VC Dispersion Modeling

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DISPERSION MODELING ANALYSES OF VINYL CHLORIDE EMISSIONS FROM THE VINYL CHLORIDE MONOMER/POLYVINYL CHLORIDE PRODUCTION COMPLEX NEAR LONG BEACH, CALIFORNIA

FOR THE BF GOODRICH COMPANY AND THE STAUFFER CHEMICAL COMPANY

Nick
for your
request.
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SUMMARY

Computerized dispersion modeling was performed of the vinyl chloride (VC) emissions emanating from the vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) production complex near Long Beach, California. The spatial variation of annual average VC concentrations and the spatial and temporal variation of 24-hour VC concentrations were estimated, both in the general area surrounding the complex as well as at certain sensitive locations such as proximal residences, schools, and hospitals. State-of-the-art methods were used to develop the VC emissions inventory and to perform the dispersion modeling, in an effort to simulate realistically the ambient VC levels which will obtain after compliance with the EPA emissions standards for VC is achieved at the facility.

The comprehensive development of the emissions inventory resulted in estimated routine emissions substantially lower than previous estimates developed by the EPA for so-called typical VCM and PVC plants. Total routine (continuous) VC emissions including both point and fugitive sources for this complex after compliance were estimated to be about 1.08 g/s (8.6 lb/hr). These continuous emissions were evaluated as to their effects on ambient VC concentrations, and in addition both non-continuous routine releases and non-continuous non-routine releases were simulated.

Modeling was performed by means of EPA computer codes recommended for applications of this type (which involved numerous point and area sources of an essentially inert contaminant), primarily the new RAM suite of codes and the AQDM. In addition, CRSTER and PTMAX were used for certain of the analyses.

The primary meteorological data input to the dispersion modeling consisted both of hourly meteorological data and the stability/wind direction/wind speed frequency distribution from the Long Beach airport for the years 1960-1964. This station is some 8 km from the site on flat terrain, and the data therefrom are adequate to characterize the dispersion of VC both at the site and in the surrounding area.

Sensitivity tests were performed to evaluate the effects on the results of the following: 1) of uncertainties in the specifications of fugitive VC emissions, 2) of the application of urban vs. rural versions of the RAM codes, and 3) of the inability of the modeling codes to treat explicitly the recirculation of VC under sea-breeze/drainage flow conditions. The first two of these tests established a range of annual and 24-hour values within the bounds of which the actual concentrations probably will lie. The recirculation effects were shown to be insignificant as regards annual average and 24-hour average concentrations.

The modeling results indicate that the maximum annual average VC concentrations at the closest sensitive locations at 0.7 km to 1 km from the plant will be on the order of 2-3 ppb. At distances greater than 2 km from the plant, annual average concentrations will be less than 1 ppb, and at distances greater than 4 km, annual average concentrations will be less than 0.2 ppb.

The modeling results indicate that the maximum expected 24-hour concentrations resulting from routine, continuous VC emissions at the closest sensitive locations (0.7 km - 1 km) will be on the order of 20-27 ppb, with the number of 24-hour values per annum greater than 10 ppb at these locations in the range of 18 to 32. If the routine, non-continuous release at the VCM plant associated with the oxychlorination vent scrubbing once per annum for a full week were to coincide with the worst case 24-hour meteorological conditions for the routine releases, the maximum expected 24-hour concentration at a sensitive location would be increased to about 28 ppb, with the remainder of the 24-hour frequency distribution essentially unchanged. The maximum 24-hour concentration resulting from the worst of the five expected relief value discharges per annum from the complex could be on the order of 500 ppb at a specific point off-site.

1. INTRODUCTION

The objective of this study was to provide estimates of ambient vinyl chloride (VC) concentrations in the area surrounding the vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) production complex near Long Beach, California. The complex consists of a PVC plant and a VCM plant owned and operated by the Stauffer Chemical Company, and a PVC plant owned and operated by the BF Goodrich Company (see Figure 1).

This complex has been in operation for nearly twenty years, and it has recently become subject to emissions standards for VC promulgated by the U. S. Environmental Protection Agency (EPA). These standards were promulgated on October 21, 1976, and they require compliance thereto by all existing and new plants which emit VC by October 21, 1978.

The California Air Resources Board (ARB) is currently considering a statutory limitation on ambient concentrations of VC. The modeling analyses presented herein were designed to provide realistic estimates of the ambient VC concentrations in the Long Beach area, so as to assist the ARB in the matters now under consideration in this regard.

The computerized dispersion modeling was performed on the basis of highly specific source parameters prepared jointly by BF Goodrich, Stauffer and Dames & Moore. Because of the critical importance of an accurate emissions inventory to the realism of the dispersion modeling, an unusually refined quantification of emissions was performed, in accordance with the methods described in Section 2.

The dispersion modeling methodology was arrived at after in-depth discussions with scientists from the Modeling Section of the ARB. The specifics of the approach are described in Section 3, and descriptions of each EPA dispersion modeling code used in the analysis are set forth in Appendix I. Although the general approach was to simulate the releases by means of various standard EPA modeling codes in accordance with Long Beach Airport meteorological data, where uncertainties were identified and/or professional judgement was applied, sensitivity analyses also were performed to clarify the range of possible outcomes subject to these uncertainties.

The modeling results are presented in Section 4, in terms of the annual average VC concentration field, and the frequency distributions of 24-hour VC concentrations at identified sensitive locations around the complex, such as the most proximal residences, schools, and hospitals.

Tables are integrated within the textual material, and all figures are presented following the text. In addition to the Appendix describing the computer codes, subsequent appendices set forth listings of certain emissions input data, meteorological input data, and VC concentration output data.

2. EMISSIONS INVENTORY

2.1 GENERAL APPROACH

At the start of this study it was tentatively presumed that the vinyl chloride (VC) emissions from the BF Goodrich-Stauffer plant complex would be roughly comparable to those estimated by the U. S. Environmental Protection Agency (EPA) for typical vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) plants operating under the regulations promulgated in October, 1976. These sets of VC emissions are referred to subsequently in this report as those from "EPA-typical" plants. Dispersion modeling of the appropriately sized EPA-typical plants in the location and under the meteorological conditions of the Long Beach, California site was thus expected to provide a reference point to which the BF Goodrich-Stauffer plant complex could be compared. For the purposes of this analysis, emissions for the Long Beach plants were calculated for operations after October 21, 1978, after which compliance with the EPA emissions standards is required.

