Appendix H

Air Quality Modeling Parameters and Results

Air Quality Modeling of Emissions from Shops with Chromium Plating Services

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Summary

It has been requested to evaluate the air quality impacts of emissions from shops with chromium plating services. The shops in this analysis vent emissions through forced ventilation (stacks) or natural ventilation (fugitive). The facilities with forced ventilation are grouped into four categories directly related to expected plume rise and amp-hour usage (low, medium, high, or horizontal). The facilities with natural ventilation are grouped into three categories dependent on the physical size of the shop (small, medium, or large). The dispersion of emissions is simulated with the latest version of the U.S. EPA air dispersion model ISCST3 (02035). The meteorological data used in the dispersion are collected from four locations throughout the state (Oakland, Fresno, San Diego, and Pasadena). In addition, a worst-case analysis is also simulated with screening meteorological conditions.

The analysis is based on a unit emission rate (1 g/s). Therefore, to obtain the estimated annual average concentration of hexavalent chromium in the air, the model results should be multiplied by the pollutant emission rate. Table S-1 shows a summary of the maximum chi/q[1] for the different shop types and screening meteorological conditions. The maximum chi/q is 1500 (μg/m^3)/(g/s) for shops with horizontal stacks or small shops with fugitive ventilation. Details of the analysis, example calculations, and additional results with historical meteorological data are described below.

[1] Chi/q is the predicted concentration based on an emission rate of 1 g/s. The chi/q is multiplied by the actual emission rate (g/s) to obtain the downwind concentration (μg/m^3). This is possible because the downwind concentration is directly proportional to the emission rate as described in the ISCST3 air quality model.

Table S.1 – Maximum (Screening) Annual Average Chi/Q ($\mu g/m^3$)/(g/s) from Shops with Chromium Plating									
Shop		Distance Downwind							
Type	Size	20 m	30 m	40 m	50 m	100 m	200 m	500 m	1000 m
Stack	Low		310	340	300	190	64	12	4
	Medium		140	140	130	84	47	12	4
	High		72	89	88	69	43	11	3
	Horizontal	1500	1300	1000	780	250	70	12	4
Fugitive	Small	1500	990	710	530	210	61	12	3
	Medium	1000	700	520	430	190	59	12	3
	Large	620	470	370	300	160	54	11	3

- Multiply by hourly emissions [annual inventory (g) / (3285 hrs/yr) / (3600 s/hr)] to obtain annual average concentration.
- A blank cell indicates no calculation because the plume is in the building wake or is still aloft.

Approach

Facilities (shops) that provide decorative and hard chromium plating services have the potential to emit hexavalent chromium. It has been requested by ARB's Stationary Source Division to analyze the downwind dispersion of emissions from various shop configurations for chrome plating facilities. Data for 26 different shops with forced ventilation (stacks) and shops with natural ventilation (fugitive) in three sizes are provided by ARB's Stationary Source Division (Appendix H-1). The data for the shops with stacks are summarized into four categories based on the potential for plume rise and amp-hour consumption (further details below).

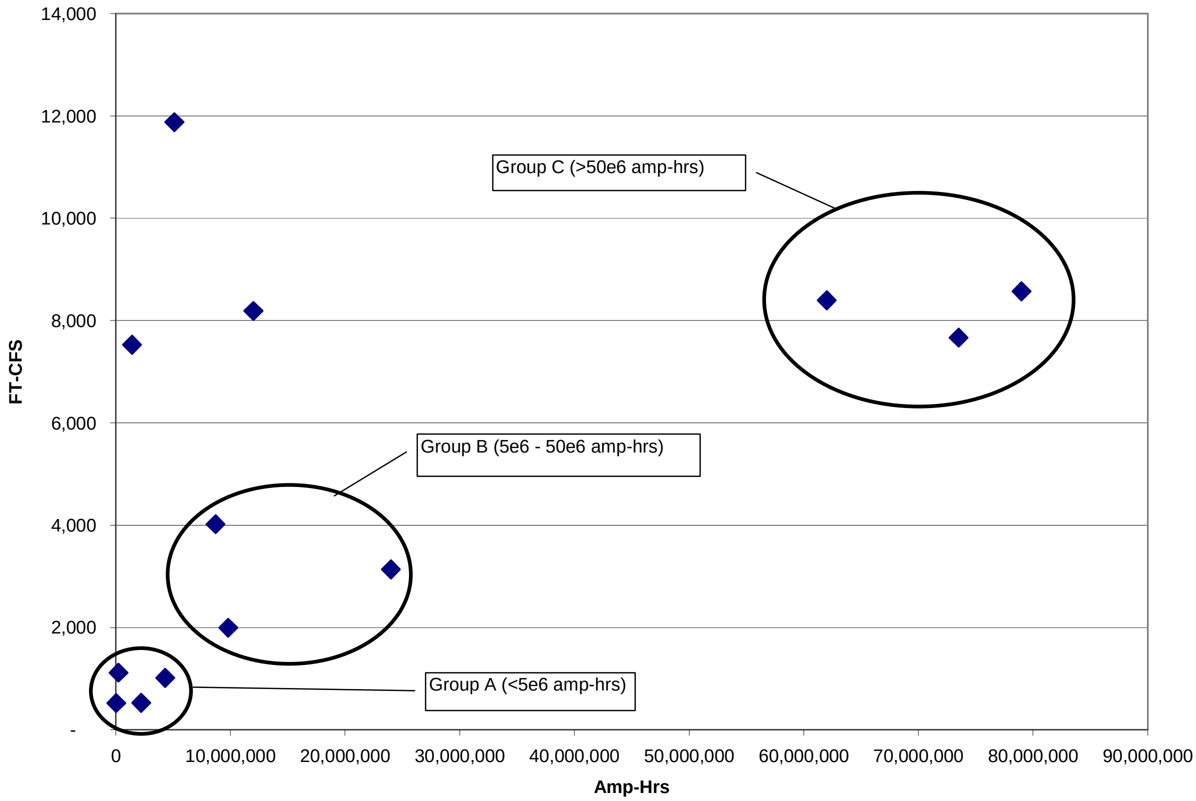
The stack parameters and fugitive building parameters are input to the latest version of the U.S. EPA ISCST3 (Version 02035) air quality model to estimate downwind impacts. Urban dispersion coefficients are used in ISCST3. Receptor heights are set at 1.2 meters above ground level. Terrain is assumed to be flat. The meteorological data used in the dispersion are collected from four locations throughout the state (Oakland, Fresno, San Diego, and Pasadena). In addition, a worst-case analysis is also simulated with screening meteorological conditions.

