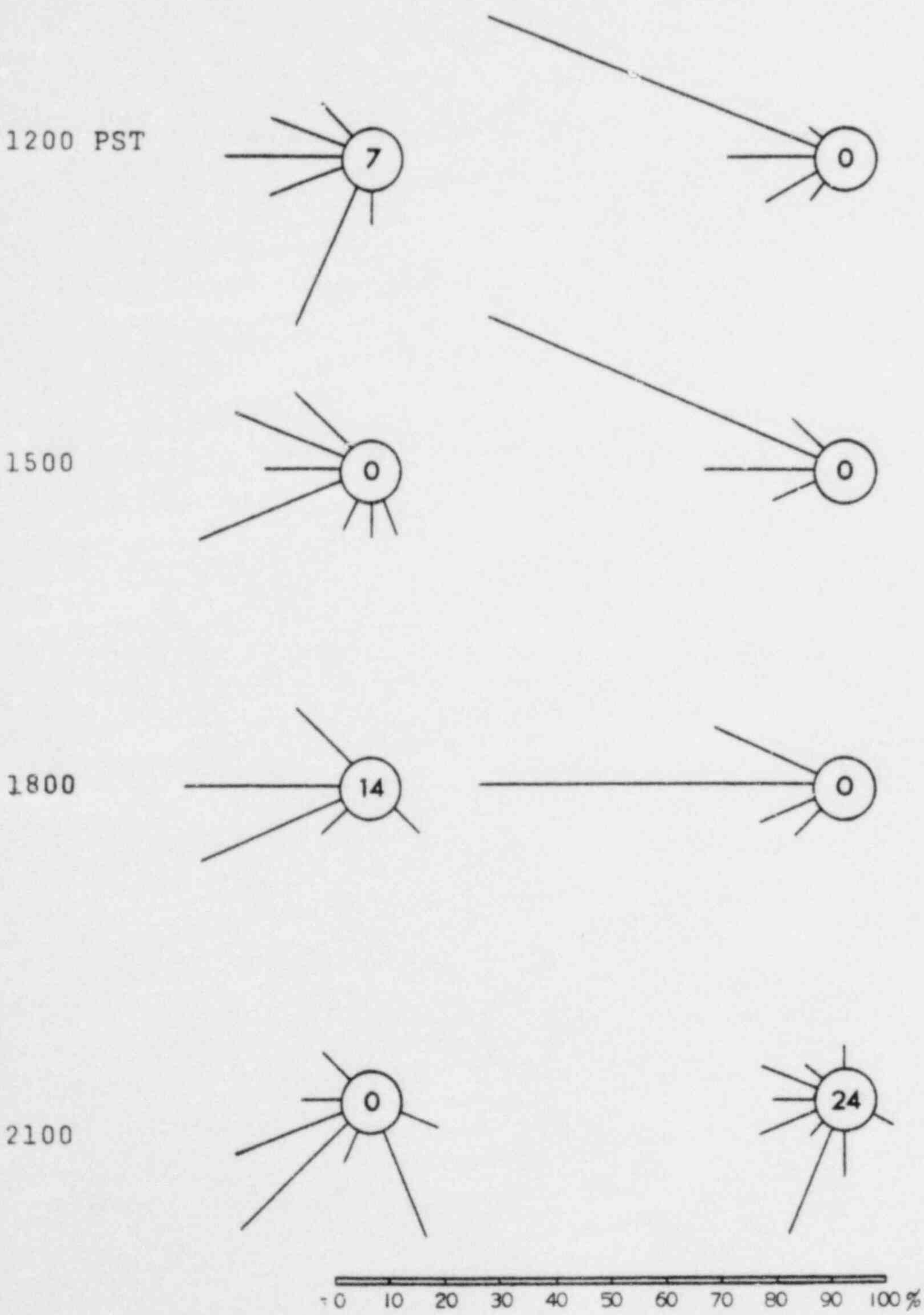
% Frequency of Winds ≤ 3 mph. in Circle

Fig. 14 WIND ROSES

Rancho Seco

1-15 June

15-30 June
1-10 July



% Frequency of Winds ≤ 3 mph. in Circle

Fig. 15 WIND ROSES

101

TABLE II

HIGHEST ONE-MINUTE AVERAGE WIND SPEEDS

Month	Direction	Speed	Year
Jan	SE	60 mph	1954
Feb	SE	51	1959
Mar	S	66	1952
Apr	SW	45	1955
May	S	35	1957
June	SW	47	1950
July	SW	36	1956
Aug	SW	38	1954
Sept	NW	42	1965
Oct	SE	68	1950
Nov	SE	70	1953
Dec	SE	70	1952

In 1965, the highest speed at Stockton was 44 mph from SSE and 42 mph from NW for Sacramento. In 1966 the high for Stockton was 39 mph from the N and Sacramento was 36 mph from the SW. While these highs occurred on different days at the two sites, overall speed agreement is good but directions may differ somewhat. Similar speeds would be expected for Rancho Seco.

3. Direction with Precipitation

The direction of the wind which may be expected during precipitation is of interest for the problem of particle washout. The frequency of occurrence (per cent) of rain versus wind direction at Sacramento for 1963 is presented in Table III. A + indicates less than one-half of one per cent.

102

TABLE III

OCCURRENCE OF RAIN VERSUS DIRECTION (%)

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	
Per Cent	3	1	+	+	1	1	15	31	
Direction	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
Per Cent	19	7	7	2	W	1	1	0	9

Note that the rain occurs with a wind direction between south and southeast 65 per cent of the time. A similar result would be expected at Rancho Seco.

4. Persistence

Wind persistences for Stockton for the winter (January-March) and summer (July-September) are presented in Figs. 16 and 17. The persistence has been determined for a one-sector (20°) and three-sector (60°) range of direction fluctuation by direction quadrants. The data in Figs. 16 and 17 show the probability of the wind continuing in the same sector for a successive number of hours after the initial establishment of the sector direction. Wind speeds of less than 3 mph were considered a discontinuity and counted as calm. Since calms are considered to have no direction, calm was not broken into quadrants and is plotted on the one-sector graph. Lines were drawn to observed points only.

The meaning of the curves can be best explained by an example. During the summer, once a wind has been observed from a W to NNW direction inclusive, it will persist within a 20° sector for about 7 hours and within a 60° sector for about 25 hours for two per cent of the expected cases. An average probability of wind direction persistence, applicable to a two-hour model and weighted according to frequency of winds from the four quadrants, was found to be 47 per cent for one sector (20°) and 69 per cent for three sectors (60°).

A wind rose showing the maximum duration of wind persistence recorded at Stockton from various directions

Winter
(Jan-March 1965)

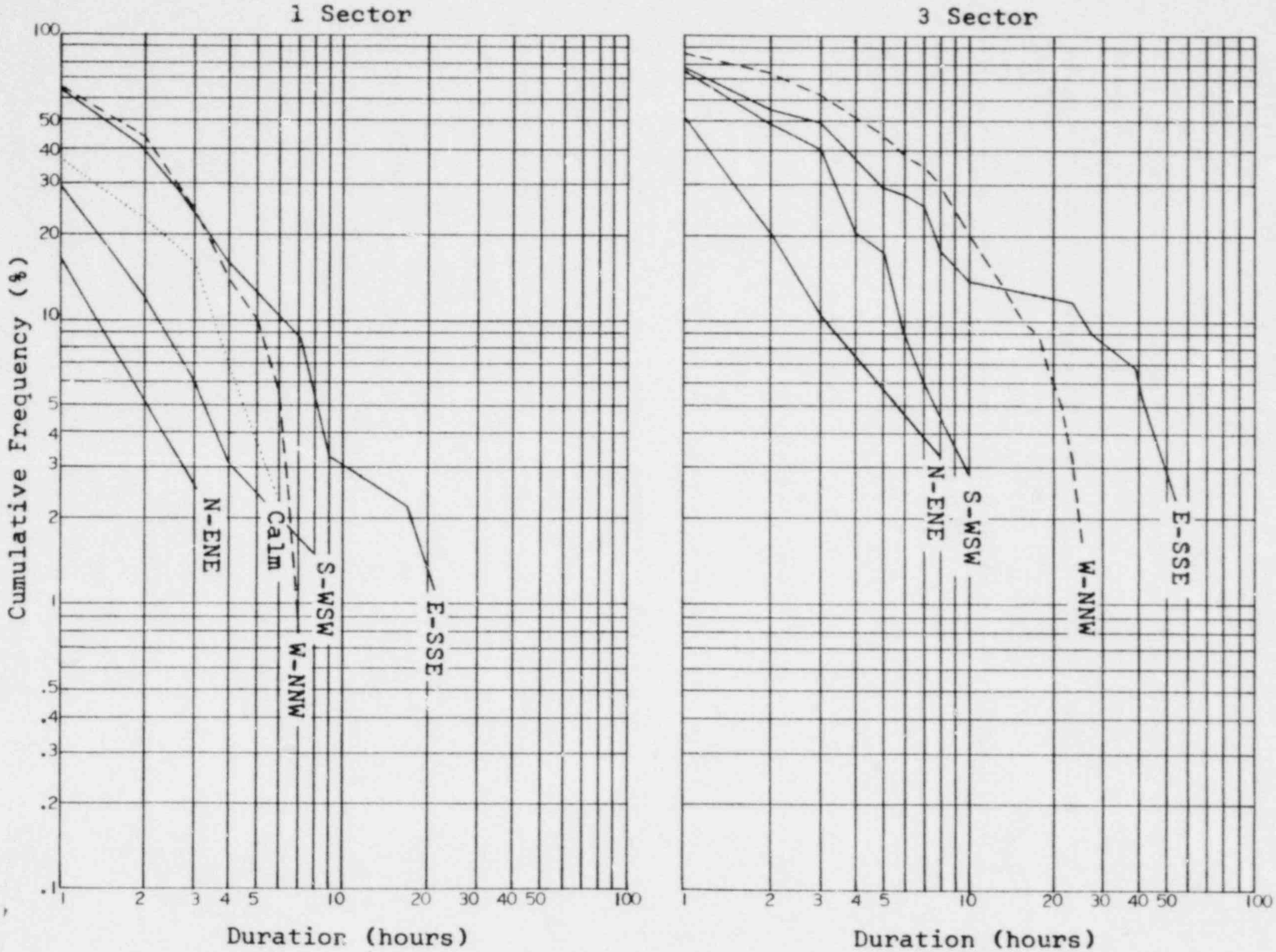


Fig. 16. STOCKTON WIND PERSISTENCE

Summer
(July-Sept 1965)