The VCM emissions sources in such plants may be conveniently divided into two classes: (1) "point sources", whose locations are well-defined, and for which estimates of emissions can be made by measurements of VC concentrations in the product stream at the location, and (2) "fugitive sources", whose locations are poorly defined, and for which accurate estimates of the emission rates are more difficult to make. An example of a fugitive source would be the sum of the small leaks from a large number of valves and flanges in certain areas of a plant.

Upon receipt by Dames & Moore of initial estimates of VC emission rates from the process engineers of the BF Goodrich and Stauffer plants, it was noted that the emission rates for the point sources were well below the values specified for the EPA-typical plants. Both the Stauffer and the BF Goodrich PVC suspension plants are roughly the same size as the 68 million kg/year EPA-typical plant. The Stauffer plant point source emission rates were estimated as roughly one-half those given for the EPA-typical plant, while the BF Goodrich point source emission rates

were estimated to be less than five percent of the EPA-typical values. (The difference between the two plants is largely determined by the different products manufactured. The polymer-water slurry for the BF Goodrich product is much more easily "stripped" of its VCM component than is the case for the slurry developed at the Stauffer plant.) For the Stauffer VCM plant, which has 23 percent of the EPA-typical plant production capacity, the only routine point source release occurs during scrubbing and venting of the oxychlorination vent, a condition that occurs routinely but infrequently (a maximum of one week per year).

In contrast to the case for the point source inventory, both BF Goodrich and Stauffer Chemical presented estimates of fugitive emissions which agreed with the EPA-typical plant values. For BF Goodrich the EPA-typical values had simply been assumed, while for Stauffer the estimate had been calculated using an actual valve count at the plant and a published value for an average leak rate for valves in petroleum refineries.

Under this initial set of assumptions concerning the fugitive emission rates, more than 95 percent of the total VC emissions from the plant complex were assigned to the very inaccurately known fugitive emission sources. Thus it became apparent that any attempt to realistically model the effects of the VC emissions from the plant complex would require a much more precise determination of the fugitive emission rates. Accordingly, a comprehensive effort was performed in an attempt to describe these fugitive emissions as accurately as possible.

The details of the development of the emissions inventory as finally used in the dispersion modeling are given in the remaining sub-sections of Section 2. The full VC emissions inventory is tabulated in Table 2-1, and the relative locations of the point sources and fugitive area sources are indicated in Figure 2.

2.2 BF GOODRICH PVC PLANT EMISSIONS

2.2.1 Point Sources

A description and characterization of the VC emissions from BF Goodrich point sources (source numbers 1 through 12 in Table 2-1) was provided by BF Goodrich. The emissions are determined, or estimated, to be those that will result from plant operation after implementation of all controls required by the federal NESHAPS standard for vinyl chloride. These controls are to become fully implemented by October 21, 1978.

With the exception of the cooling tower source, all of the point sources indicated are due to regulated releases from the process stream of PVC slurry, storage of the product PVC, or scheduled testing of the quality of the PVC slurry. The values of the emission rates from these sources are thus determined with a considerable degree of confidence.

The emission rate from the cooling tower is an estimate of possible contamination of plant cooling water by leaks from the product stream in heat exchangers--in this case, primarily the cooling jackets of the PVC reactor vessels. Measurements of vinyl chloride concentrations in the cooling water at the inlet to the cooling tower and in the cooling tower sump were supplied by BF Goodrich. The initial data indicated a concentration of 0.07 ppm in water going to the tower, and 0.03 ppm in the tower sump. The difference of 0.04 ppm was presumed to be released to the atmosphere in the cooling tower, leading to the emission rate given for this source in Table 2-1. A similar loss rate could be inferred from data supplied by Stauffer Chemical, which indicated that 5 percent of samples of cooling water showed vinyl chloride concentrations of 1 or 2 ppm, with the remainder at zero measured concentration. This implies an average concentration of approximately 0.05 ppm. If this entire concentration is presumed lost from the cooling tower, then one is lead to substantially the same emission rate as was calculated from the initial BF Goodrich data.

Why? Why!

Are we sure it's VCM?

BF Goodrich personnel later made additional measurements of cooling water vinyl chloride concentrations. These measurements indicated a uniform concentration of 0.04 ppm VCM in water both approaching and

leaving the cooling tower; i.e., apparently zero loss of vinyl chloride from the cooling tower. Nonetheless, it was decided to retain the emission rate as originally calculated in the modeling of dispersion of VC gas from the plant complex. This decision was made in order to take a conservative approach to a source whose emission rate could not be accurately determined.

2.2.2 Area Sources

Fugitive emissions from four classes of sources were considered in the development of an area VC emission rate for this plant. These source classes, and the contribution of each to the total area emission rate, are indicated in Table 2-2. The area being considered is shown as source A4 in Table 2-1 and Figure 2.

The first three of the contributions in Table 2-2 were estimated by BF Goodrich. The materials handling and transfer source is due to transfer of VCM from tank cars into the plant process stream. This is a regulated source, and thus the emission rate is controlled and determined. The "miscellaneous emissions in the neighborhood of the poly building" figure is a best estimate by plant personnel of possible losses from routine plant operation in the area of the PVC reactors. The emission rate given for "miscellaneous equipment opening and repair" is based on a figure of an average loss of 5 lbs VC per maintenance opening. It was estimated that such openings would occur on an average of once a month. This frequency was arbitrarily increased to once a day in the calculation of the emission rate given in Table 2-2, simply to provide a conservative estimate.

Why?

No emissions were assumed to exist from pump or compressor shaft seals, because only double-sealed shafts would be in operation in the plant after October, 1978.

The major fugitive source is that due to leakage from valves and flanges in VCM or PVC slurry service. An estimate of this emission rate required a very detailed inventory of all valves and flanges in such service within the plant. The data and assumptions used in developing the emission rate used are described below.