The model results are presented as annual average chi/q, which are concentrations based on a unit emission rate (1 g/s). In this way, the model results may be scaled to represent annual average concentrations from any facility by multiplying the chi/q with the facility emission rate.

Release Parameters - Stack Emissions

Stack data for shops with forced ventilation provided by SSD (Appendix H-1). These stack data are grouped in order to reduce the number of air dispersion model runs. Since all stacks essentially emit at approximately ambient conditions, temperature is not considered for stratifying the data. Of the stack parameters with vertical stack releases, we calculate the stack height (feet) multiplied by the gas flow (cubic feet per second). These two parameters are directly used to estimate final plume rise in the air dispersion model and are related to estimating downwind concentration. Figure 1 shows the stratified data as a function of facility amp-hours.

Figure 1 – Height * Stack Flow vs Amp - Hours



The data shown in Figure 1 are stratified into four groups. Table 1 shows the four stratified groups.

Table 1 – Stack Data Stratified		
Shop Group	Plume Rise Potential	Amp Hours
A	Low	< 5,000,000 amp-hrs
B	Medium	5,000,000 – 50,000,000 amp-hrs
C	High	> 50,000,000 amp-hrs
D	Horizontal	any amp-hrs with horizontal stack or raincap

Group D is for all stacks with horizontal releases or raincaps regardless of amp-hours. Plume rise is canceled when the stacks are horizontal or in the presence of a raincap for ambient temperature plumes.

Mean stack conditions for the vertical stacks, groups A-C, are used for each group in Table 1 as inputs to the air dispersion model. Figure 1 also shows data that lie outside of the groups. These data are not used in the mean. As a result, the predicted downwind concentrations for groups A and B will be biased towards overestimation of the mean. Table 2 shows the mean stack parameters for the four groupings. The stack data for the 26 shops (Appendix H-1) are incomplete for all necessary parameters to estimate plume rise. Therefore the mean conditions calculated in Table 2 is based on data from the shops where all parameters are available.

Table 2 – Stack Parameters

Parameter	Group A	Group B	Group C	Group D
Number of Facilities	4	3	3	4
Flow (cfs)	28	111	200	na
Diameter (m)	0.32	0.66	0.92	0.81
Velocity (m/s)	10.4	12.2	8.5	0.001
Temperature (C)	24	24	24	24
Stack Height (m)	9.1	9.1	12.8	5.6
Building Height (m)	8.8	8.8	12.5	5.3
Building Length (m)	10	10	10	10

Note 1: Building length, width and height are used for building downwash. We assume all stacks are impacted by building downwash. Therefore, building height is one foot (0.3 m) below stack height and building length and width is assumed to be ten meters.

Note 2: Raincaps and horizontal stacks (group D) are treated differently by setting the exit velocity to 0.001 m/s, turning stacktip downwash off, and reducing the stack height by three times the stack diameter (OEHHA Air Toxics Hot Spots Program Risk Assessment Guidelines, Part IV, 2000).

Release Parameters - Fugitive Emissions

Data for the shops with natural ventilation are provided by SSD (Appendix H-1). Table 3 shows a summary of the assumed release parameters for volume source releases in the dispersion model. The release parameters summarized in Table 3 reflect the lower range of the building dimensions in order to bias the predicted concentrations towards overestimation.