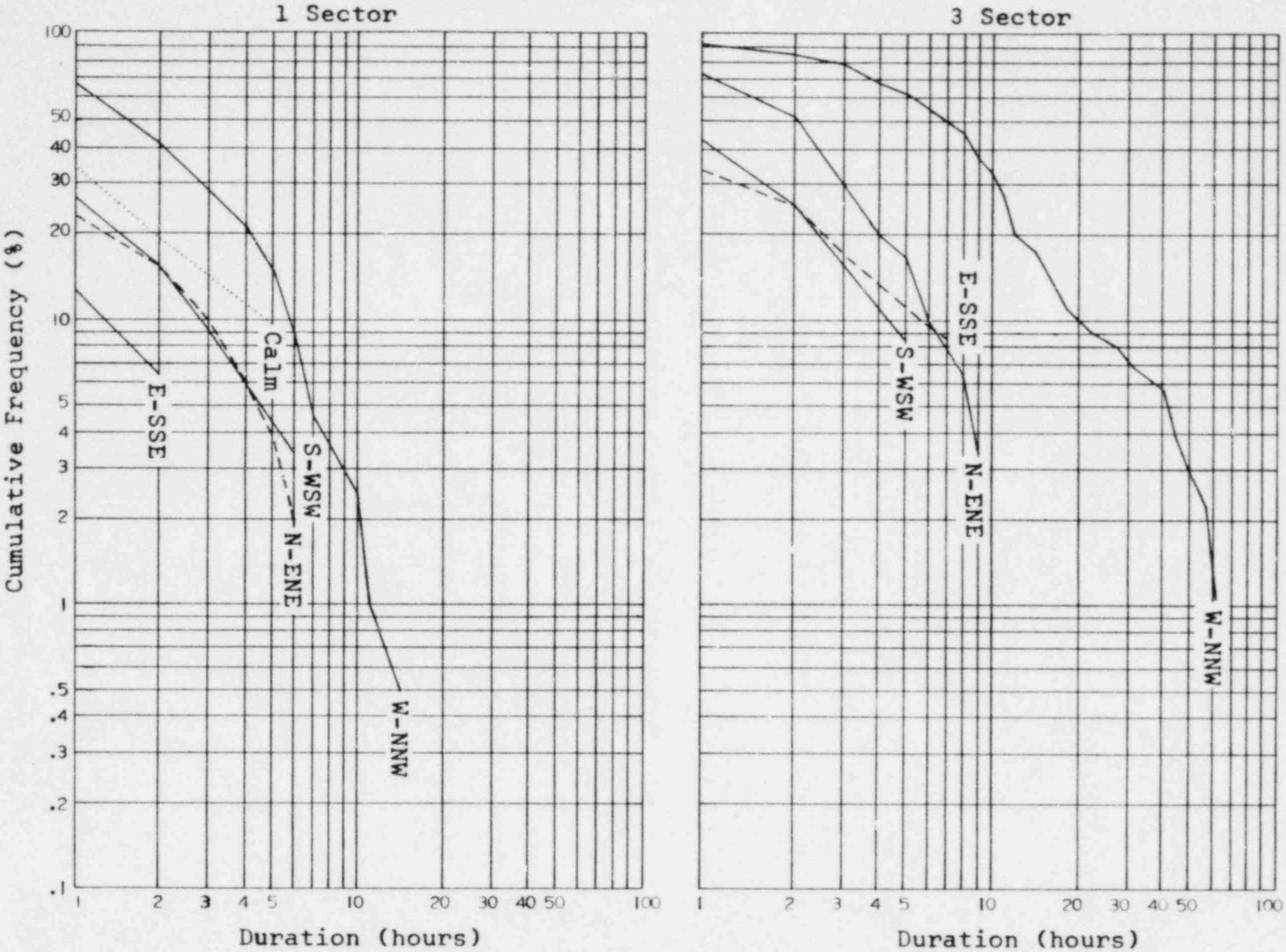


Fig. 17. STOCKTON WIND PERSISTENCE

is shown in Fig. 18, together with corresponding stability categories. The period of data record used for Stockton was 1949-1954.

C. Temperature

1. Surface

The normals, means and extremes of temperature for Sacramento and Stockton are presented in Table IV. All temperatures are in degrees Fahrenheit. The normals are based upon data for the 1931-1960 period with the extremes based upon six years of data at Sacramento and seven years at Stockton. The data are from the "Annual Summary with Comparative Data, 1966 of Local Climatological Data" published by ESSA for each location.

TABLE IV

STOCKTON TEMPERATURE NORMALS AND EXTREMES

	Normals			Extremes	
Month	Daily Maximum	Daily Minimum	Monthly	Highest	Lowest
Jan	52.4	37.0	44.7	65	19
Feb	58.2	39.7	49.0	73	26
Mar	65.0	42.3	53.7	87	29
Apr	72.8	46.5	59.7	93	32
May	80.6	51.7	66.2	100	38
June	88.6	56.9	72.8	111	45
July	95.4	60.9	78.2	113	52
Aug	93.1	59.3	76.2	107	52
Sept	88.6	56.7	72.7	101	45
Oct	77.7	50.2	64.0	98	36
Nov	64.6	41.3	53.0	84	26
Dec	53.9	37.9	45.9	71	21
Year	74.2	48.4	61.3	113	19

106

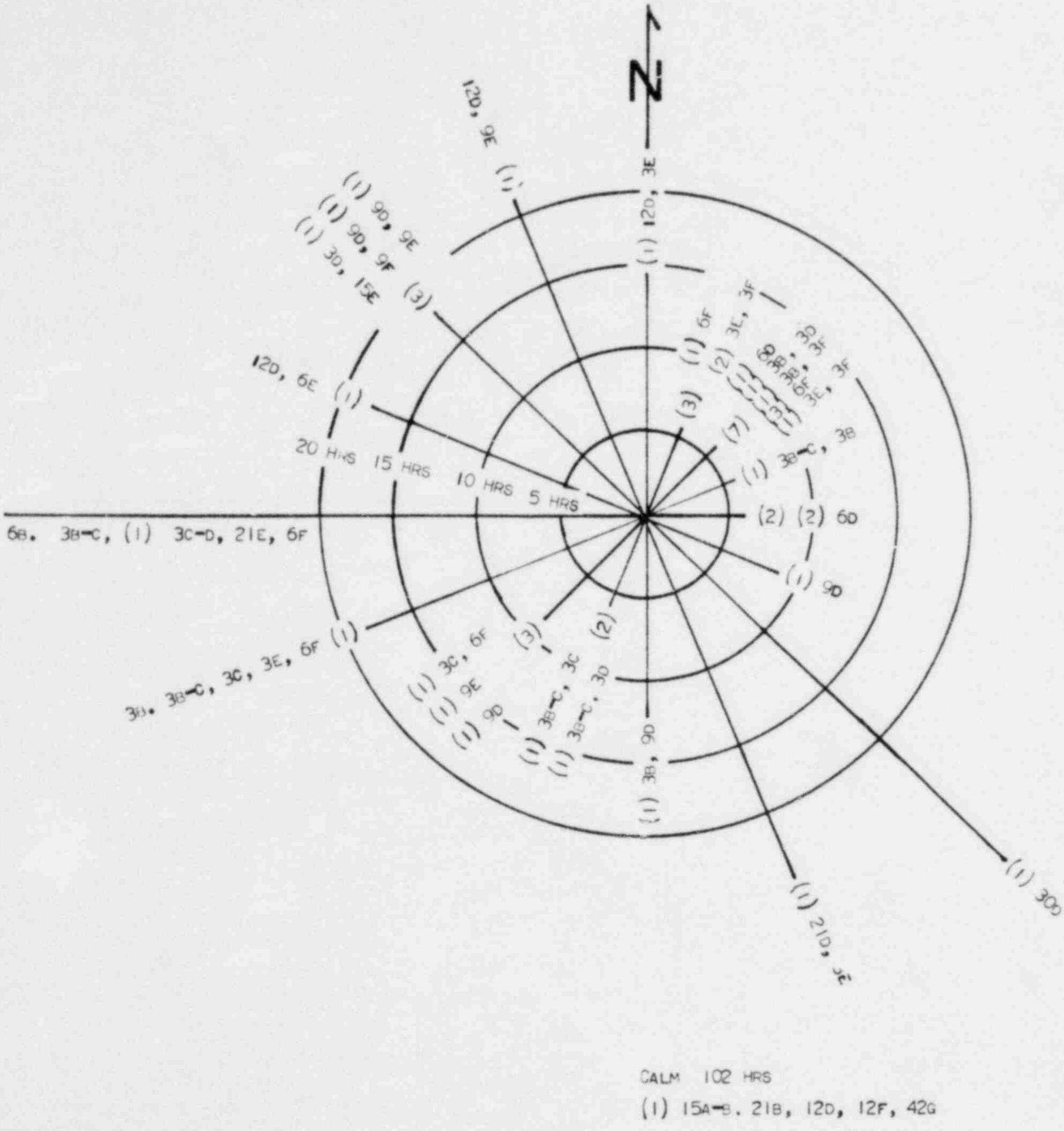


Fig. 18. PERSISTENCE WIND ROSE

SACRAMENTO TEMPERATURE NORMALS AND EXTREMES

Month	Normals Daily Maximum	Daily Minimum	Monthly	Extremes Highest	Lowest
Jan	53.2	37.2	45.2	67	23
Feb	58.6	39.8	49.2	76	28
Mar	64.8	42.0	53.4	86	28
Apr	71.4	45.3	58.4	91	34
May	78.2	49.7	64.0	99	37
June	86.5	54.4	70.5	115	43
July	93.4	57.4	75.4	113	50
Aug	91.9	56.3	74.1	107	49
Sept	88.2	55.0	71.6	104	43
Oct	77.6	49.4	63.5	99	38
Nov	64.2	41.6	52.9	87	26
Dec	54.6	38.1	46.4	66	24
Year	73.6	47.2	60.4	115	23

Maximum and minimum temperatures were compiled for Stockton, Sacramento and Rancho Seco for the six-weeks field period. The average maximum, minimum and mean for each month or portion available are included in Table V.

TABLE V

AVERAGE TEMPERATURE EXTREMES AND MEANS (1967)

	21-30 Apr	May	1-11 June	All
Stockton-Maximum	60.4°F	81.0	75.3	75.8
Minimum	41.8	51.4	51.4	49.5
Mean	51.1	66.2	63.3	62.7
Sacramento-Maximum	60.5	80.9	74.3	75.6
Minimum	41.4	49.5	50.6	48.2
Mean	51.0	65.2	62.5	61.9
Rancho Seco-Maximum	58.3	79.9	73.5	74.4
Minimum	40.9	49.9	48.4	47.9
Mean	49.6	64.9	60.9	61.1

108

The above data indicate general agreement in temperature for the three sites with a tendency for Rancho Seco to be slightly cooler than the others. Differences in thermometer exposure and calibration could account for most of the small variations observed.

2. Inversions

Inversions occur in the Great Central Valley as a result of cold air advection near the ground or radiational cooling of the earth causing a cooling of the air near the ground. Radiational cooling will occur at night when there are no low clouds. Both types will occur at Rancho Seco with the advection type usually associated with the westerly flow bringing in cool air which originated over the Pacific Ocean.

The frequency of occurrence (per cent) of the height of the inversion base at Oakland within various altitude categories is listed in Table VI. The percentage is that portion of the soundings taken within the five-year interval which fall within the indicated categories. As an example, at 0400 PST in April, 41 per cent of the soundings had an inversion at the surface, none between 1 and 500 feet, two between 501 and 1000 feet and 18 per cent had no inversions under 10,000 feet. The annual variation in inversion base height for the nighttime hours is shown in Fig. 18.