TABLE 2-1

VC EMISSIONS INVENTORY FOR BF GOODRICH/STAUFFER
CHEMICAL VCM-PVC PLANT COMPLEX

#/hr ≈ g/s x 7.91

SOURCE NAME	SOURCE NUMBER	UTM COORDINATES EAST	UTM COORDINATES NORTH	EMISSION RATE (g/s)	STACK HEIGHT (m)	EXIT TEMPERATURE (K)	EXIT VELOCITY (m/s)	STACK DIAMETER (m)
BFG Tall Stack	1	385.453	3743.000	0.0072	24.4	Ambient [a]	14.33	0.76
BFG Centrifuge	2	385.469	3743.010	0.0053	6.0	310.9	0.00	4.69
BFG Blend Tanks	3	385.494	3742.995	0.0045	18.3	322.0	15.33	0.62
BFG Dryer	4	385.508	3742.987	0.0063	15.2	360.9	33.09	0.68
BFG Dryer	5	385.509	3742.960	0.0096	9.1	360.9	21.16	0.95
BFG Silos	6	385.513	3743.009	0.0006	15.2	Ambient	1.07	0.89
BFG Silos	7	385.545	3743.007	0.0003	15.2	Ambient	1.07	0.63
BFG Silos	8	385.559	3742.949	0.0006	18.3	Ambient	1.07	0.89
BFG Silos	9	385.508	3742.980	0.0003	12.2	Ambient	1.07	0.63
BFG Silos	10	385.495	3742.891	0.0006	24.4	Ambient	1.07	0.89
BFG Cooling Tower	11	385.491	3742.960	0.0162	5.5	Ambient	7.93	10.20
BFG Lab Vent	12	385.460	3742.938	0.0027	5.5	Ambient	1.10	0.60
SC Oxychlorination	13	385.668	3743.082	0.3780 [b]	33.0	310.9	43.69	0.20
SC PVC No. 1	14	385.661	3743.126	0.0009	11.0	327.6	5.83	0.25
SC PVC No. 2	15	385.668	3743.103	0.0014	11.0	327.6	5.83	0.25
SC PVC No. 3	16	385.714	3743.102	0.0040	11.0	327.6	10.36	0.48
SC Blend Tanks	17	384.633	3743.105	0.1184	9.0	355.4	8.74	0.22
SC Blend Tanks	18	385.747	3743.069	0.0202	9.0	355.4	8.74	0.13
SC Dryer	19	385.617	3743.103	0.0743	3.0	338.7	6.78	0.84
SC Dryer	20	385.617	3743.120	0.0378	7.0	338.7	11.44	1.54

TABLE 2-1. (Continued)

SOURCE NAME	SOURCE NUMBER	UTM COORDINATES EAST	UTM COORDINATES NORTH	EMISSION RATE (g/s)	STACK HEIGHT (m)	EXIT TEMPERATURE (K)	EXIT VELOCITY (m/s)	STACK DIAMETER (m)
SC Dryer	21	385.747	3743.063	0.0416	15.0	338.7	24.27	0.61
SC Centrifuge	22	385.641	3743.112	0.0592	10.0	338.7	0.20	0.25
SC Centrifuge	23	385.747	3743.063	0.0101	10.0	338.7	0.15	0.20
SC Silos	24	385.593	3743.138	0.0140	22.0	Ambient	0.85	0.74
SC Silos	25	385.600	3743.086	0.0060	22.0	Ambient	0.85	0.49
SC Silos	26	385.724	3743.063	0.0070	22.0	Ambient	0.85	0.53
SC Cooling Tower 1	27	385.540	3743.072	0.0207	14.9	Ambient	7.93	12.80
SC Cooling Tower 2	28	385.704	3743.076	0.0080	13.7	Ambient	7.93	6.40
SC Cooling Tower 3	29	385.695	3743.050	0.0139	15.2	Ambient	7.93	9.10
SC Lab Vent	30	385.681	3743.148	0.0053	5.5	Ambient	1.10	0.60
SC Area	A1	385.660	3743.099[c]	0.2163	6.0			
SC Area	A2	385.435	3743.024	0.1869	6.0			
SC Area	A3	385.585	3743.024	0.0794	6.0			
BFG Area	A4	385.435	3742.949	0.1003	6.0			

[a] The dispersion model computer codes require these to be not less than the highest ambient temperature in the meteorological data. Plume temperatures of 310.0 K were assigned for runs using one year of meteorological data.

[b] This emission rate occurs for a maximum of one week per year. An emission rate of 0.0001 g/s was assigned for routine cases, and the higher rate was used only in runs on days of interest defined by the highest predicted concentrations.

[c] Location of southwest corner of each square area, 75 m on each side.

Table 2-2. BF Goodrich Fugitive Source Contributions

Type Of Source	Contribution To Emission Rate (g/s)
Materials Transfer and Handling	0.0002
Miscellaneous Emissions in the Neighborhood of the Poly Building	0.0026
Miscellaneous Equipment Opening and Repair	0.0263
Leakage From Valves and Flanges	0.0712
TOTAL	0.1003

A total of 895 valves and 3085 flanges were included in the initial inventory supplied by BF Goodrich and used in this calculation. These valves and flanges were classified by height above ground (four height classes: ground level, 15 feet, 30 feet, and 45 feet), and by concentration of VCM in the product stream (three VCM concentration classes: 100 percent, 30-40 percent, and 5 percent or lower). The valves were further classified by type and size of the valve. An emission rate for each of the four levels could then be estimated by multiplying the valve and flange counts by the appropriate loss rates and VCM concentrations.

Loss rates from valves in refineries in Los Angeles County were the object of a study by Palmer, et al (1957). This study indicated an average loss rate for valves in high-volatility service (product vapor pressure greater than that of kerosene) of 0.49 lb/day per valve. The distribution of loss rates in the population studied was very skewed, with 0.2 percent of the valves contributing 40 percent of the total loss rate, and 1.5 percent of the valves contributing 84 percent of the total loss rate. Eighty-eight percent of the tested valves showed no detectable loss rate, and elimination of the worst 1.5 percent of the valves reduced the average loss rate to 0.06 lb/day per valve. As was pointed out by the authors of this report, the loss rates appropriate to any particular plant are extremely sensitive to the quality of the valve maintenance program at the plant in question. Another factor which has an important effect is the type of valve being considered, valves with rising stems being more leak-prone than those of the plug or ball type construction.

A senior professional from Dames & Moore who has extensive experience with process streams of the type used in these plants visited the plant complex in order to assess the condition of the valves and to arrive at realistic estimates of valve loss rates based upon professional knowledge and judgment.

As a result of this professional judgment, the following loss rate formula was used in calculating the VC leakage from valves in the BF Goodrich PVC plant: For all rising-stem valves a loss rate of 0.02 lb/day

per valve was assumed, and for all non-rising-stem valves a loss rate of 0.01 lb/day per valve was assumed. Rising-stem type valves constitute 12.5 percent of the valves in the BF Goodrich plant.

Following Palmer, et al (1957), the loss rate for flanges was taken to be one-tenth the plant-wide average valve loss rate. This yielded a loss rate of 0.0011 lb/day per flange.