Table 3 – Volume (Fugitive) Source Parameters

Parameter	Group A-Vol (Small)	Group B-Vol (Medium)	Group C-Vol (Large)
Number of Facilities	14	42	11
Area Size (m^2)	<279	279 – 929	929 – 2787
Modeled Length (m)	10	17	30
Release Height (m), H/2	2.5	2.5	2.5
Syo (m), L/4.3	2.3	4.0	7.0
Szo(m), H/2.15	2.3	2.3	2.3
20 m receptor distance (m)	25	28	35

Meteorological Data

Meteorological data for this analysis are from four representative locations plus a screening analysis. Table 4 shows the latest consecutive five years of processed meteorological data, as recommended by the U.S. EPA Guideline on Air Quality Models. Shorter periods are used where longer periods are not available. The operating period for the chrome platers is 6 am to 3 pm. Therefore, Table 4 also includes a summary of meteorological conditions during normal operating hours. Appendix H-2 is the wind rose companion for Table 4.

Table 4 – Meteorological Data Summary

		Oakland	Fresno	San Diego (Miramar)	Pasadena	screening
Period	Winds	1960-1964	1985-1989	1967-1971	1981	Screening meteorological data are restricted to P-G stabilities A-D (daytime conditions only).
24 hours	Avg. Speed	4.5 m/s	3.1 m/s	2.8 m/s	1.6 m/s	
	Calms	11%	14%	17%	22%	
6 am – 3 pm	Avg. Speed	4.5 m/s	2.9 m/s	3.1 m/s	1.6 m/s	
	Calms	9%	13%	14%	16%	

Screening meteorological data represents inputs used in the U.S. EPA SCREEN3 air dispersion model. Our application is limited to daytime hours, Pasquill-Gifford stabilities A through D, since it is assumed emissions occur within the time period of 6 am to 3 pm. To estimate annual averages from the screening 1-hour averages, we multiply by the scaling factors of 0.5 to obtain an eight hour average and then we multiply by 9/24 to obtain the annual average as described in the HARP User Guide, December 2003.

Receptors

Receptors are placed at a minimum distance of 20 meters from the edge of building or stack. Polar receptors are used to plot the maximum downwind annual average concentration regardless of wind direction. Flagpole receptors set at 1.2 meters (4 ft.) above ground.

Results

Table 5 shows the annual average chi/q for screening conditions. As a result the chi/q in Table 5 are biased towards overprediction. Additional tables are provided below that show results with actual meteorological conditions for four locations in the state. The average emission rate (grams/second) should be multiplied by the chi/q to obtain the annual average concentration (µg/m^3). The average emission rate (grams/second) is based on nine hour days and 365 days per year. This is lower than the actual hourly emission rate during plating activity. However, since emissions may be distributed at any time throughout 6 am to 3 pm, we assumed the emissions are uniformly distributed over nine hours for modeling purposes.

Table 5 – Maximum (Screening)
Annual Average Chi/Q (µg/m^3)/(g/s)
from Shops with Chromium Plating

Shop		Distance Downwind							
Type	Size	20 m	30 m	40 m	50 m	100 m	200 m	500 m	1000 m
Stack	Low		310	340	300	190	64	12	4
	Medium		140	140	130	84	47	12	4
	High		72	89	88	69	43	11	3
	Horizontal	1500	1300	1000	780	250	70	12	4
Fugitive	Small	1500	990	710	530	210	61	12	3
	Medium	1000	700	520	430	190	59	12	3
	Large	620	470	370	300	160	54	11	3

- Multiply by hourly emissions [annual inventory (g) / (3285 hrs/yr) / (3600 s/hr)] to obtain annual average concentration.
- A blank cell indicates no calculation because the plume is in the building wake or is still aloft.

As an example for using Table 5, if the annual hexavalent chromium inventory for a shop is 0.1 lbs/yr, the maximum annual average concentration is estimated as follows:

$$AnnualAverage = 0.0058\frac{\mu g}{m^3} = \underbrace{1500\frac{(ug/m^3)}{(g/s)}}_{\text{chi/q}} \times \underbrace{0.1(lbs/yr)}_{\text{inventory}} \times \underbrace{\frac{454(g/lb)}{3285(hrs/yr)\times 3600(s/hr)}}_{\text{conversion factors}}$$

The chi/q results based on meteorological data from Oakland, Fresno, San Diego, and Pasadena are shown in Tables 6 through 9, respectively. The example calculation shown above should be used to convert the chi/q in Tables 6-9 to annual average concentrations. The results based on Pasadena meteorology, Table 9, show the highest chi/q.

Table 6 – Maximum (Oakland) Annual Average Chi/Q ($\mu g/m^3$)/(g/s) from Shops with Chromium Plating									
Shop		Distance Downwind							
Type	Size	20 m	30 m	40 m	50 m	100 m	200 m	500 m	1000 m
Stack	Low		58	51	43	17	4.9	0.8	0.2
	Medium		46	44	39	16	4.8	0.8	0.2
	High		17	22	22	13	4.4	0.8	0.2
	Horizontal	170	120	86	63	19	5.0	0.8	0.2
Fugitive	Small	180	110	70	50	17	4.7	0.8	0.2
	Medium	140	83	58	45	17	4.7	0.8	0.2
	Large	97	66	48	36	17	4.7	0.8	0.2

- Multiply by hourly emissions [annual inventory (g) / (3285 hrs/yr) / (3600 s/hr)] to obtain annual average concentration.
- A blank cell indicates no calculation because the plume is in the building wake or is still aloft.