During the six-weeks study, a surface inversion between 6 and 53 feet occurred every night having usable data (47 nights between 21 April and 15 June). The period of transition between the normal lapse rate of daytime to the nighttime inversion was around 0600 and 1800. The average temperature difference for the inversion period was: 109

2100 PST	2.0°F
0000	2.9
0300	3.1

On 14 June during the on-site study, several aircraft soundings were made in the afternoon and early evening. Normal lapse to 3000 feet was observed at 1730, with an

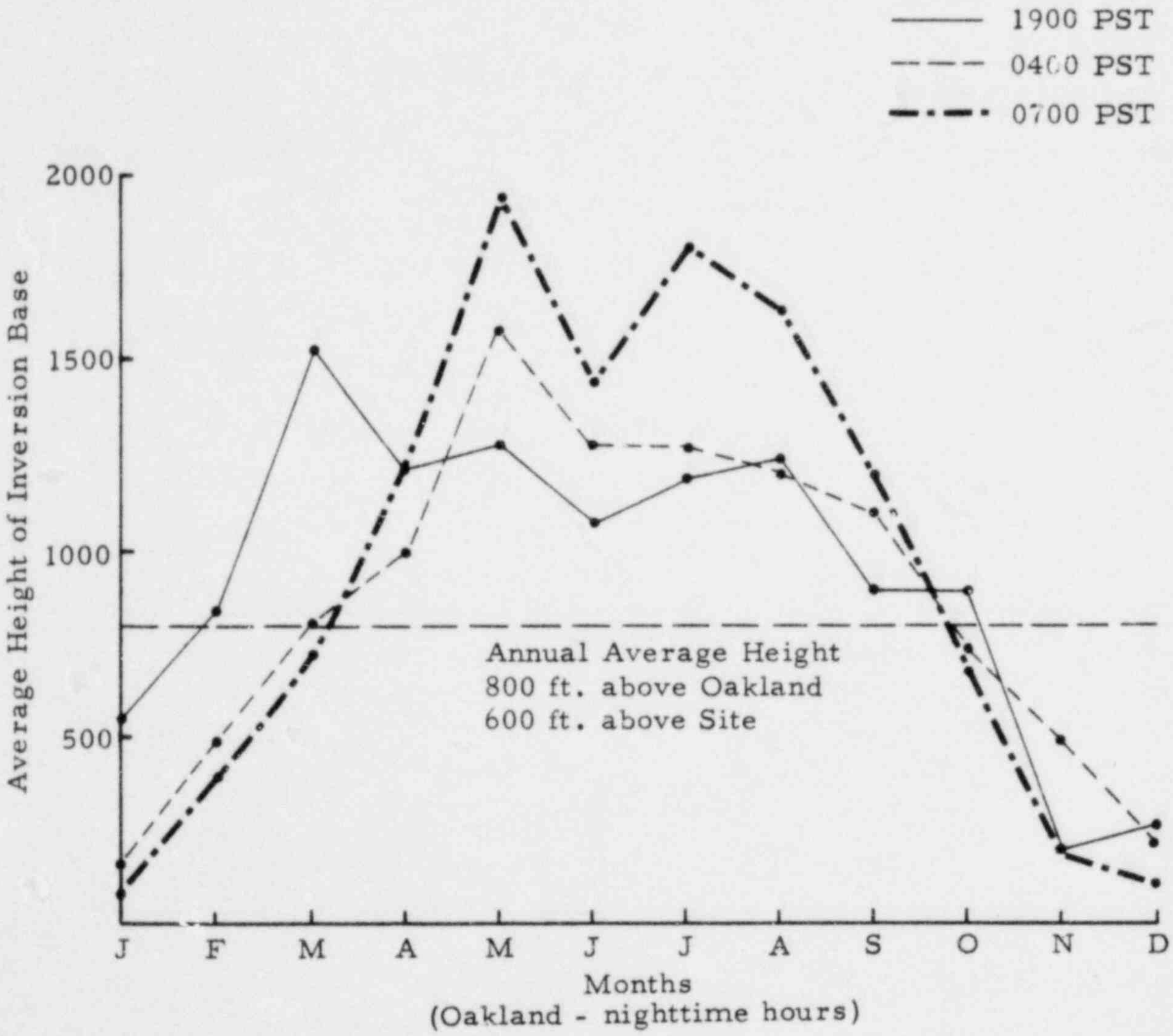


Fig. 19. ANNUAL VARIATION IN INVERSION BASE HEIGHT

110

TABLE VI

OAKLAND, CALIFORNIA INVERSIONS

Month	Time	Height of Inversion Base: 0 (Sfc)	1-500 ft	501-1000 ft	None under 10,000 ft
Jan	0400	76	1	1	14%
	1600	7	6	5	32
Feb	0400	50	1	1	29
	1600	1	0	3	60
Mar	0400	45	5	0	22
	1600	0	3	4	48
Apr	0400	41	0	2	18
	1600	0	17	7	28
May	0400	26	2	2	10
	1600	0	10	10	23
June	0400	26	27	8	1
	1600	0	29	19	9
July	0400	18	3	10	0
	1600	3	36	25	3
Aug	0400	21	5	12	0
	1600	2	30	31	5
Sept	0400	35	5	8	7
	1600	2	27	17	14
Oct	0400	52	5	5	10
	1600	5	17	11	24
Nov	0400	64	3	4	8
	1600	5	5	10	34
Dec	0400	66	18	2	5
	1600	11	7	10	17

inversion appearing based at 600 feet on the 1900 sounding and on the surface at 2030. On-site reports indicate a noticeable decrease in visibility and temperature about 1800, probably associated with the arrival of the sea air in the westerly flow and probably accounting for the 600-foot inversion at 1900. The top of the inversion on the 14th was about 1000 feet. If this persisted, the maximum temperature inversion between the surface and 1000 feet would have been 22°F.

D. Precipitation

The Great Central Valley of California has a dry season in the summer and a wet season beginning in October or November, lasting until April or May. The following table shows the normal amount and the maximum 24-hour amount of precipitation (inches) and the mean number of days having 0.01 inch or more for each month and the year for Sacramento and Stockton.

TABLE VII

PRECIPITATION

	Stockton			Sacramento		
Month	Normal	Maximum 24 Hours	Mean Days 0.01 or More	Normal	Maximum 24 Hours	Mean Days 0.01 or More
Jan	2.55	2.82	9	3.18	2.67	10
Feb	2.46	2.28	8	2.99	2.51	9
Mar	2.05	1.58	8	2.36	2.07	8
Apr	1.14	1.54	6	1.40	2.22	6
May	0.44	1.22	3	0.59	0.78	3
June	0.07	0.53	1	0.10	0.63	1
July	0.01	0.14	0	T	0.09	0
Aug	T	0.35	0	0.02	0.65	0
Sept	0.19	2.64	1	0.19	1.56	1
Oct	0.63	1.59	3	0.77	5.59	3
Nov	1.17	2.23	6	1.45	2.09	6
Dec	2.66	3.01	4	3.24	3.64	9
Year	13.37	3.01	48	16.29	5.59	35

T indicates a trace, an amount too small to measure. The normals for both sites are for the period 1931-1960. The 24-hour maximums for Stockton are for a 25-year period and for an 18-year period for Sacramento. The mean number of days having 0.01 inch or more for Stockton is for a 24-year period and Sacramento is for 27 years. The data were taken from the ESSA "Local Climatological Data" annual summary for 1966 for each site.

No data are available from Rancho Seco to relate to either Stockton or Sacramento. However, one would expect the range of variation between Rancho Seco and Stockton and Sacramento to be within the range of variation between Sacramento and Stockton.

The frequency of occurrence of a given precipitation intensity is given in the following table for a 5-year period for Sacramento (in per cent).

TABLE VIII

PRECIPITATION INTENSITY
(inches/hour)

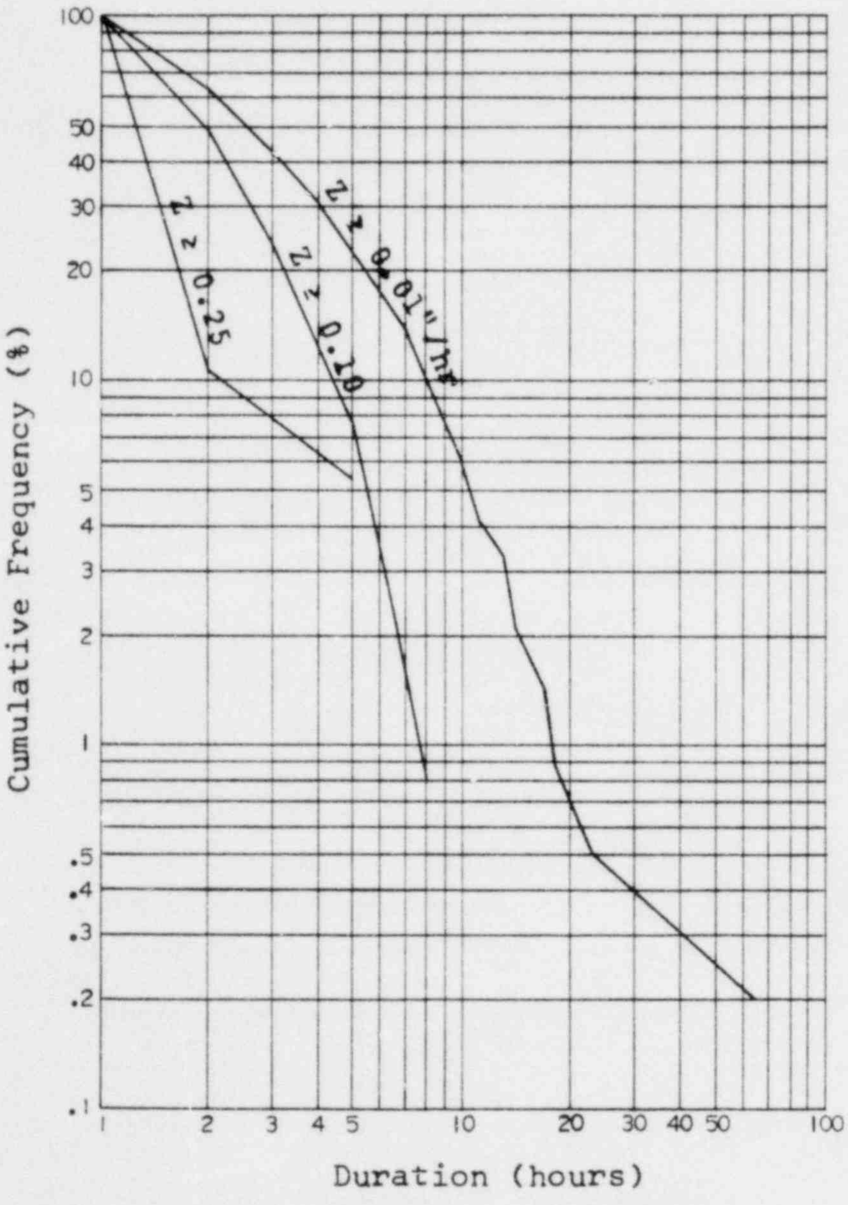
Year	0.01-0.09	0.10-0.24	0.25-0.49	0.50-0.99
1961	79.5%	17.7%	2.3%	0.5%
1962	81.8	17.0	0.8	0.4
1963	80.0	17.8	2.2	0.0
1964	86.2	11.3	2.2	0.3
1965	89.0	10.0	1.0	0.0
1961-65	83.5	14.6	1.7	0.2

As an example of the meaning of the table only 14.6 per cent of the total number of hours having measurable precipitation had intensities within the 0.10-0.24 inches per hour range for the 5-year period.