The computer dispersion codes used in this study can only accept a single height for a given area source. For this reason the height resolution of the valve and flange emission rate data could not be completely utilized in the modeling procedure. The mean height of the 100 percent VCM equivalent valves for this plant was slightly more than 4 m. As this height is not greatly different from the 6 m area source height used routinely by the EPA, the effective stack height for this area source was assumed to be 6.0 m.

2.3 STAUFFER CHEMICAL VCM-PVC PLANT EMISSIONS

2.3.1 Point Sources

A description of the VC emission characteristics from Stauffer Chemical point sources (source numbers 13 through 30 in Table 2-1) was provided by Stauffer Chemical. These emission rates are determined, or estimated, to be those in effect after October, 1978.

With the exception of the cooling tower sources, all of the point sources indicated are due to regulated releases from the process stream of VCM or PVC slurry, product storage, or scheduled testing of VCM and PVC slurry quality. The values of the emission rates from these sources are thus determined with a considerable degree of confidence.

Source number 13, the oxychlorination vent, is normally vented to the incinerator, and thus has an emission rate of zero. However, for regularly scheduled, but infrequent, periods during which this vent is being scrubbed (occurring a maximum of one week per year), this source emits VC gas at the rate indicated in Table 2-1. This source was handled by assigning it a pro-rated emission rate (0.0001 g/s) for routine calculations of concentrations in the neighborhood of the plant. On the days which were subsequently identified as having the highest concentrations, the calculations were reperformed using the larger value of the emission rate for this source.

The emission rates from the cooling towers (source numbers 27, 28, and 29) are an estimate of possible contamination of the plant cooling water by leaks from the product stream in heat exchangers--in this case, primarily the cooling jackets of the PVC reactor vessels. Data supplied by Stauffer Chemical from routine measurements of the cooling water VCM content indicated that one to two ppm concentrations were present in the water in approximately 5 percent of the measurements, with undetectably small concentrations in the remaining 95 percent of the measurements. From this it was assumed that an average concentration of 0.05 ppm was lost from water passing through the cooling towers, for the purposes of the emissions inventory. This estimate is consistent with the value

determined independently for initial data on cooling water VCM concentrations in the BF Goodrich plant, as described in Section 2.2.1. As indicated in that section, the value is quite likely overestimated, but is a reasonably conservative approach to a source for which the emission rate cannot be accurately determined.

2.3.2 Area Sources

Three areas, identified as A1, A2, and A3 in Table 2-1 and Figure 2-2, were needed to model the fugitive contributions to the Stauffer Chemical plant's VC emissions. Area A1 includes the PVC reactors, Area A2 includes the VCM units 1 and 2, and Area A3 includes VCM unit 3. Five categories of VC sources were considered for each of these areas, as listed in Table 2-3.

The emission rates given for the first four categories of sources in Table 2-3, i.e., pump seal losses, sampling losses, losses from miscellaneous equipment openings, and losses from sewer vents, were explicitly supplied by Stauffer Chemical.

The major fugitive source is that due to leakage from valves and flanges in VCM or PVC slurry service. An estimate of this emission rate required a very detailed inventory of all valves and flanges in such service within the plant. The data and assumptions used in developing the emissions rates used are described below.

A total of 2482 valves and 984 flanges (not associated with valves) were included in the inventory supplied by Stauffer Chemical and used in this calculation. This inventory was categorized by valve type (rising-stem or non-rising-stem), by height class (6 classes ranging from zero to 60 feet), by concentration of VCM (9 classes ranging from 60 ppm to 100 percent), and by area within the plant (17 localized areas). This very detailed inventory provides a basis for a fugitives emissions inventory of high resolution, if taken in conjunction with the appropriate loss rates for the various valve types and conditions.

Loss rates from valves in refineries in Los Angeles County were the object of a study by Palmer, et al (1957). This study indicated an average loss rate for valves in high-volatility service (product vapor

Table 2-3. Stauffer Chemical Fugitive Source Contributions (g/s)

Type of Source	Area A1	Area A2	Area A3
Pump Seal Losses	0.0004	0.0002	0.0001
Sampling	-0-	0.0005	0.0005
Miscellaneous Equipment Opening	0.0001	0.0001	0.0001
Sewer Vents	-0-	0.0227	0.0240
Valve & Flange Losses	0.2158	0.1634	0.0547
AREA TOTALS	0.2163	0.1869	0.0794

pressure greater than that of kerosene) of 0.49 lb/day per valve. The distribution of loss rates in the population studied was very skewed, with 0.2 percent of the valves contributing 40 percent of the total loss rate, and 1.5 percent of the valves contributing 84 percent of the total loss rate. Eighty-eight percent of the tested valves showed no detectable loss rate; and elimination of the worst 1.5 percent of the valves reduced the average loss rate to 0.06 lb/day per valve. As was pointed out by the authors of this report, the loss rates appropriate to any particular plant are extremely sensitive to the quality of the valve maintenance program at the plant in question. Another factor which has an important effect is the type of valve being considered, valves with rising stems being more leak-prone than those of the plug or ball type construction.

A senior professional from Dames & Moore who has extensive experience with process streams of the type used in these plants visited the plant complex in order to assess the condition of the valves and to arrive at realistic estimates of valve loss rates based upon professional knowledge and judgment.

As a result of this professional judgment, the following loss rate formula was used in calculating the VC leakage from valves in the Stauffer Chemical VCM and PVC plant:

1. For all non-rising stem valves a loss rate of 0.01 lb/day per valve was assumed.
2. For rising-stem valves in plant local areas 11 and 12 (included in area source A2), 50 percent were assigned a loss rate of 0.49 lb/day per valve, and the remaining 50 percent were assigned a loss rate of 0.02 lb/day per valve.
3. For rising-stem valves in the remaining areas of the plant, 35 percent were assigned a loss rate of 0.49 lb/day per valve, and the remaining 65 percent were assigned a loss rate of 0.02 lb/day per valve.

Following Palmer, et al (1957), the loss rate for flanges was taken to be one-tenth the plant-wide average loss rate. This yielded a loss rate of 0.0048 lb/day per flange.

The RAM suite of dispersion model computer codes require that area sources be handled in a very uniform manner, in terms of area source sizes and placement. For this reason the original areas indicated by the Stauffer Chemical valve and flange inventory, which were of varying sizes, were consolidated into the uniformly-sized area sources A1, A2, and A3. Also, the computer codes allow only a single height to be stipulated for a given area source. In the Stauffer Chemical plant, the mean height of 100 percent VCM-equivalent valves was found to be 4.1 m. This is close to the EPA Area Source Standard height of 6 m. An effective stack height of 6.0 m was therefore assigned to each of the area sources.