Table 7 – Maximum (Fresno) Annual Average Chi/Q ($\mu g/m^3$)/(g/s) from Shops with Chromium Plating									
Shop		Distance Downwind							
Type	Size	20 m	30 m	40 m	50 m	100 m	200 m	500 m	1000 m
Stack	Low		61	54	44	16	4.7	0.8	0.2
	Medium		43	41	36	15	4.4	0.8	0.2
	High		17	23	23	13	4.1	0.7	0.2
	Horizontal	180	130	87	63	19	4.9	0.8	0.2
Fugitive	Small	180	110	70	50	17	4.7	0.8	0.2
	Medium	140	83	58	45	17	4.7	0.8	0.2
	Large	95	65	47	36	17	4.6	0.8	0.2

- Multiply by hourly emissions [annual inventory (g) / (3285 hrs/yr) / (3600 s/hr)] to obtain annual average concentration.
- A blank cell indicates no calculation because the plume is in the building wake or is still aloft.

Table 8 – Maximum (San Diego, Inland) Annual Average Chi/Q ($\mu g/m^3$)/(g/s) from Shops with Chromium Plating									
Shop		Distance Downwind							
Type	Size	20 m	30 m	40 m	50 m	100 m	200 m	500 m	1000 m
Stack	Low		71	64	53	20	5.4	0.9	0.2
	Medium		49	47	41	17	5.2	0.9	0.2
	High		20	27	27	15	4.8	0.8	0.2
	Horizontal	220	150	110	75	22	5.6	0.9	0.2
Fugitive	Small	220	130	85	60	20	5.3	0.9	0.2
	Medium	220	100	71	54	20	5.3	0.9	0.2
	Large	120	83	59	44	20	5.3	0.9	0.2

- Multiply by hourly emissions [annual inventory (g) / (3285 hrs/yr) / (3600 s/hr)] to obtain annual average concentration.
- A blank cell indicates no calculation because the plume is in the building wake or is still aloft.

Table 9 – Maximum (Pasadena) Annual Average Chi/Q ($\mu g/m^3$)/(g/s) from Shops with Chromium Plating									
Shop		Distance Downwind							
Type	Size	20 m	30 m	40 m	50 m	100 m	200 m	500 m	1000 m
Stack	Low		130	120	100	38	11	1.7	0.4
	Medium		52	53	50	28	9.6	1.7	0.4
	High		25	38	39	25	9.0	1.6	0.4
	Horizontal	470	320	220	150	43	11	1.8	0.4
Fugitive	Small	420	250	160	120	39	10	1.7	0.4
	Medium	340	190	130	100	38	10	1.7	0.4
	Large	230	150	110	81	38	10	1.7	0.4

- Multiply by hourly emissions [annual inventory (g) / (3285 hrs/yr) / (3600 s/hr)] to obtain annual average concentration.
- A blank cell indicates no calculation because the plume is in the building wake or is still aloft.

Appendix H-1

Chromium Plating Shop Physical Descriptions for Emission Release Parameters Provided by ARB's Stationary Source Division

Chromium Plating & Anodizing Facilities Dispersion Modeling Parameters

There are two types of facilities that need to be modeled. Facilities with ventilation systems (49%), and facilities without ventilation systems (51%).

Ventilated facilities with stacks:

Amp-hr distribution:	Range	Median	Mean
	500 – 83,000,000	1,000,000	8,000,000

Operating Parameter vary from continuous operation to the minimum of 4 hrs/day, 5 days/week

Facility Amp-hrs	Stack height (ft)	Stack diameter (in)	Exit Velocity (ft/sec)	Temperature (^oF)
10,000	building height	10 X 15	26.56	78.5
35,000	25	11.5 X 14.5	18.1	82
200,000	25-Hor	34	21.5	78
225,000	26	13.5	43.2	73
1,100,000	building height	15 X 7.5	28.9	70
1,300,000	building height	19 1/2 X 26	13	85
1,400,000	30	28	58.7	69
2,200,000	?	12	50.4	75
2,200,000	32	8	47.3	70
4,300,000	34	14	28	69
5,100,000	55	26	58.6	77
8,700,000	25	30.75	31.2	75
9,800,000	30	13.5	67	94
10,700,000		48	35	55
12,000,000	45	32	32.6	91
17,800,000	building+185"	32	56.8	81
18,500,000	25-Hor	26 X 22	17.5	70
24,000,000	30	30	21.3	78
28,700,000	30-horizontal	27.75 X 39.75	23.75	78
30,500,000	25-Hor	26.75 X 21.75	21	60
34,000,000	Building +11'	24	16	84
62,000,000	40.5	34	32.9	75
	39	39	40.83	78
73,500,000	50	39	18.5	64
	50	39	13.5	64
79,000,000	36	36	33.7	70

South Coast Data: on stack height (64):
28 with 4.3 – 7.3m stack   30 with 7.3 – 15 m stack   5 with > 15m stack

Unventilated Facilities:

Volume source we need building dimensions. The source has usually one tank.