The persistence of given precipitation intensities is presented in Fig. 19. The curves are based upon the 1961-65

113

Sacramento, Calif.
1961-1965



Intensities ≥0.5 inches/hour
occurred for 1 hour or less

Fig. 20. PERSISTENCE OF PRECIPITATION

precipitation data from Sacramento. As an illustration of the use of this graph, once a precipitation intensity ≥ 0.10 inches/hour had occurred for one hour, that rate would be maintained ten per cent of the time for a total of about 4.4 hours. It should be noted that the curve for intensities ≥ 0.25 inches/hour does not follow the smooth pattern of the others. This is due to the small number of occurrences of precipitation intensities of this magnitude (see Table VIII). Intensities ≤0.50 never occurred over a longer period than an hour in the 5-year period.

Snow and sleet are very rare in the area with Sacramento having reported a trace as its maximum monthly total within the last 18 years. Stockton recorded none in the last 12 years.

E. Humidity

Table IX presents the occurrences of each 10 per cent division of relative humidity for given ranges of temperature and wind speed. The data are for January, April, July, and October for Sacramento from 1951-1960 as presented in the "Climatography of the United States No. 82-4, Summary of Hourly Observations for Sacramento, California".

The average relative humidity for four different hours of the day at Sacramento, Stockton and Mather AFB is presented in Table X.

Stockton data are for a 7-year period, Sacramento for 6 and Mather AFB for 10 years. Note that Mather AFB is summarized for 3-hour periods.

A hygrothermograph was operated at the Rancho Seco site during the six-weeks study. Humidities from this instrument were compared with the corresponding humidities at Sacramento for the available data of record. In general, the sites show good agreement with 90 per cent of the pair of values being within 10 per cent relative humidity of each other. There is

115

TABLE IX

TEMPERATURE AND WIND SPEED–RELATIVE HUMIDITY OCCURRENCES

SACRAMENTO, CALIF.
Municipal Airport

1951-1960

JANUARY

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP (°F)	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
69/ 65				2				3	1	2						2									10
64/ 60		1	5	2	1	1		1	33	5	19	3		7	6		13	9		1	3		1	1	112
59/ 55		2	36	21	21	17		24	79	67	44	87		18	30	29	19	64		1	5	6	12	7	589
54/ 50		11	57	39	70	66		35	173	111	193	251		15	52	69	75	149		3	7	14	32	40	1442
49/ 45		25	50	70	131	310	1	40	121	152	274	581		10	19	40	109	166	3	1	5	13	41	48	2210
44/ 40		13	25	37	98	307	1	24	65	74	229	516	2	8	32	14	79	79	1	7	1	7	8	26	1653
39/ 35		2	9	29	47	269		6	65	38	148	339		1	16	9	18	21		1	5				1001
34/ 30			7	25	24	102			21	33	48	94		3	4	4	1	3		3	1				373
29/ 25				10	8	14				4	7	7													50
TOTAL		54	189	235	400	1086	2	131	538	486	962	1878	2	62	159	147	314	491	4	17	27	40	94	122	7440

APRIL

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP (°F)	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
94/ 90		1					6																		7
89/ 85	5	6	1				15	14					1	1											43
84/ 80	21	35	1				58	77	1				12	6					1						212
79/ 75	16	53	13				68	146	29				28	31	2				4	2					391
74/ 70	15	54	33	2			52	178	87	2			17	53	19				7	3					522
69/ 65	6	62	73	8	3		43	170	202	23	1		42	81	64	1			6	3	6				752
64/ 60	5	28	82	30	12		28	113	307	94	30		33	48	110	18	4	1	5	7	19	1			984
59/ 55	2	12	50	72	75	20	11	72	275	228	176	35	7	33	109	51	27	17	4	7	8	3	1	6	1301
54/ 50		7	35	58	128	63	1	45	136	249	355	159	3	22	50	78	69	14		4	3	4	9	3	1482
49/ 45		2	19	37	86	66		17	70	131	335	185		13	15	37	44	33			1	1	2	12	1105
44/ 40		1	5	5	37	21		9	26	62	87	81		2	3	1	5	2							347
39/ 35			3	1	11				1	11	20	3													50
34/ 30										1	3														4
TOTAL	68	241	314	222	352	167	282	761	1133	801	997	463	143	270	372	186	149	67	27	26	37	9	12	21	7200

JULY

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP (°F)	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
114/110							1																		1
109/105	6						18						1												25
104/100	24						92	2					12	1											131
99/ 95	28	4					233	53					40	5											363
94/ 90	34	32					240	225					39	54											624
89/ 85	7	62	1				105	359	1				40	111						1					687
84/ 80	2	82	3				29	400	28				15	156	2				1	3					721
79/ 75	1	61	46				7	296	165				4	103	34					2					719
74/ 70		41	113	2			3	184	425	2				48	88					3	2				911
69/ 65		9	138	14	1			43	675	77	2			7	100	2	1				4				1073
64/ 60			49	60	14			15	426	422	127	3		1	47	58	3				3	1			1229
59/ 55			1	16	22	3			80	254	318	21			4	46	72	2					3		842
54/ 50					2	3			2	18	52	15				1	14	6					1		114
TOTAL	102	291	351	92	39	6	728	1577	1802	773	499	39	151	486	275	107	90	8	1	9	9	1	4		7440

OCTOBER

WIND	0-4 M.P.H.						5-14 M.P.H.						15-24 M.P.H.						25 M.P.H. AND OVER						TOTAL OBS.
REL. HUMID. / TEMP (°F)	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Under 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
99/ 95	3	2					3	1																	9
94/ 90	17	5					15	2					3												42
89/ 85	55	36					39	19					8	1											158
84/ 80	52	83	4				64	92	1				13	7											316
79/ 75	53	133	14				93	216	30				39	23	1				2						604
74/ 70	30	183	71	4			53	273	136	3			35	36	28	2			12						866
69/ 65	7	111	146	10	2		32	176	206	36	13		26	40	56	8	7		17	1					988
64/ 60	6	55	197	64	21	14	18	97	343	145	97	25	24	49	31	27	14	9	5	10	2	1			1254
59/ 55	3	21	130	147	80	29	9	82	229	256	222	97	12	55	18	21	26	14		10	1		2	2	1466
54/ 50		13	82	82	171	83	2	41	126	126	272	152	7	18	10	10	15	11		3			1		1226
49/ 45		10	31	53	46	50		20	29	36	78	64		1		1									418
44/ 40		1	8	9	10	10		3	17	9	14	4			1										86
39/ 35				1	1				1		2	2													7
TOTAL	226	653	685	370	331	188	328	1024	1207	611	698	344	167	230	145	69	62	34	36	24	3	2	3	2	7440

116

TABLE X

AVERAGE RELATIVE HUMIDITY
(in per cent)

	Stockton				Sacramento			
	Hour				Hour			
Month	0400	1000	1600	2200	0400	1000	1600	2200 PST
Jan	90	87	69	86	91	88	72	87
Feb	88	79	59	80	86	79	59	80
Mar	85	68	50	76	85	70	53	78
Apr	81	55	40	71	85	61	45	76
May	77	47	34	64	84	54	39	73
June	70	42	28	56	78	48	32	66
July	65	41	24	49	77	48	28	62
Aug	66	44	27	51	77	51	29	64
Sept	67	47	30	55	77	52	32	65
Oct	74	56	38	64	78	58	41	69
Nov	86	78	61	80	87	78	63	81
Dec	93	90	80	90	92	89	78	90
Year	79	61	45	69	83	65	47	74

Mather AFB

	Hour			
Month	03-05	09-11	15-17	21-23
Jan	90	82	72	87
Feb	85	72	59	80
Mar	82	63	49	74
Apr	81	57	43	72
May	79	51	37	67
June	72	46	30	58
July	65	43	26	51
Aug	68	46	32	55
Sept	68	47	28	57
Oct	72	51	36	61
Nov	81	65	52	73
Dec	87	79	69	83

117

a tendency for Sacramento to have higher relative humidities than Rancho Seco for the values above 40 per cent. Study of Table X indicates a similar relationship between Stockton and Sacramento, at least during the same time of year.

The average minimum relative humidity for the six-weeks period was found to be 40.6 per cent for Rancho Seco compared to 41.9 per cent for Sacramento. Considering the 3-5 per cent relative humidity accuracy to be expected with the hygrothermograph, the difference in the average minimum relative humidity between the two sites cannot be considered significant.

118

VI. DIFFUSION MODELS

A. General

The most commonly used equation for diffusion from a continuous point source is:

$$\chi(x, y, 0) = \frac{Q}{\Pi \bar{u} \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{h^2}{\sigma_z^2}\right)\right]$$

where χ is the concentration at ground level at a downwind distance of x from the source and a crosswind distance of y. Q represents source strength, $\bar{u}$ the mean wind speed and h the height of the source above ground. σ_y and σ_z are the standard deviations of the cloud width and height, respectively, at the distance, x, from the release.

Although most diffusion prediction systems utilize the above equation as a basic model, a variety of methods has been suggested for evaluation of the σ_y, σ_z parameters required in the equation.

B. Estimation of Diffusion Parameters

1. Pasquill Method

A technique for estimating σ_y and σ_z was formulated by Pasquill (1961) and subsequently extended by Hilsmeier and Gifford (1962). Nomograms were developed for estimating σ_y and σ_z, based on experimental data extended by theoretical expectations.

Meteorological parameters which served as inputs into the estimating technique were gross in nature and related to but not fundamental to the diffusion process. The technique, in effect, describes an empirical relation between the commonly measured weather parameters and the associated diffusion characteristics under average terrain conditions. In smooth or changing terrain situations, for example, there is no adjustment available within the model to account for the non-average conditions.

2. Markee Method

Markee (1966) has recently adapted the Pasquill system for the local conditions characteristic of the NRTS site in Idaho. The adaptation consisted first of defining the Pasquill meteorological categories distinctly by times of day and cloud cover which applied to the NRTS site. This definitization is necessary for computer processing of large quantities of climatological data into frequencies of occurrence of the various categories.

A second modification in the Pasquill system was the attention called to length of release. Analysis of long duration releases generally showed broader plumes for stable conditions than predicted by the Pasquill system. This feature has been attributed to the slow meandering character of the wind under stable conditions. In terms of long release times, this meandering may serve to decrease the total exposure at any specific location by a significant amount. The Markee curves take into account a reasonable amount of this meandering and are thus intended to be applied to release durations of 15-60 minutes.

C. Turbulence Measurements

The Pasquill and Markee techniques are not able to take into account the effects of local site characteristics on the diffusion conditions. Direct measurements of turbulence have been suggested by various workers as a means of incorporating these local effects. Diffusion models based on turbulence observations have been developed by Hay and Pasquill (1959), Cramer (1959) and Fuquay, Simpson and Hinds (1964) among others. The technique suggested by Fuquay et al. has been compared to other models and to experimental data (Fuquay and Simpson, 1964) and has been shown to give results comparable to the Pasquill system. The Fuquay technique has the further advantage that experimental data (taken at Hanford) from large distances (to about 20 miles) have been used in developing the model and such data have not been incorporated into the previous techniques.

The Fuquay system consists of an empirical equation for the calculation of σ_y from observed data of σ_θ and $\bar{u}$ where σ_θ is the standard deviation of the horizontal wind fluctuations and $\bar{u}$ is the mean wind speed. The input parameters into the model are the product ($\bar{u}\sigma_\theta$) and the time of travel to the exposure location. The following equation is given as a predictor of σ_y:

$$\sigma_y = At - A\alpha + A\alpha e^{-t/\alpha}$$

where $A = 13 + 232.5\ \sigma_\theta\bar{u}$

$$\alpha = \frac{A}{2(\sigma_\theta\bar{u})^2}$$

t = time of travel.