2.4 RELIEF VALVE DISCHARGE EVENTS

Non-routine releases of VC may occur at the plant complex due to process upsets leading to the opening of safety relief valves. These occurrences are infrequent and unpredictable. Information concerning the characteristics of such releases were obtained from BF Goodrich and Stauffer Chemical, and the types of events with an estimated frequency of occurrence of once per year or greater were included in the dispersion modeling. These events are listed in Table 2-4.

These events were modeled in two different ways for their contributions to annual average and 24-hour concentrations in the neighborhood of the plant complex. For the annual average calculation using code AQDM, all three types of events were included, the total emissions from them were arbitrarily doubled, and these emissions then averaged over the year's time. In order to estimate a short-term contribution from these sources, the largest emission amount of the three events was used, with an assumed duration of 5 minutes used to calculate an emission rate, and this source modeled by means of the PTMAX code.

TABLE 2-4

ESTIMATED CHARACTERISTICS OF RELIEF VALVE DISCHARGE EVENTS

SOURCE	VCM RELEASE (kg)	FREQUENCY OF OCCURRENCE	DURATION (min)	HEIGHT (m)	TEMPERATURE (k)	VERTICAL VELOCITY (m/s)	DIAMETER (m)
BF Goodrich	46 ~100#	3 per year	1 to 5	12.2	333	26	0.07
Stauffer, Reactor #1	120	1 per year	1 to 5	12.2	333	26	0.07
Stauffer, Reactor #2	283	1 per year	1 to 5	12.2	333	26	0.07

2.5 CONSOLIDATION OF SOURCES FOR THE CRSTER CODE

The dispersion model code CRSTER was used to compare the concentrations produced under 1964 meteorological conditions with those for the years 1960 through 1963. The CRSTER code admits only co-located point sources to a maximum number of nineteen. Thus some consolidation of the thirty point sources and four area sources of this plant complex was necessary before input to the CRSTER code. Sources with similar exit characteristics (height, temperature, exit velocity and diameter) were collected into consolidated point sources. In this manner an emissions inventory consisting of fourteen point sources was produced for use only in the CRSTER code.

3. MODELING METHODOLOGY

3.1 GENERAL

In order to predict realistically the ambient VC levels in the area surrounding the two plants, two basic data sets are required as input for the most appropriate dispersion modeling codes. The two required input data sets are the emissions inventory and the meteorological data, with each resolved to the requirements of the concentration averaging period of interest. The development of the detailed VC emissions inventory is described in the preceding Section 2.

Published studies have indicated that the suspected effects on health of VC are associated with long term exposures thereto; therefore, the expected annual average concentration patterns were regarded to of interest in this study. Inasmuch as the ARB is considering a limitation on 24-hour average concentrations, the patterns of variations of 24-hour average values also were addressed herein.

The following sub-sections describe the meteorological data used as input to the modeling codes, the selection of the receptor grids, the selection and the manner of application of appropriate modeling codes, and the sensitivity tests which were performed.

3.2 METEOROLOGICAL DATA

The Long Beach airport is located some 8 km due east of the plant site, as is shown in Figure 1. Both long term summarized data and hourly data are available for this station in the format required by standard Gaussian dispersion modeling codes. The plant site is extremely flat, as is the area lying between the plant site and the airport. Therefore, meteorological measurements taken at the airport are sufficiently representative of conditions at the plant site, even though there is a hill small in areal extent (Signal Hill) lying some 2 km to the south-southwest of the airport. The maximum relief of this hill is about 300 feet, which could cause some channeling of flow along a west-northwest/east-southeast axis.

The wind rose for this location for the period 1960-1964 is displayed as Figure 4. Although this wind rose indicates that the most prevalent direction is in fact west-northwest, this direction (as well as west) is associated primarily with sea-breeze flow conditions.

In order to perform calculations of annual average concentrations, the stability/wind speed/wind direction frequency distribution for the period was obtained for input. In order to calculate the frequency distribution of 24-hour concentrations at sensitive receptor locations, hourly data for the same period of 1960-1964 were also obtained. The processing of this latter data set is described in sub-section 3.5 below.

Table 3-1 (Continued)

RECEPTOR	SOURCE NUMBER	TYPE	UTM COORDINATES EAST	UTM COORDINATES NORTH	DISTANCE FROM CENTER OF COMPLEX (km)
Catskill Ave. School	21	"	382.40	3741.72	3.44
Broad Ave. Elem.	22	"	383.10	3740.47	3.54
Banning H.S.	23	"	383.10	3739.60	4.19
Delores St. School	24	"	382.26	3742.88	3.35
St. Philomena School	25	"	381.82	3743.72	3.86
Carson St. School	26	"	381.92	3744.06	3.85
School, Unknown	27	"	384.23	3746.06	3.39
Los Cerritos School	28	"	388.91	3743.55	3.35

3.3 SENSITIVE RECEPTOR LOCATIONS

Inasmuch as the plant complex is located within an area of highly diverse land use, it was of interest not only to calculate the general patterns of ambient VC concentrations but also concentrations at specific locations in the immediate area. Three categories of "sensitive" locations were identified, on the basis either of potential long term exposure or of possible vulnerability. In the former class were placed residences, and in the latter schools and hospitals.

A detailed area map was surveyed to identify in each sector from the plant the locations of the closest residences, schools and hospitals. On this basis, some 28 sensitive locations were specified within about 4 km of the plant. Figure 5 displays the locations of these points relative to the plant site, on a standard UTM coordinate system on which one unit represents 1 km. Table 3-1 provides a brief description of each numbered location, of which the first eight are the closest residences, the following two are the closest hospitals, and the last eighteen are the closest schools. Subsequent dispersion modeling runs used these locations in addition to regular cartesian grids.

3.4 ANNUAL AVERAGE CONCENTRATIONS

The EPA computer code used to obtain the annual average VC concentration fields was the Air Quality Display Model (AQDM). This code has been probably the most frequently applied modeling program in air quality evaluations since its development in 1969, and it is specifically recommended for use by the EPA in the "Interim Guideline on Air Quality Models (EPA, 1977). It is specifically designed to simulate the dispersion of a large number of point and area sources with respect to annual average concentrations over a regular 15 x 15 square receptor grid, with ad hoc receptors specifiable at off-grid locations. Appendix I presents a further description of AQDM.