Amp-hr distribution:	Range	Median	Mean
	120 – 10,000,000	70,000	470,000

Operating Parameter vary from 12 hrs/day, 7days/week to the minimum of 2 hrs/day, 5 days/week

SCAQMD building dimensions for 68 volume sources

14 with < 279 m^2
42 with 279 – 929 m^2
11 with 929 – 2,787 m^2

Appendix H-2

Wind Roses and Modeling Outputs

Figure B1 – Oakland Wind Rose (6 am – 3 pm)

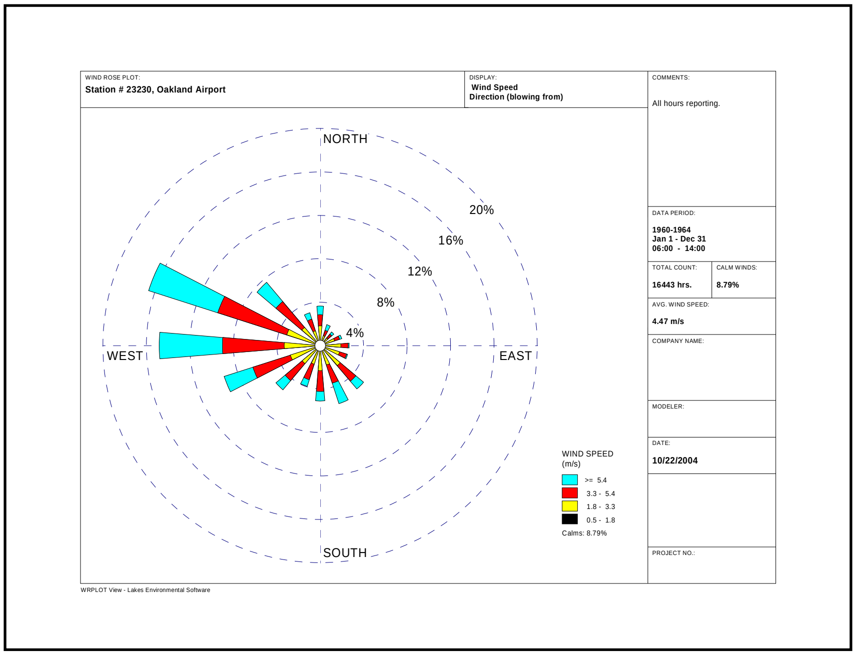


Figure B2 – Oakland Wind Rose (All Hours)

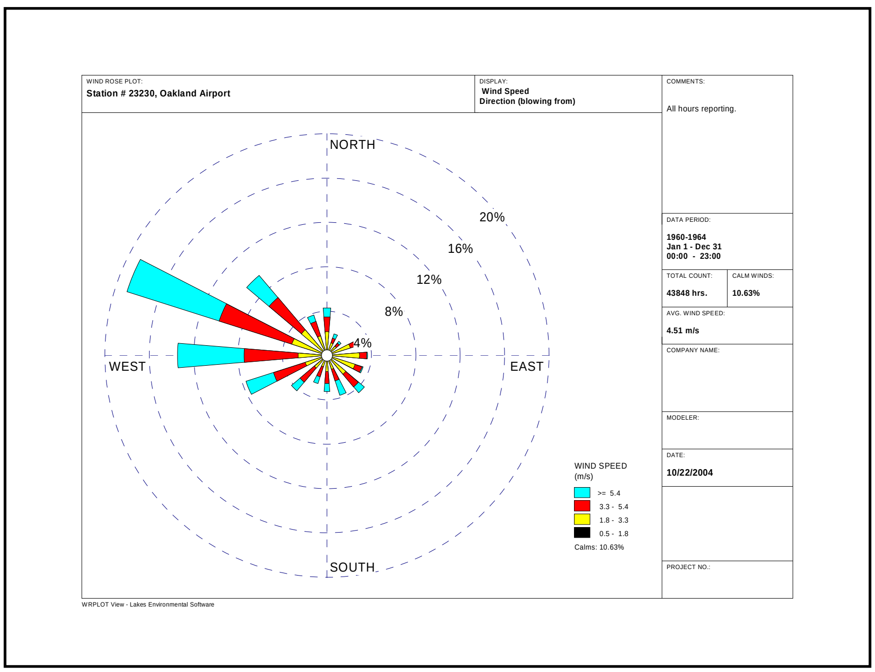


Figure B3 – Fresno Wind Rose (6am – 3pm)