The equation is also given in nomogram form in the quoted reference (Fuquay, Simpson and Hinds, 1964).

Vertical growth characteristics of the diffusing cloud are treated in the Fuquay technique by incorporation of the Richardson number:

$$Ri = \frac{g}{T}\frac{(\partial T/\partial z + \Gamma)}{(\partial u/\partial z)^2}$$

where g = 32.2 ft/sec

T = air temperature

Γ = 5.4°F/1000 ft

u = wind velocity 121

z = height above ground.

The Richardson number, in this usage, expresses a relation between the heights of 7 and 50 feet above ground.

Exposures at specific locations are given in nomogram form in terms of travel time, $\sigma_\theta\bar{u}$ and the Richardson number.

D. Development of Climatological Statistics

The development of an annual diffusion climatology for the Rancho Seco site requires the use of the Pasquill or Markee system since no wind fluctuation data (σ_θ) exist for the site over any extended period of time. Standard weather observations can, however, be used to estimate the diffusion climatology for the Pasquill or Markee techniques. For this purpose, Sacramento and Stockton weather data were available as the closest locations to the Rancho Seco site with long periods of record.

In order to process the large amount of data required for the climatology, a computer program (WBANDA) was used to categorize the data into the various diffusion categories for each three-hour interval of record. In order to avoid ambiguity in the categorization, a definitive classification system was set up to describe the categories in terms of the available weather data. This classification system follows the Pasquill-Markee methods closely wherever possible but, where minor questions developed, the latitude, radiational characteristics and solar angles of the Rancho Seco site were used for the final adjustment of the system. The details of the system used for the Rancho Seco site are given in Table XI.

The classification system shown in Table XI was used on seven years of data from the Sacramento airport and six years of data from the Stockton airport. The data were summarized at three-hour intervals and grouped for the entire day. Frequencies of occurrence for each diffusion type are shown in Table XII. Additional details on the frequencies of occurrence as a function of wind direction for Stockton and Sacramento are given in Tables XIII and XIV.

The most striking feature of Table XII is the difference in the G category for Sacramento and Stockton. It is apparent that the nocturnal drainage flow from the Sierra Nevada Range has a more pronounced effect at Sacramento and keeps many of the nighttime hours from falling into the G category. A longer period of record from the site will be needed to

TABLE XI

DIFFUSION CLASSIFICATION SYSTEM FOR RANCHO SECO SITE

<u>Time of Day by Month</u>

Nov Dec Jan Feb	Mar Apr May Sept Oct	June July Aug	Wind Speed (knots)	Cloud Cover 0/10-5/10	6/10-9/10	Overcast	Insolation
09	09		<4.0	B	C	D	Slight
15			4.0-5.9	C	C	D	
			6.0-9.8	C	D	D	
			>9.8	D	D	D	
12	12	09	<4.0	A-B	B	C	Moderate
	15	15	4.0-5.9	B	B-C	D	
			6.0-9.8	B-C	C-D	D	
			9.9-11.7	C-D	D	D	
			>11.7	D	D	D	
		12	<4.0	A	B	C	Strong
			4.0-5.9	A-B	B	C	
			6.0-9.8	B	C	D	
			9.9-11.7	C	C	D	
			>11.7	C	D	D	
18-06	18-06	18-06	<4.0	G	F	D	Night
			4.0-5.9	F	E	D	
			6.0-9.8	E	D	D	
			>9.8	D	D	D	

The cloud cover categories include:

0/10-5/10 is scattered, thin broken, or thin overcast.
6/10-9/10 is broken.
Overcast is 10/10, opaque.

TABLE XII

PERCENTAGE FREQUENCIES OF DIFFUSION CATEGORIES

Category	Sacramento % Occurrence	Sacramento Mean Wind Speed (knots)	Stockton % Occurrence	Stockton Mean Wind Speed (knots)
A	0.58	2.5	0.61	2.8
A-B	5.31	2.9	4.77	2.9
B	8.49	4.1	9.45	4.3
B-C	4.51	8.4	7.12	8.3
C	5.31	6.3	5.94	5.6
C-D	1.58	10.8	1.42	10.2
D	33.57	11.0	21.50	6.8
E	17.32	8.4	10.83	8.1
F	12.73	4.9	12.81	4.6
G	10.59	2.4	25.56	1.8

DIFFUSION STABILITY CATEGORIES

A. Extremely unstable
B. Moderately unstable
C. Slightly unstable
D. Neutral
E. Slightly stable
F. Moderately stable
G. Extremely stable

TABLE XIII

SACRAMENTO STABILITY DATA

*** ANNUAL AVERAGE (BASED ON 7 YEAR OF DATA) *** SACRAMENTO AREA *** (Calm < 0.5 knots)

** STABILITY INDEX DISTRIBUTION IN PERCENT OF TOTAL OBS. **

INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
						WIND DIRECTION											
A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.08	0.04	0.08	0.08	0.11	0.03	0.02	0.07
A-B	0.05	0.10	0.04	0.07	0.02	0.12	0.07	0.36	0.29	0.74	0.39	0.77	0.39	0.73	0.34	0.23	0.60
B	0.12	0.20	0.04	0.18	0.09	0.38	0.20	0.54	0.65	1.20	0.69	0.80	0.50	1.03	0.69	0.47	0.72
B-C	0.03	0.02	0.00	0.01	0.01	0.03	0.09	0.31	0.79	1.22	0.37	0.18	0.15	0.56	0.52	0.22	0.00
C	0.07	0.08	0.02	0.11	0.10	0.30	0.28	0.48	0.48	0.74	0.19	0.26	0.20	0.72	0.70	0.45	0.13
C-D	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.12	0.30	0.57	0.08	0.02	0.01	0.16	0.20	0.05	0.00
D	0.30	0.32	0.19	0.73	0.72	3.96	4.23	3.92	3.80	6.33	0.87	0.61	0.42	2.14	2.84	1.62	0.57
E	0.06	0.05	0.02	0.16	0.39	3.04	2.09	2.91	1.97	3.55	0.49	0.20	0.18	0.96	0.77	0.48	0.00
F	0.13	0.26	0.13	0.52	0.58	2.14	1.21	1.89	0.87	1.48	0.35	0.44	0.27	0.94	0.76	0.69	0.06
G	0.23	0.54	0.17	0.80	0.41	1.07	0.53	0.84	0.49	0.95	0.30	0.64	0.18	0.81	0.49	0.81	1.34

** AVERAGE WIND SPEED FOR EACH STABILITY INDEX AND DIRECTION (IN KNOTS) **

INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
						WIND DIRECTION											
A	3.0	3.0	0.0	0.0	0.0	0.0	3.0	3.0	3.0	2.8	2.8	2.9	2.9	2.9	3.0	3.0	0.0
A-B	2.5	2.8	2.8	2.8	2.8	2.7	2.6	3.1	3.1	3.4	3.7	3.2	3.4	3.3	3.2	3.1	0.0
B	3.5	3.3	3.2	2.7	3.1	3.2	4.0	4.4	5.0	5.6	5.4	4.2	4.6	4.4	4.6	3.9	0.0
B-C	8.0	7.0	0.0	7.5	8.0	7.7	7.4	8.5	8.5	8.6	8.0	7.4	7.8	8.2	8.7	8.7	0.0
C	4.4	3.6	4.6	3.7	5.3	5.6	5.3	6.1	8.5	8.4	6.3	4.3	5.1	6.2	6.4	6.5	0.0
C-D	9.0	0.0	11.0	0.0	0.0	9.0	11.0	10.7	10.9	11.0	10.1	11.3	11.0	10.6	10.7	11.4	0.0
D	6.8	3.7	4.3	4.7	6.6	10.7	13.3	10.3	12.0	13.0	10.8	6.9	7.6	10.4	12.5	10.0	0.0
E	7.5	7.6	7.2	7.1	8.0	8.1	8.3	8.4	8.6	8.7	8.5	9.1	7.8	8.3	8.3	8.2	0.0
F	4.3	4.6	4.6	4.6	4.9	5.0	5.1	5.0	4.9	5.1	4.9	4.7	4.8	4.8	4.9	4.6	0.0
[illegible]	2.8	2.7	2.7	2.7	2.7	2.8	2.8	[illegible]	2.8	2.8	2.7	2.8	2.7	2.8	2.8	2.7	[illegible]

125

TABLE XIII (continued)

*** ANNUAL AVERAGE (BASED ON 7 YEAR OF DATA) *** SACRAMENTO AREA ***

** WIND ROSE FOR EACH STABILITY INDEX (IN PERCENT OF EACH INDEX TOTAL) **

	WIND DIRECTION																
INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
A	0.85	0.85	0.00	0.00	0.00	0.00	0.85	2.54	4.24	14.41	7.63	14.41	13.56	19.49	5.93	3.39	11.86
A-B	1.01	1.84	0.74	1.38	0.46	2.21	1.29	6.82	5.44	14.01	7.28	14.56	7.28	13.73	6.45	4.24	11.24
B	1.38	2.31	0.52	2.07	1.04	4.50	2.36	6.34	7.67	14.18	8.07	9.39	5.88	12.16	8.07	5.53	8.53
B-C	0.76	0.43	0.00	0.22	0.22	0.76	1.95	6.84	17.48	27.14	8.25	3.91	3.37	12.38	11.51	4.78	0.00
C	1.29	1.47	0.46	2.03	1.84	5.71	5.25	9.02	9.12	13.90	3.50	4.97	3.78	13.54	13.26	8.38	2.49
C-D	0.93	0.00	0.31	0.00	0.00	1.24	1.24	7.45	18.94	36.02	5.28	1.24	0.93	10.25	12.73	3.42	0.00
D	0.89	0.96	0.55	2.17	2.14	11.79	12.59	11.69	11.32	18.84	2.59	1.82	1.25	6.38	8.45	4.84	1.71
E	0.37	0.31	0.14	0.93	2.23	17.54	12.06	16.78	11.36	20.48	2.82	1.16	1.02	5.56	4.44	2.80	0.00
F	1.00	2.04	1.04	4.08	4.58	16.80	9.50	14.88	6.81	11.65	2.77	3.46	2.11	7.38	6.00	5.42	0.50
G	2.17	5.08	1.57	7.53	3.83	10.07	4.99	7.90	4.67	8.96	2.86	6.05	1.71	7.67	4.67	7.62	12.66

** GROSS WIND ROSE (IN PERCENT OF TOTAL OBS.) **

	WIND DIRECTION																
INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
	1.01	1.57	0.62	2.57	2.31	11.06	8.72	11.38	9.66	16.87	3.77	4.01	2.38	8.17	7.35	5.04	3.50