The meteorological input to AQDM was the 1960-1964 STAR Program listing for the Long Beach airport. Two regular 15 x 15 grids were applied, one being a 1 km grid and the second a 2 km grid displaced so as to not duplicate receptor locations of the 1 km grid run. Additionally, the identified sensitive receptor points were used as ad hoc receptor locations.

The sensitivity of the annual average concentrations to uncertainties in the VC fugitive emission inventory was tested by performing runs on both grids on the assumption that the actual mass rate of fugitive emissions could be 50 percent higher or lower than the final calculated values. Therefore, the sensitivity runs used as input total fugitive emission rates increased by 50 percent.

TABLE 3-1

SENSITIVE RECEPTOR LOCATIONS IN NEIGHBORHOOD OF VCM/PVC COMPLEX
NEAR LONG BEACH

(Plant Center at E:385.61, N:3742.96)

RECEPTOR	SOURCE NUMBER	TYPE	UTM COORDINATES EAST	UTM COORDINATES NORTH	DISTANCE FROM CENTER OF COMPLEX (km)
Wilmington Ave. & S.D. Fwy.	1	Residence	385.03	3743.39	0.72
Arlington St.	2	"	386.62	3742.88	1.01
223rd St.	3	"	384.52	3743.19	1.11
Alameda St.	4	"	386.43	3743.72	1.12
223rd & Lucerne	5	"	384.16	3743.19	1.47
Spring St.	6	"	386.91	3741.77	1.76
Wilmington & Sepulveda	7	"	383.75	3741.36	2.45
Avalon Village	8	"	383.22	3742.21	2.51
Pacific Hospitl	9	Hospital	389.53	3741.24	4.28
Seaside Mem. Hosp.	10	"	389.17	3738.74	5.53
Del Amo Elem.	11	School	385.22	3744.47	1.56
Daniel Webster Elem.	12	"	387.34	3742.37	1.83
Stephens Jr. H.S.	13	"	387.22	3741.43	2.22
Andrew Carnegie Jr. H.S.	14	"	383.53	3743.75	2.22
Bonita St.	15	"	383.32	3743.65	2.40
Dominguel Elem.	16	"	387.49	3744.47	2.41
Muir School	17	"	387.92	3741.87	2.55
Eliz. Hudson Elem.	18	"	387.00	3740.40	2.92
St. Lucy School	19	"	387.36	3740.40	3.11
Wilmington Park Elem.	20	"	384.55	3738.90	4.19

3.5 24-HOUR CONCENTRATIONS

The primary code selected to calculate the 24-hour average VC concentrations was the Real-Time Air Quality Simulation Model (RAM). This suite of codes was recently developed by the EPA, and it is specifically designed to address the effects on short-term concentrations of multiple point and area sources. RAM actually includes four basic modeling codes, i.e., RAM, RAMR, RAMF and RAMFR.

RAM and RAMR use as input 24 hours or less of hourly meteorological data, whereas RAMF and RAMFR are programmed to run on a full year of hourly data. RAM and RAMF simulate dispersion in accordance with the urban dispersion coefficients of McElroy and Pooler (1968), and RAMR and RAMFR use the rural dispersion coefficients referred to as the Pasquill-Gifford curves (Turner, 1969). Appendix I presents additional information on this set of codes, which is also one of those specifically recommended by the EPA in the guideline document (EPA, 1977).

The versions of the codes used herein were the "official" versions recently released by the EPA. Although no User's Manual is available yet, Dames & Moore is very familiar with these codes, having previously assisted the EPA in their debugging stages.

Inasmuch as an objective was to calculate a representative frequency distribution of 24-hour VC concentrations, the use either of RAMF or RAMFR was dictated, i.e., the codes which run on long period hourly data. Initially it was presumed that RAMF would be more appropriate to this application than RAMFR, because the McElroy-Pooler urban curves were developed on the basis of low level tracer releases in St. Louis. Particularly owing to the importance of the fugitive VC emissions from this complex, which are non-buoyant and are released at low levels, it was anticipated that the urban version (RAMF) would be more appropriate. Both versions were tested to ascertain the sensitivity of results to this selection, and RAMFR was ultimately used for reasons discussed in sub-section 3.6 below.

Five years of hourly meteorological data for 1960-1964 were available from the Long Beach airport. However, the resolution of the 1964 data was better than that for 1960-1963, due to the universal change in the observing practice of the Weather Bureau. Prior to 1964, wind direction was reported by meteorological sector, i.e., resolved to the 22.5° of the sixteen such sectors. Beginning in 1964, wind direction was reported to the nearest 10°, sector, i.e., resolved within the thirty-six so-defined sectors. Furthermore, for the years after 1964, the hourly data resolved to 10° sectors are not routinely available in machine-readable form, because only the three-hourly data are systematically placed on tape.

Therefore, in general, the 1964 data are the only data generally available in the required format and degree of resolution suitable for the RAM codes, as was the case of the Long Beach data. This necessitated reliance upon 1964 as the hourly data set used as input to the RAM codes in this study. However, sensitivity tests were performed to compare the representativeness and degree of conservatism of the 1964 data, by comparison with the 1960-63 data, as discussed in sub-section 3.6 below.

An analysis of the annual wind rose (Figure 4) indicates that calm winds are reported 15.5 percent of the time at Long Beach. This is a relatively high percentage, particularly because such a hourly observation lacking a specified wind speed and wind direction is not directly usable for performing dispersion calculations. The EPA preprocessing program treats the reported calms as in the following way. The wind speed is arbitrarily assigned as 1 m/s, and the assigned wind direction is that of the last reported wind direction, (which then is randomized within the assigned 10° sector). With a 15.5 percent general incidence of reported calms, it can be expected that on some days, many consecutive reported calms would occur. Professional judgment suggests that application of the same wind direction (whthin ±5°) for long consecutive strings of calms is both unrealistic and excessively conservative. Therefore, for the purposes of this evaluation, only the first calm in a reported consecutive string was assigned to the same sector as the last

reported direction, and then randomized within 10°. Subsequent calms in a string were randomized within a 40° sector, i.e. ±20°, to reflect more realistically yet still conservatively the highly variable actual wind direction under these light wind conditions.

In most other respects, the data preprocessor was applied without modification to the hourly data, with the exception of the mixing height treatment. For the low level releases treated in this analysis, mixing height variation has a negligible effect on ground level concentrations at the short travel distances of interest. Therefore, mean seasonal mixing heights for the area were used as input.