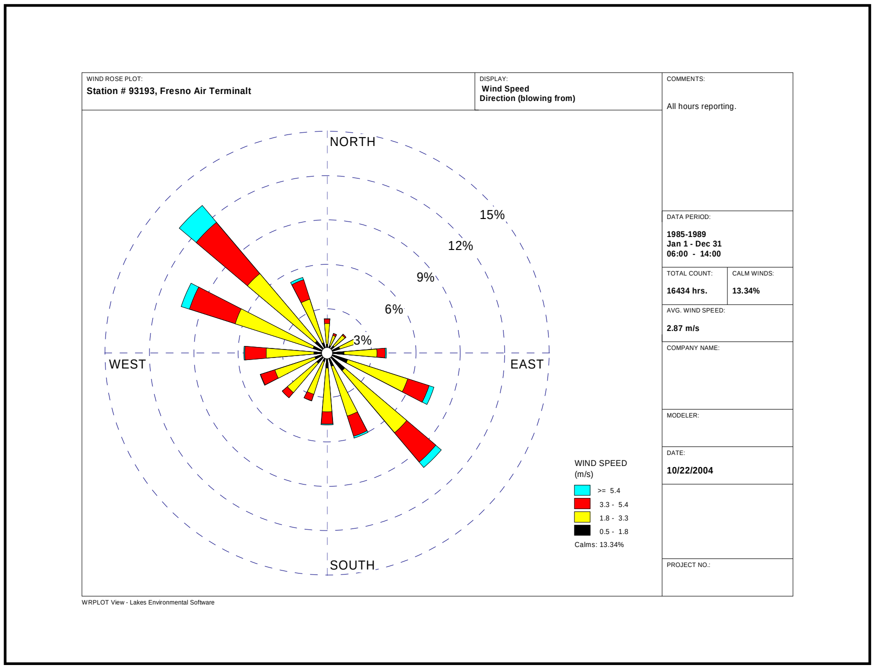


Figure B4 – Fresno Wind Rose (All Hours)

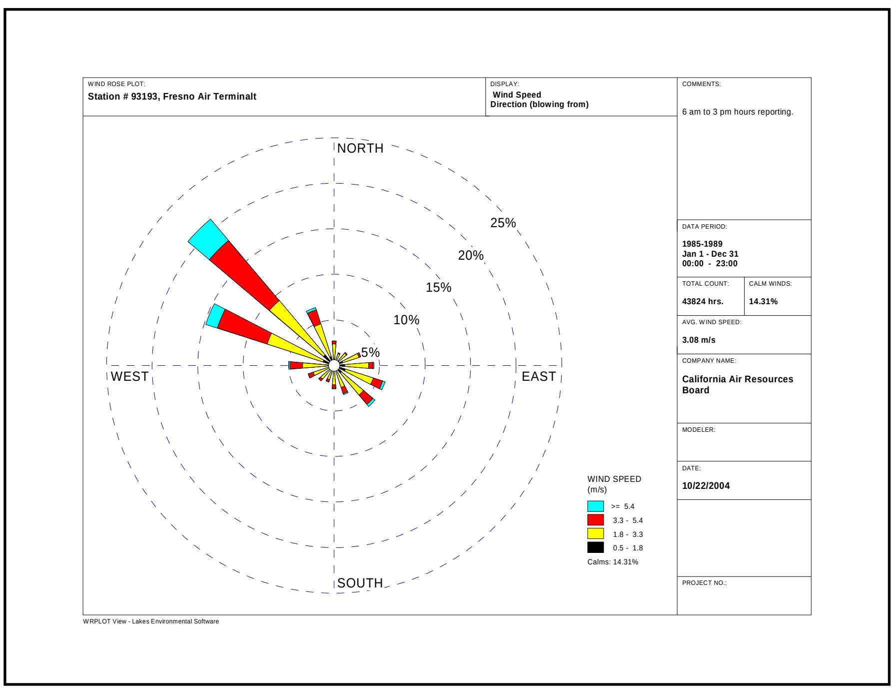


Figure B5 – San Diego (Miramar) Wind Rose (6am – 3pm)

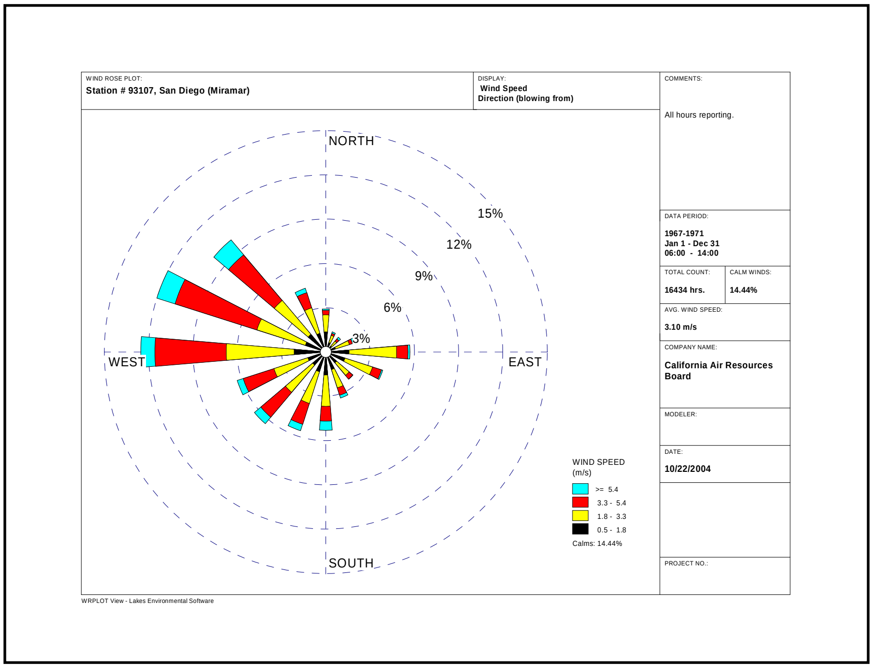


Figure B6 – San Diego (Miramar) Wind Rose (All Hours)