** STABILITY INDEX DISTRIBUTION FOR EACH WIND DIRECTION (IN PERCENT OF DIRECTION TOTAL) **

	WIND DIRECTION																
INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
A	0.48	0.31	0.00	0.00	0.00	0.00	0.06	0.13	0.25	0.49	1.17	2.08	3.29	1.38	0.47	0.39	1.96
A-B	5.31	6.23	6.30	2.85	1.06	1.06	0.79	3.18	2.99	4.41	10.25	19.29	16.26	8.92	4.66	4.47	17.06
B	11.59	12.46	7.09	6.84	3.81	3.45	2.30	4.73	6.73	7.14	18.16	19.90	20.99	12.63	9.32	9.33	20.70
B-C	3.38	1.25	0.00	0.38	0.42	0.31	1.01	2.71	8.15	7.25	9.86	4.40	6.38	6.83	7.06	4.28	0.00
C	6.76	4.98	3.94	4.18	4.23	2.74	3.20	4.21	5.01	4.38	4.93	6.59	8.44	8.80	9.59	8.84	3.78
C-D	1.45	0.00	0.79	0.00	0.00	0.18	0.22	1.03	3.09	3.37	2.20	0.49	0.62	1.98	2.73	1.07	0.00
D	29.47	20.56	29.92	28.33	31.08	35.80	48.51	34.48	39.34	37.51	23.09	15.26	17.70	26.23	38.62	32.26	16.36
E	6.28	3.43	3.94	6.27	16.70	27.48	23.98	25.54	20.35	21.03	12.97	5.01	7.41	11.80	10.45	9.62	0.00
F	12.56	16.51	21.26	20.15	25.16	19.34	13.87	16.64	8.96	8.79	9.34	10.99	11.32	11.50	10.39	13.70	1.82
G	22.71	34.27	26.77	30.99	17.55	9.65	6.06	7.35	5.11	5.63	8.04	16.00	7.61	9.94	6.72	16.03	38.32

TABLE XIII (continued)

*** ANNUAL AVERAGE (BASED ON 7 YEAR OF DATA) *** SACRAMENTO AREA ***

** TOTAL NUMBER OF OBSERVATIONS = 20435

** HOURLY STABILITY INDEX DISTRIBUTION (IN PERCENT OF TOTAL OBS) **

HOUR	STABILITY INDEX A	A-B	B	B-C	C	C-D	D	E	F	G
0	0.00	0.00	0.00	0.00	0.00	0.00	3.97	3.90	2.73	1.90
300	0.00	0.00	0.00	0.00	0.00	0.00	4.07	3.64	2.77	2.02
600	0.00	0.00	0.00	0.00	0.00	0.00	4.26	2.38	2.83	3.03
900	0.00	0.45	3.30	0.81	2.77	0.18	4.49	0.00	0.00	0.00
1200	0.58	3.00	2.67	1.54	1.22	0.50	2.99	0.00	0.00	0.00
1500	0.00	1.36	2.52	2.16	1.33	0.89	4.24	0.00	0.00	0.00
1800	0.00	0.00	0.00	0.00	0.00	0.00	5.44	3.32	1.76	1.97
2100	0.00	0.00	0.00	0.00	0.00	0.00	4.11	4.09	2.63	1.67

** HOURLY STABILITY INDEX DISTRIBUTION, (IN PERCENT OF HOURLY OBS.) **

HOUR	STABILITY INDEX A	A-B	B	B-C	C	C-D	D	E	F	G
0	0.00	0.00	0.00	0.00	0.00	0.00	31.81	31.18	21.82	15.20
300	0.00	0.00	0.00	0.00	0.00	0.00	32.55	29.11	22.18	16.16
600	0.00	0.00	0.00	0.00	0.00	0.00	34.09	19.02	22.66	24.23
900	0.00	7.60	26.43	6.46	22.16	1.45	35.90	0.00	0.00	0.00
1200	4.62	24.03	21.33	12.29	9.75	4.03	23.95	0.00	0.00	0.00
1500	0.00	10.85	20.16	17.31	10.61	7.13	33.95	0.00	0.00	0.00
1800	0.00	0.00	0.00	0.00	0.00	0.00	43.56	26.56	14.10	15.79
2100	0.00	0.00	0.00	0.00	0.00	0.00	32.84	32.72	21.06	13.39

** DAY-NIGHT STABILITY INDEX DISTRIBUTION (IN PERCENT OF TOTAL OBS.) **

HOUR	STABILITY INDEX A	A-B	B	B-C	C	C-D	D	E	F	G
DAY	0.58	5.31	6.49	4.51	5.31	1.58	11.72	0.00	0.00	0.00
NIGHT	0.00	0.00	0.00	0.00	0.00	0.00	21.85	17.32	12.73	10.59

** AVERAGE WIND SPEED FOR EACH STABILITY INDEX (IN KNOTS) **

	STABILITY INDEX A	A-B	B	B-C	C	C-D	D	E	F	G
SPEED	2.5	2.9	4.1	8.4	[illegible]	10.8	11.0	9.4	4.9	2.4

TABLE XIV

STOCKTON STABILITY DATA

*** ANNUAL AVERAGE (BASED ON 6 YEAR OF DATA) *** STOCKTON AREA *** (Calm < 0.5 knots)

** STABILITY INDEX DISTRIBUTION IN PERCENT OF TOTAL OBS. **

	WIND DIRECTION																
INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
A	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.06	0.05	0.14	0.07	0.17	0.02	0.02	0.03
A-B	0.07	0.11	0.05	0.09	0.03	0.11	0.07	0.16	0.07	0.24	0.19	0.90	0.57	0.90	0.21	0.27	0.70
B	0.13	0.15	0.05	0.15	0.10	0.33	0.16	0.29	0.10	0.23	0.41	1.59	1.51	2.11	0.58	0.49	1.08
B-C	0.05	0.03	0.02	0.02	0.01	0.09	0.09	0.03	0.03	0.05	0.45	1.14	1.85	2.44	0.63	0.22	0.00
C	0.06	0.13	0.02	0.17	0.10	0.44	0.27	0.19	0.06	0.16	0.24	0.80	0.84	1.32	0.43	0.29	0.40
C-D	0.01	0.01	0.00	0.00	0.00	0.03	0.04	0.02	0.00	0.05	0.21	0.16	0.29	0.45	0.14	0.03	0.00
D	0.18	0.44	0.20	0.77	0.74	3.85	2.23	1.09	0.25	0.52	0.92	1.77	1.54	1.99	1.22	0.91	2.89
E	0.11	0.06	0.01	0.03	0.03	0.33	0.11	0.04	0.01	0.18	1.08	3.52	2.53	1.72	0.62	0.45	0.00
F	0.34	0.34	0.07	0.27	0.18	0.50	0.21	0.25	0.08	0.35	0.99	3.29	1.91	1.68	0.54	1.07	0.74
G	0.58	0.84	0.39	0.78	0.29	0.65	0.41	0.59	0.22	0.96	1.00	3.53	1.58	1.96	0.80	1.27	9.69

** AVERAGE WIND SPEED FOR EACH STABILITY INDEX AND DIRECTION (IN KNOTS) **

	WIND DIRECTION																
INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
A	3.0	3.0	0.0	0.0	0.0	3.0	0.0	3.0	3.0	3.0	3.0	2.9	3.0	3.0	2.8	3.0	0.0
A-B	3.2	3.0	3.0	3.0	3.2	3.1	3.0	3.0	2.8	3.2	3.4	3.6	3.6	3.4	3.8	3.5	0.0
B	3.7	3.4	4.4	3.3	3.3	3.4	3.6	3.6	3.4	3.4	5.2	5.1	5.7	5.2	4.8	4.5	0.0
B-C	7.9	5.2	8.0	7.3	4.0	7.9	8.2	7.2	8.4	9.0	8.0	8.2	8.4	8.4	8.4	8.1	0.0
C	4.1	3.8	4.8	4.0	4.7	5.0	5.5	4.0	4.0	4.8	6.5	5.9	6.6	7.1	7.5	5.5	0.0
C-D	9.0	8.0	0.0	0.0	0.0	8.8	9.6	8.3	0.0	9.6	10.1	9.4	10.6	10.7	10.7	10.2	0.0
D	5.0	4.7	4.3	4.6	5.7	7.7	8.4	4.9	4.4	5.5	8.3	8.0	8.4	10.0	12.7	7.6	0.0
E	6.9	7.0	4.0	6.4	7.3	6.8	7.3	6.1	9.0	8.2	8.3	8.2	8.2	8.3	8.0	7.7	0.0
F	4.8	4.6	4.6	4.3	4.7	4.5	4.2	4.1	3.6	4.5	4.9	4.9	5.1	5.0	4.9	5.0	0.0
G	2.9	2.9	2.8	2.9	2.9	2.9	2.9	2.9	2.8	2.9	2.9	3.0	3.0	2.9	3.0	3.0	0.0

TABLE XIV (continued)

*** ANNUAL AVERAGE (BASED ON 6 YEAR OF DATA) *** STOCKTON AREA ***

** WIND ROSE FOR EACH STABILITY INDEX (IN PERCENT OF EACH INDEX TOTAL) **

INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
						WIND DIRECTION											
A	0.94	0.94	0.00	0.00	0.00	1.89	0.00	0.94	1.89	9.43	8.49	23.58	12.26	27.36	3.77	2.83	5.66
A-B	1.56	2.40	0.96	1.80	0.72	2.40	1.56	3.35	1.56	5.03	4.07	18.80	11.98	18.92	4.43	5.75	14.73
B	1.33	1.63	0.48	1.63	1.09	3.50	1.69	3.02	1.03	2.48	4.29	16.80	15.95	22.30	6.10	5.20	11.48
B-C	0.64	0.40	0.24	0.24	0.08	1.28	1.20	0.40	0.40	0.64	6.33	15.95	25.96	34.21	8.89	3.13	0.00
C	0.96	2.12	0.38	2.88	1.73	7.40	4.62	3.17	1.06	2.69	4.04	13.56	14.23	22.31	7.31	4.81	6.73
C-D	0.40	0.40	0.00	0.00	0.00	2.41	2.81	1.20	0.00	3.21	14.86	11.24	20.48	31.33	9.64	2.01	0.00
D	0.82	2.04	0.93	3.58	3.45	17.92	10.35	5.07	1.14	2.42	4.30	8.23	7.17	9.24	5.65	4.25	13.43
E	1.05	0.53	0.11	0.26	0.32	3.00	1.00	0.37	0.11	1.63	10.01	32.51	23.39	15.86	5.69	4.16	0.00
F	2.63	2.67	0.58	2.09	1.43	3.92	1.65	1.96	0.62	2.76	7.75	25.67	14.88	13.10	4.19	8.33	5.75
G	2.26	3.31	1.52	3.06	1.14	2.52	1.61	2.30	0.87	3.75	3.93	13.83	6.19	7.68	3.15	4.96	37.93

** GROSS WIND ROSE (IN PERCENT OF TOTAL OBS.) **

INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
						WIND DIRECTION											
	1.52	2.12	0.80	2.28	1.50	6.35	3.59	2.65	0.83	2.79	5.56	16.84	12.70	14.73	5.19	5.02	15.54