3.6 SENSITIVITY TESTS

There were several aspects of this study in which data uncertainties were identifiable and where there were known limitations in the available analytical methods, thereby necessitating the exercise of professional judgment. In the most important of these, sensitivity testing was applied to assess the effects on the modeling results of such imponderables.

As indicated previously in sub-section 3.4 above, the uncertainty associated with the quantification of the fugitive VC emissions was thought to be at most ±50 percent. Therefore, AQDM runs were performed with the total fugitive emission rates increased by 50 percent. In general, this resulted in increases of the calculated annual average concentrations of 25 percent to 30 percent, not an unexpected result inasmuch as the fugitive VC sources represent about half of the total inventory. If the fugitives were decreased by 50 percent, then the effect on calculated annual average concentrations would be a decrease of 25 percent to 30 percent.

As discussed in sub-section 3.5 above, only the 1964 data were available for Long Beach resolved to 10° sectors. This degree of refinement is desirable for input to the RAM codes, and the 1960-1963 hourly data are resolved only to the 22.5° sectors. Two tests were performed upon the 1964 data, to ascertain whether they were either representative of longer term dispersion conditions or a conservative specification thereof.

Because the low level fugitive VC sources dominate in relation to maximum short term concentrations at close locations, the worst dispersion cases in general will be under low wind speeds. Figure 4 indicates that the frequency of occurrence of calm winds for the full period of 1960-1964 was 15.5 percent, and an analysis of the frequency of calms in 1964 showed the value of 18.3 percent pertaining thereto. Therefore, at least from this point of view, 1964 affords a conservative characterization of longer term dispersion conditions in this area as regards low level sources.

A second test of the sensitivity of using only 1964 hourly data was made by means of CRSTER, the EPA single source model. This code also runs on hourly data for a year at a time, but all input sources must be co-located, and area sources cannot be treated explicitly. Appendix I contains a more detailed description of CRSTER. All point sources from the complex were artificially co-located, and area sources were simulated as point sources at the same location. The 1964 hourly wind directions were randomized within 22.5°, so that they would be resolved to the same extent as the 1960-1963 hourly data. Each year in turn was used as input to CRSTER, and the calculated annual average concentrations, highest 24-hour concentrations, and second highest 24-hour concentrations at several locations of interest were compared. Generally the concentration values for the year 1964 were the median value (third highest) of the five years, with exceptions usually being the fourth highest value. Therefore, on the basis of this and the previous comparison, it was concluded that the year 1964 is sufficiently representative of a longer period of record in this area.

All of the dispersion modeling codes used in these analyses employ Gaussian, straight-line trajectory techniques, i.e., RAM, AQDM, CRSTER and PTMAX. If a flow reversal of 180° occurs, such as under daytime sea-breeze and nighttime drainage flow conditions, VC could recirculate of a location over which it had previously passed, adding to the concentration previously registered. None of the computer codes applied in this study are capable of treating the recirculated aspect of the plume(s). Therefore, the possible importance of this deficiency was investigated, and it was found to be insignificant as regards 24-hour average and annual average VC concentrations from an areally small plant in this locale, for two reasons.

The first of these reasons was that in general the sea-breeze in this area has a westerly component, rather than a southerly component, due primarily to the local topography. The main drainage flow at night from the north (San Gabriel Mountains) is essentially normal to this sea-breeze flow, and thus the flow reversal simply does not take place, thereby obviating recirculation.

However, it was assumed that a flow reversal could conceivably occur, either E-W or N-S. Dispersion calculations were performed under different postulated sea-breeze cum drainage flow cases, e.g., 16 hours (or 12 hours) of D with wind speed of 3 m/s, followed by a reversal with 8 hours (or 12 hours) of F with 3 m/s. Both the point and fugitive sources from the plant were so simulated, with the effects on receptors at 0.5 km and at 3 km calculated. Concentrations for 24-hour averages were obtained at each such receptor, both excluding and including the contribution from recirculation. The relative differences were shown to be primarily a function of receptor distance and wind speed, but in any case insignificant (<1 percent) at the distances of primary interest (0.5 km - 8 km) for the averaging periods of interest (24-hours and annual). Therefore, the neglect of recirculation by the dispersion codes used in this analysis was shown to be unimportant, on two counts.

Perhaps the major area in which professional judgment was applied in this study was in the selection of the version or option of the RAM codes applicable to this study, i.e., either RAMF (urban dispersion coefficients) or RAMFR (rural dispersion coefficients). Intuition suggested that RAMF was more appropriate, but analyses indicated that RAMFR would provide more realistic concentration estimates, and it was used for the final applications runs.

To begin with, RAMF and the urban coefficients have undergone little operational validation. An explanatory note is in order at this point. The urban vertical dispersion coefficients are far greater than the rural vertical dispersion coefficients, for the corresponding stability class and distance. Therefore, RAMF generally predicts higher maximum concentrations for elevated sources and for lower concentrations for low level sources than does RAMFR, given the same emissions and meteorological input.

The writer has recently performed a major study of sulfur dioxide (SO_2) dispersion in three urbanized areas in Florida (Dames & Moore, 1978). One conclusion of the study was that RAMF overestimated maximum observed 24-hour SO_2 concentrations by factors of 3 or 4, whereas RAMFR

yielded more far realistic concentration estimates. Of course, these Florida analyses primarily involved elevated sources, in contradistinction to this study. However, these Florida results suggest that for low level sources, if anything RAMF would be expected to underestimate concentrations.

To analyze this possibility further, RAMF and RAMFR were run with the VC sources from the plant on 1964 data, and a receptor grid consisting of sensitive receptors 1 and 2 (see Figure 5). Annual average VC concentrations were calculated, as well as the frequency distribution of 24-hour VC concentrations. An AQDM run also was performed, with these two ad hoc receptor locations, to generate two additional annual average values for comparison at the same locations. AQDM has been used and evaluated so often that the results therefrom can be reasonably thought of as providing a "ball park" reference point.