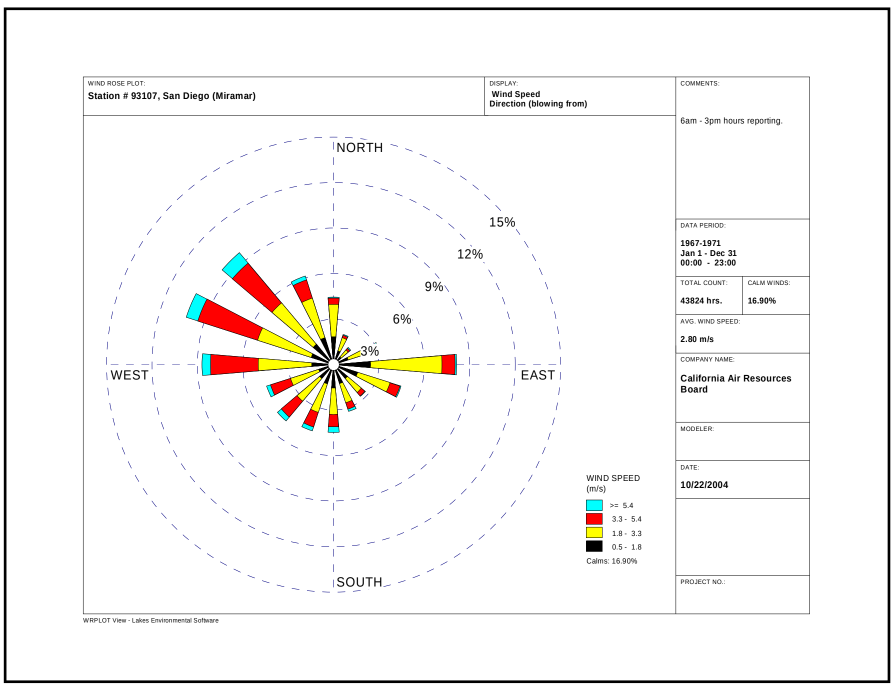


Figure B7 – Pasadena Wind Rose (6am – 3pm)

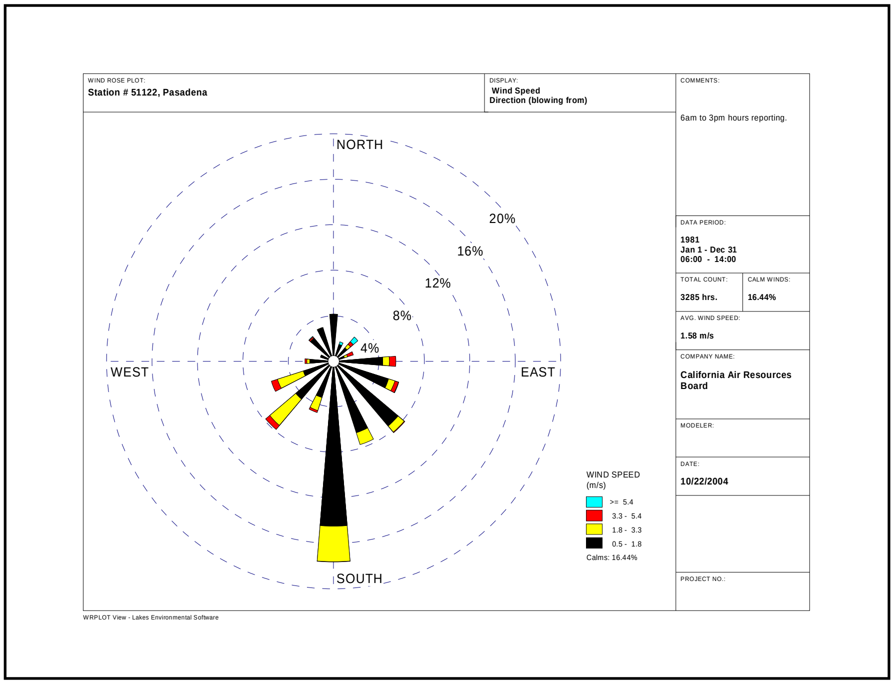
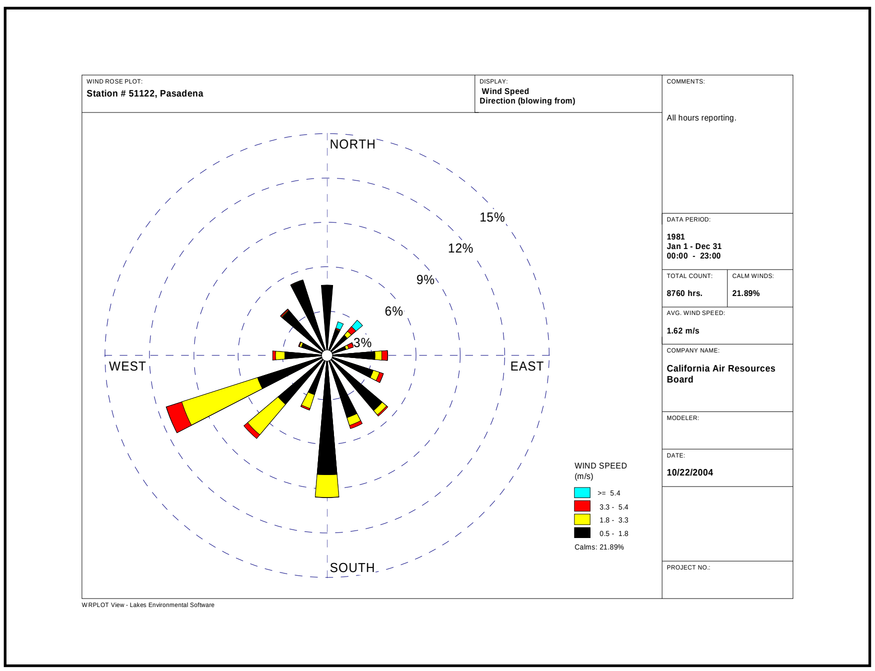