** STABILITY INDEX DISTRIBUTION FOR EACH WIND DIRECTION (IN PERCENT OF DIRECTION TOTAL) **

INDEX	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM
						WIND DIRECTION											
A	0.38	0.27	0.00	0.00	0.00	0.18	0.00	0.22	1.37	2.04	0.92	0.85	0.58	1.12	0.44	0.34	0.22
A-B	4.89	5.39	5.67	3.76	2.29	1.80	2.07	6.02	8.90	8.59	3.49	5.32	4.49	6.12	4.07	5.46	4.52
B	8.27	7.28	5.67	6.77	6.87	5.22	4.45	10.75	11.64	8.38	7.29	9.42	11.87	14.30	11.11	9.78	6.98
B-C	3.01	1.35	2.13	0.75	0.38	1.44	2.38	1.08	3.42	1.64	8.11	6.75	14.56	16.55	12.21	4.44	0.00
C	3.76	5.93	2.84	7.52	6.87	6.92	7.63	7.10	7.53	5.73	4.31	4.78	6.65	8.99	6.36	5.69	2.57
C-D	0.38	0.27	0.00	0.00	0.00	0.54	1.11	0.65	0.00	1.64	3.80	0.95	2.29	3.02	2.64	0.57	0.00
D	11.65	20.75	24.82	33.83	49.62	60.70	62.00	41.08	29.45	18.61	16.63	10.51	12.13	13.49	23.43	18.20	18.59
E	7.52	2.70	1.42	1.25	2.29	5.13	3.02	1.51	1.37	6.34	19.51	20.92	19.96	11.67	11.88	8.99	0.00
F	22.18	16.17	9.22	11.78	12.21	7.91	5.88	9.46	9.59	12.68	17.86	19.53	15.01	11.40	10.34	21.27	[illegible]
[illegible]	37.97	39.89	46.23	34.34	19.47	10.16	11.45	[illegible]	[illegible]	34.36	18.07	20.98	12.45	13.33	15.51	25.26	[illegible]

129

TABLE XIV (continued)

*** ANNUAL AVERAGE (BASED ON 6 YEAR OF DATA) *** STOCKTON AREA ***

** TOTAL NUMBER OF OBSERVATIONS = 17519

** HOURLY STABILITY INDEX DISTRIBUTION (IN PERCENT OF TOTAL OBS) **

	STABILITY INDEX									
HOUR	A	A-B	B	B-C	C	C-D	D	E	F	G
0	0.00	0.00	0.00	0.00	0.00	0.00	2.35	1.50	2.61	6.03
300	0.00	0.00	0.00	0.00	0.00	0.00	2.72	1.04	2.31	6.42
600	0.00	0.00	0.00	0.00	0.00	0.00	2.97	1.40	2.39	5.75
900	0.00	0.90	3.90	1.01	3.30	0.09	3.31	0.00	0.00	0.00
1200	0.61	2.87	3.19	2.21	1.14	0.50	1.99	0.00	0.00	0.00
1500	0.00	1.00	2.36	3.90	1.50	0.83	2.90	0.00	0.00	0.00
1800	0.00	0.00	0.00	0.00	0.00	0.00	2.95	4.38	2.22	2.96
2100	0.00	0.00	0.00	0.00	0.00	0.00	2.31	2.52	3.28	4.40

** HOURLY STABILITY INDEX DISTRIBUTION. (IN PERCENT OF HOURLY OBS.) **

	STABILITY INDEX									
HOUR	A	A-B	B	B-C	C	C-D	D	E	F	G
0	0.00	0.00	0.00	0.00	0.00	0.00	18.83	11.97	20.93	48.26
300	0.00	0.00	0.00	0.00	0.00	0.00	21.79	8.31	18.50	51.39
600	0.00	0.00	0.00	0.00	0.00	0.00	23.74	11.19	19.09	45.98
900	0.00	7.17	31.17	8.08	26.38	0.73	26.47	0.00	0.00	0.00
1200	4.84	22.93	25.54	17.68	9.09	3.97	15.94	0.00	0.00	0.00
1500	0.00	8.04	18.86	31.23	12.01	6.67	23.20	0.00	0.00	0.00
1800	0.00	0.00	0.00	0.00	0.00	0.00	23.60	35.01	17.75	23.64
2100	0.00	0.00	0.00	0.00	0.00	0.00	18.44	20.17	26.20	35.19

** DAY-NIGHT STABILITY INDEX DISTRIBUTION (IN PERCENT OF TOTAL OBS.) **

	STABILITY INDEX									
HOUR	A	A-B	B	B-C	C	C-D	D	E	F	G
DAY	0.61	4.77	9.45	7.12	5.94	1.42	8.20	0.00	0.00	0.00
NIGHT	0.00	0.00	0.00	0.00	0.00	0.00	13.30	10.83	12.81	25.56

** AVERAGE WIND SPEED FOR EACH STABILITY INDEX (IN KNOTS) **

	STABILITY INDEX									
	A	A-B	B	B-C	C	C-D	D	E	F	G
SPEED	2.8	2.9	4.3	8.3	5.6	10.2	6.8	8.1	4.6	1.8

130

determine whether the Rancho Seco conditions are more similar to those at Sacramento or at Stockton.

In general, for both locations, the G category is relatively large. This situation results from the predominance of the thermally-driven wind circulation which dies out during the night and contributes to the frequent occurrence of light winds and stable temperature conditions.

From Table XII an average condition for the zero to two-hour dosage model of F with a wind speed of 4.6 knots (2.4 m/sec) can be assumed.

E. Rancho Seco Site Study

A six-weeks observing program was set up at Rancho Seco during May and June 1967 in order to obtain a brief comparison with Sacramento and Stockton conditions. Results of the six-weeks program are shown in the following table:

TABLE XV

COMPARISON OF FREQUENCY OF OCCURRENCE OF DIFFUSION CATEGORIES (May-June 1967)

	Rancho Seco				Sacramento		Stockton	
	%	$\bar{u}$ (knots)	σ_θ* (avg)	ΔT**	%	$\bar{u}$ (knots)	%	$\bar{u}$ (knots)
A-B	4.8	3.1	21.8°	-1.3°C	2.5	3.4		
B	10.5	4.7	19.3	-1.2	8.5	3.9	5.0	4.9
B-C	7.1	7.8	13.1	-1.2	6.2	8.2	5.0	6.1
C	6.2	4.9	18.6	-0.7	5.9	4.6	5.3	5.8
C-D	2.8	9.1	10.3	-0.9	3.1	9.0	4.7	8.3
D	26.4	9.1	5.0	0.2	35.9	9.5	46.9	10.0
E	15.0	7.2	6.4	0.7	14.4	6.9	16.8	6.1
F	10.2	4.3	5.4	1.1	12.2	4.1	11.5	4.8
G	17.0	2.8	7.5	1.3	11.3	1.7	4.7	0.6

* 10-minute standard deviation

** Avg temperature difference from 53 to 6 ft at Rancho Seco.

The data from the different sites in Table XV are in reasonable agreement, with Sacramento having the best agreement with Rancho Seco. It should be emphasized that enough variance exists between the sites, especially in the G category, that more data are required in order to completely define the relationship between the sites over a long period of time.

A comparison was made between the Pasquill, Markee and Fuquay systems for calculating diffusion using the six-weeks period of record (May-June 1967) from the Rancho Seco site. Calculations of σ_y at a distance of 1.5 miles were made as a means of comparing the three systems. Pasquill and Markee nomograms were used to obtain σ_y while the average σ_θ and $\bar{u}$ values shown in Table XV were used for the Fuquay system. Results of the comparison are shown in the following table

TABLE XVI

COMPARISON OF DIFFUSION CALCULATION SYSTEMS

(σ_y in feet)

Category	Pasquill	Markee	Fuquay (10 min)	Fuquay (1 hour)
A-B	410	510	290	380
B	370	390	270	330
B-C	310	350	200	220
C	280	310	280	300
C-D	230	210	170	220
D	180	140	95	190
E	130	250	110	140
F	90	370	95	200
G	70	---	140	250

The Pasquill system relates to short releases of the order of 10-15 minutes. The Markee system should apply to releases of 15 minutes to one hour. Results of this difference are shown in the larger cloud widths for the Markee system, particularly for E and F categories. A comparison of the Fuquay system used for a 10-minute release and a one-hour release shows slightly larger values of σ_y (hour) for all categories from A-B through E. For F and G, however, the differences in σ_y due to the meandering wind over a one-hour period are readily apparent. Comparison of the Fuquay one-hour values with Pasquill's data shows good agreement for all categories except F and G. It is seen in Table XVI that the Markee system overestimates σ_y on the basis of on-site measured values and should not be used. Accordingly, it is recommended that the Pasquill curves be used for the Rancho Seco site for categories A-B through E. For categories F and G it is recommended that the Fuquay one-hour values be used. These have been plotted in Fig. 21 where the original Pasquill A, B, C, D, E curves appear but new F and G curves have been drawn to correspond to values calculated by the Fuquay system for a one-hour duration release.

The average conditions used for the calculation of the one-hour release values are as follows:

TABLE XVII

RANCHO SECO AVERAGE CONDITIONS

Category	$\bar{u}$ (knots)	σ_θ(°)*
A-B	3.1	35.0
B	4.7	26.6
B-C	7.8	16.4
C	4.9	23.1
C-D	9.1	15.6
D	9.1	10.8
E	7.2	10.0
F	4.3	13.3
G	2.8	16.4

*Hourly standard deviation

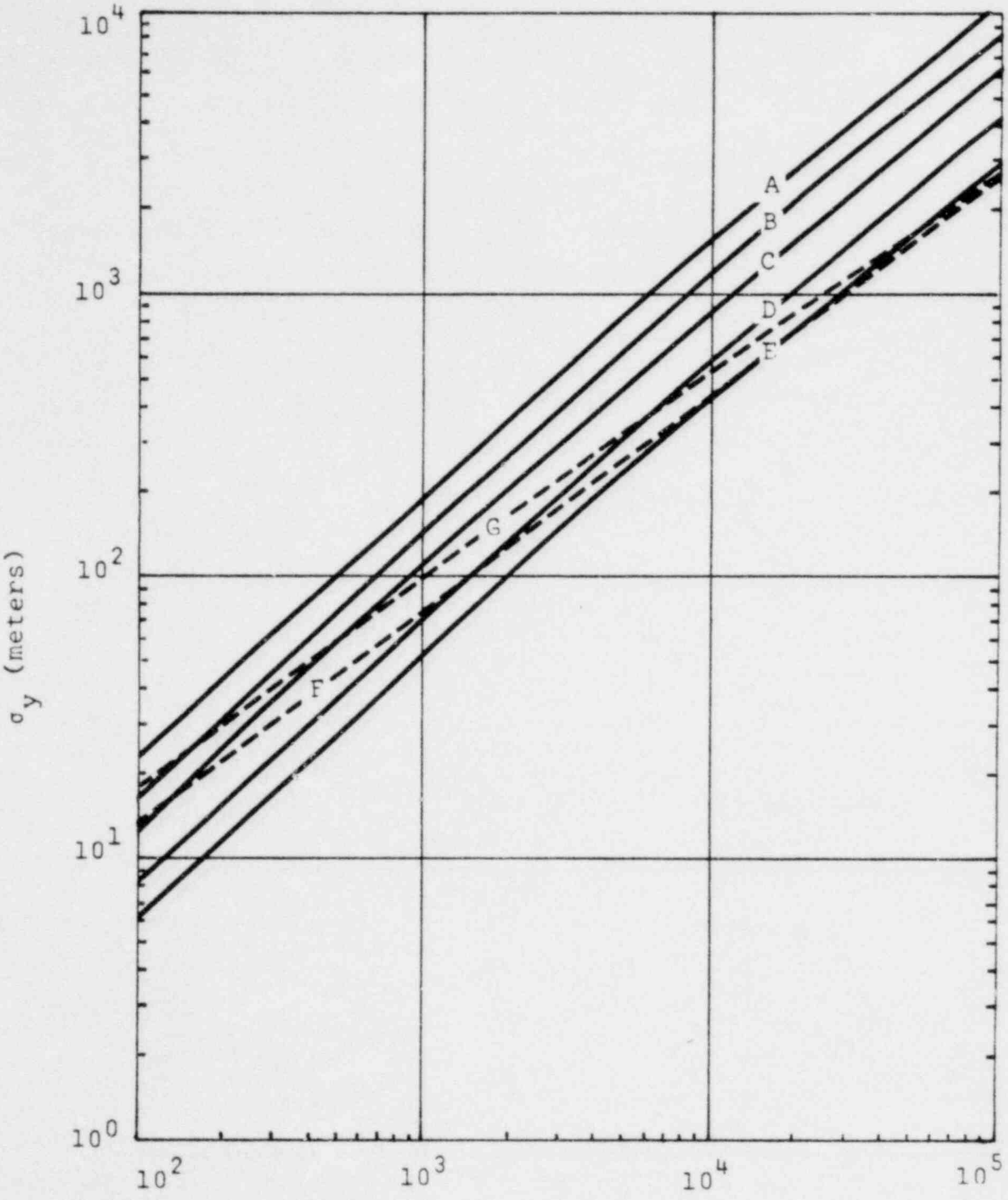


Fig. 21. PASQUILL σ_y CURVES MODIFIED FOR HOURLY RELEASE

Allowance should be made in the σ_z values for the frequent presence of inversions in the area. Figure 19 shows the annual variation in average height of the inversion base for all inversions occurring during the night below 5001 feet. An annual average has been plotted in the figure representing a height of 800 feet above Oakland or 600 feet (200 m) above the site. This average value has been used for the purpose of including the typical effects of the inversion on downwind exposures.