Figure B8 – Pasadena Wind Rose (All Hours)



Modeling

Chrome Plating with a stack source, unit emission rate

q (g/s)	days/week	**q (g/yr)**	**q (lb/yr)**
1	7	**11,793,600**	**26,000**
(m)	(ug/m3)	(ug/m3)	(ug/m3)
Distance from edge of facility	Fresno	San Diego, Inland	Pasadena
20			
Low	n/a	n/a	n/a
Medium	n/a	n/a	n/a
High	n/a	n/a	n/a
Horizontal	180.00	220.00	470.00
30			
Low	61.00	71.00	130.00
Medium	43.00	49.00	52.00
High	17.00	20.00	25.00
Horizontal	130.00	150.00	320.00
40			
Low	54.00	64.00	120.00
Medium	41.00	47.00	53.00
High	23.00	27.00	38.00
Horizontal	87.00	110.00	220.00
50			
Low	44.00	53.00	100.00
Medium	36.00	41.00	50.00
High	23.00	27.00	39.00
Horizontal	63.00	75.00	150.00
100			
Low	16.00	20.00	38.00
Medium	15.00	17.00	28.00
High	13.00	15.00	25.00
Horizontal	19.00	22.00	43.00
200			
Low	4.70	5.40	11.00
Medium	4.40	5.20	9.60
High	4.10	4.80	9.00
Horizontal	4.90	5.60	11.00
500			
Low	0.80	0.90	1.70
Medium	0.80	0.90	1.70
High	0.70	0.80	1.60
Horizontal	0.80	0.90	1.80
1000			
Low	0.20	0.20	0.40
Medium	0.20	0.20	0.40
High	0.20	0.20	0.40
Horizontal	0.20	0.20	0.40

ISCST (Version 02035) Model Results In addition to the details in the figures, the following met. Data are used to estimate long term (annual) averages) These data are the latest available processed databases.

Modeling

Chrome Plating with fugitive source, unit emission rate

q (g/s)	hrs/day	days/week	**q (g/yr)**	**q (lb/yr)**
1	9	7	**11,793,600**	**26,000**
	|--------- period (annual) average -------------------------------|			
(m)	(ug/m3)	(ug/m3)	(ug/m3)	(ug/m3)
Distance from edge of facility	Oakland	Fresno	San Diego, Inland	Pasadena
20				
small	180.00	180.00	220.00	420.00
medium	140.00	140.00	220.00	340.00
large	97.00	95.00	120.00	230.00
30				
small	110.00	110.00	130.00	250.00
medium	83.00	83.00	100.00	190.00
large	66.00	65.00	83.00	150.00
40				
small	70.00	70.00	85.00	160.00
medium	58.00	58.00	71.00	130.00
large	48.00	47.00	59.00	110.00
50				
small	50.00	50.00	60.00	120.00
medium	45.00	45.00	54.00	100.00
large	36.00	36.00	44.00	81.00
100				
small	17.00	17.00	20.00	39.00
medium	17.00	17.00	20.00	38.00
large	17.00	17.00	20.00	38.00
200				
small	4.70	4.70	5.30	10.00
medium	4.70	4.70	5.30	10.00
large	4.70	4.60	5.30	10.00
500				
small	0.80	0.80	0.90	1.70
medium	0.80	0.80	0.90	1.70
large	0.80	0.80	0.90	1.70
1000				
small	0.20	0.20	0.20	0.40
medium	0.20	0.20	0.20	0.40
large	0.20	0.20	0.20	0.40

ISCST (Version 02035) Model Results
In addition to the details in the figures, the following met. data are
used to estimate long term (annual) averages)
These data are the latest available processed databases.

REFERENCE

ARB Compilation of Emission Testing Results from Chromium Plating and Chromic Acid Anodizing Facilities