Figure 22 shows the Pasquill nomogram for σ_z as modified for adaptation to a 200 m inversion base height. The modification was made as recommended by Smith and Singer (1966). This consists of limiting the vertical growth of the cloud to a σ_z value determined by the following relation:

$$1.25\ \sigma_z = H$$

where H is the inversion base height (200 m in this case). As shown in Fig. 22, small changes are indicated in the D and E curves as a result of this modification but it is assumed that the A, B and C classifications do not apply to the nighttime conditions when the low-level inversion is present. Hence, those curves remain unchanged from the original Pasquill system. Use of Fig. 22 is recommended to represent average, stable, nocturnal conditions. Variations in inversion base height from day to day or month to month could be included by modifying Fig. 22 in the appropriate fashion.

Data shown in Table VI indicate a comparatively high frequency of surface inversions at Oakland during the night. The Rancho Seco site is expected to be similar with conditions at least as favorable for the development of low-level inversions. These radiation inversions are typically 100-200 feet deep. The proposed stack height of 200 feet will deliver material above or near the top of the inversion and will minimize the problem of high exposures in the vicinity

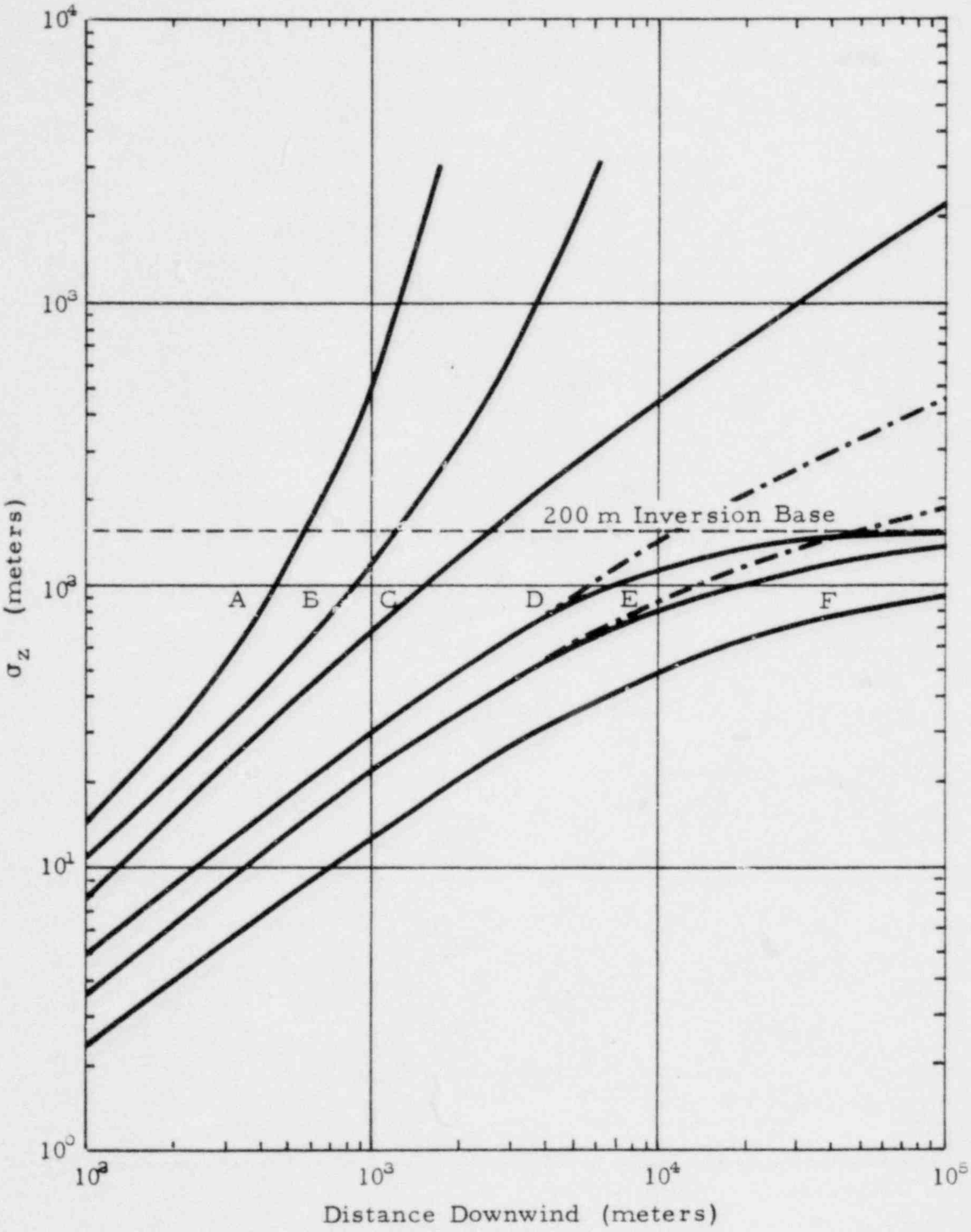


Fig. 22. PASQUILL σ_z CURVES MODIFIED FOR 200 m INVERSION

of the site due to the low-level nocturnal stability. Additional on-site data on the vertical temperature structure in the lowest 200 feet will permit a better definition of the downwind exposures under these nocturnal conditions.

VII. CONCLUSIONS

1. The climate of the Rancho Seco site is generally that of the Great Central Valley of California including hot, cloudless summers and mild winters when the rainy season occurs. Radiational fogs may persist for several days at a time, particularly during winter.

2. Tornadoes occurred 22 times in California between 1953 and 1962. The probability of an occurrence at any one site in the state is 4×10^{-5} per year and the mean recurrent interval is 23,200 years.

3. Thunderstorms are infrequent, occurring about three times each year at Stockton and five times at Sacramento. The frequency of occurrence at Rancho Seco should be similar.

4. The wind flow in the Rancho Seco area is primarily associated with a thermally-driven circulation in the summer and to a somewhat lesser extent in the spring and fall. The site is situated near a divergent flow zone caused by the deflection of air into the northern and southern sections of the Central Valley. The resulting flow at Rancho Seco is west to north-northwest at midday becoming light at night. It may remain westerly at night, become calm or if drainage from the Sierra Nevada is sufficient, it may turn southeasterly with speeds equal to the daytime flow. Strange synoptic pressure gradients prevail during the winter resulting in similar wind trajectories in the Sacramento, Stockton and Rancho Seco areas.

5. Extreme wind speeds at Sacramento and Stockton are similar and would probably be representative of the Rancho Seco site. Sacramento's extreme wind speed of record has been 70 mph.

6. Precipitation occurs at Sacramento with southeast to south winds 65 per cent of the time. Since these winds are associated with the synoptic gradient, a similar relationship can be expected at Rancho Seco.

7. Temperatures at Stockton, Sacramento, and Rancho Seco are, on the average, in agreement with each other.

8. Temperature inversions at Rancho Seco may be expected frequently at night at the surface as a result of radiation. During the summer an inversion depth of several hundreds of feet occurs as the result of the flow of cool marine air into the area during the late afternoon and evening hours. Radiational fogs occur in the winter occasionally persisting for several days.

9. The yearly rainfall occurs mostly between October and May. The yearly normal for Sacramento is 16.29 inches and 13.37 inches for Stockton with maximum 24-hour amounts of 5.59 inches for Sacramento and 3.01 inches for Stockton. Rancho Seco should be similar.

10. During a six-weeks comparative study the relative humidity at Stockton, Sacramento and Rancho Seco were, on the average, in agreement with each other, within the accuracies of measuring equipment.

11. An average condition for the zero to two-hour dosage model of F with a wind of 2.4 m/sec is recommended for the Rancho Seco site.

12. Existing information available for the Rancho Seco site suggests the use of a slightly modified form of Pasquill's diffusion calculation system to provide estimates of downwind exposures. The Pasquill A through E curves have been retained but new F and G curves have been drawn by use of the Fuquay technique to take into account the effect of meandering winds on hourly dosages under stable conditions. A slight modification is recommended in the σ_z curves due to the frequent presence of low-level inversions in the area. The annual average height of the inversion base is about 200 m above the site.

139

VIII. REFERENCES

1. Cramer, H. E., 1959: A Brief Survey of the Meteorological Aspects of Atmospheric Pollution, Bull. Amer. Meteor. Soc., 40, 4, 165-171.
2. Fuquay, J. J. and C. L. Simpson, 1964: Atmospheric Diffusion Experiments and Prediction Models, Nuclear Safety, 5, 4, 403-409.
3. Fuquay, J. J., C. L. Simpson, and W. T. Hinds, 1964: Prediction of Environmental Exposures from Sources Near the Ground Based on Hanford Experimental Data, J. Appl. Meteor., 3, 761-770.
4. Hay, J. S. and F. Pasquill, 1959: Diffusion from a Continuous Source in Relation to the Spectrum and Scale of Turbulence, Adv. in Geophys., 6, Acad. Press, Inc., New York, 345-365.
5. Hilsmeier, W. F., and J. A. Gifford, Jr., 1962: Graphs for Estimating Atmospheric Dispersions, U. S. Weather Bureau, Oak Ridge, Tenn., USAEC Rept., ORO-545.
6. Pasquill, F., 1961: The Estimation of the Dispersion of Windborne Material, The Meteorological Magazine, 90, 33-49.
7. Smith, M. E. and I. A. Singer, 1966: An Improved Method of Estimating Concentrations and Related Phenomena from a Point Source Emission, J. Appl. Meteor., 5, 631-639.
8. Thom, H. S. C., 1963: Tornado Probabilities, Mo. Wea. Rev., 91, 10-12, 730-736.
9. Yanskey, G. R., E. H. Markee, Jr., and A. P. Richter, 1966: Climatography of the National Reactor Testing Station, Idaho Falls, Idaho, ARFRO Rept., IDO-12048.

140