The results of the annual average comparisons showed that the AQDM values were intermediate between those of RAMF and RAMFR at each of the two locations. At location 1, the values were as follows: RAMF, 0.71 ppb; AQDM, 1.79 ppb; RAMFR, 2.34 ppb. At location 2, the values were as follows: RAMF, 0.59 ppb; AQDM, 1.36 ppb; RAMFR, 2.37 ppb. When it is considered 1) that the meteorological data input to AQDM was the STAR listing for 1960-1964, and the meteorological input to the RAM codes was 1964 hourly data, and 2) that the dispersion algorithms differ, it can be concluded that the RAMFR and AQDM results are reasonably consistent with each other. The RAMF annual concentrations are not consistent with the other two sets, and are lower by a factor of 3 or 4. This ratio essentially held for the maximum 24-hour concentrations from RAMFR and RAMF, i.e. RAMF predicted lower maxima by a factor of about 4. Therefore, because 1) available model validations indicate that the urban dispersion coefficient used in RAMF unrealistic, 2) results from RAMFR and AQDM were reasonably consistent, and 3) RAMFR provides far more conservative concentration estimates for the source types under consideration herein, RAMFR was selected for the applications runs.

4. MODELING RESULTS

4.1 ANNUAL AVERAGE VINYL CHLORIDE CONCENTRATIONS

Figures 6 and 7 display the results of the AQDM runs on the 1960-1964 Long Beach data. All continuous routine vinyl chloride releases were simulated, and non-routine releases were also included in a conservatively pro-rated manner.

To prepare Figures 6 and 7, the calculated VC concentrations in $\mu g/m^3$ were converted to ppb and plotted at each indicated grid point. The indicated isopleths were drawn by hand. Figure 6 displays the results of the 1 km grid run, and Figure 7 those of the 2 km grid run. These results indicate that the maximum annual average concentrations greater than 1 ppb are restricted to locations within about 1.5 km of the plant. At distances greater than 2 km, concentrations are less than 0.5 ppb.

These AQDM results are consistent in pattern with if somewhat lower in magnitude than the annual average concentrations predicted by RAMFR. RAMFR indicated maximum annual average concentrations at several of the sensitive receptor locations within 0.7 km - 1 km of the plant of 2-3.4 ppb.

Figures 6 and 7 indicated that annual average VC conditions rapidly drop off with distance from the plant site. A synthesis of the AQDM and RAMFR results is that the maximum annual average VC concentrations at the closest sensitive receptor locations at 0.7 km - 1 km can be expected to be on the order of 2-3 ppb, that at distances greater than 2 km, annual values will be less than 0.5 ppb, and at distances greater than 4 km, annual concentrations will be less than 0.2 ppb.

Appendix II sets forth a listing of the emissions input to the AQDM runs. Appendix III lists the meteorological data input thereto. Appendix IV sets forth a listing of the VC concentration output listings from AQDM.

4.2 24-HOUR VINYL CHLORIDE CONCENTRATIONS

Figure 8 displays the results of the RAMFR runs on the 1964 hourly Long Beach data. All continuous routine vinyl chloride releases were simulated, and non-routine releases were also included in a conservatively pro-rated manner.

To prepare Figure 8, the calculated maximum 24-hour VC concentrations at each sensitive receptor were converted to ppb and plotted at the appropriate location. The indicated isopleths were drawn by hand. Figure 8 is a composite worst case 24-hour concentration plot, because the indicated concentrations do not occur during simultaneous 24-hour periods. This plot indicates that maximum 24-hour VC concentrations greater than 20 ppb can be expected out to distances less than 2 km from the plant complex, and that 24-hour maxima greater than 10 ppb can be expected out to distances less than 4 km from the plant.

In addition to calculating the maximum expected 24-hour concentrations at sensitive receptor locations, full annual frequency distributions of the 366 consecutive 24-hour concentrations at these locations were calculated, in order to define the expected variability in 24-hour concentrations. Maximum 24-hour concentrations at receptors 3, 1, and 5 were greater than 20 ppb, and these three locations are situated within the 20 ppb isopleth at distances less than 1.5 km from the plant. The frequency distributions at these locations are summarized in Table 4-1. At receptor 3, where the overall 24-hour maximum value of 27.1 ppb, 32 predicted values exceeded 10 ppb. At receptor 1, at which the maximum was 20.9 ppb, 18 values exceeded 10 ppb; and at receptor 5, the maximum was 20.3 ppb and 18 values exceeded 10 ppb.

In order to define the expected temporal variation of 24-hour VC concentrations, the sequence of the 366 calculated values were listed for the most heavily affected location, i. e., receptor 3. The sequential plot of these values is presented in Figure 9. An inspection of the listing of these 366 values indicated that during this data year, there were three occurrences when two or more consecutive 24-hour calculated values exceeded 10 ppb, during one of which three consecutive

TABLE 4-1

FREQUENCY DISTRIBUTIONS OF 24-HOUR VINYL CHLORIDE CONCENTRATIONS IN ppb AT THREE HIGHEST RECEPTOR LOCATIONS

	Range (ppb)	Receptor 3	Receptor 1	Receptor 5
Maximum Value (ppb)		27.1	20.9	20.3
	25-30	1	0	0
	20-25	4	1	1
	15-20	9	3	1
	10-15	18	14	16
	5-10	66	48	48
	0-5	268	300	300

values greater than 10 ppb occurred, on days 34, 35, and 36. There were no occurrences when consecutive days exceeded 15 ppb.

In order to examine more explicitly the effects on possible 24-hour concentrations of the oxychlorination vent scrubbing, the associated VC emissions were assumed to occur on the worst identified day at the worst receptor, even though this release occurs only for about one week per annum. The identified day was that which produced the value of 27.1 ppb at receptor 3, and the resimulation by RAMR of this day with the additional vent scrubbing emissions increased the calculated value to about 28 ppb.

In order to evaluate the effects of the five postulated relief value discharges per annum, the associated emissions thereof were used as input to PTMAX (see Appendix I). These releases are generally of the order of 5 minutes in duration, and therefore any high concentrations would be of very short duration. PTMAX uses a full spectrum of hypothetical meteorological conditions as input, and therefore a wide range of calculated concentration values for these rare events is possible. Selection of roughly the 90th percentile worst of these conditions in conjunction with the worst of the five postulated relief valve discharges, and averaging the results to 24-hour concentrations yielded an estimated value on the order of 500 ppb at very close-in locations (0.2 km) offsite.

Appendix II sets forth a listing of the emissions in put to the RAMFR runs. Appendix III lists the hourly meteorological data of that day which produced the highest 24-hour VC concentration of 27.1 ppb from the routine releases. Appendix IV sets forth listings of the 24-hour frequency distributions at the 10 worst sensitive receptor locations, and the sequential listing of values at receptor 3.

REFERENCES

Not yet available.

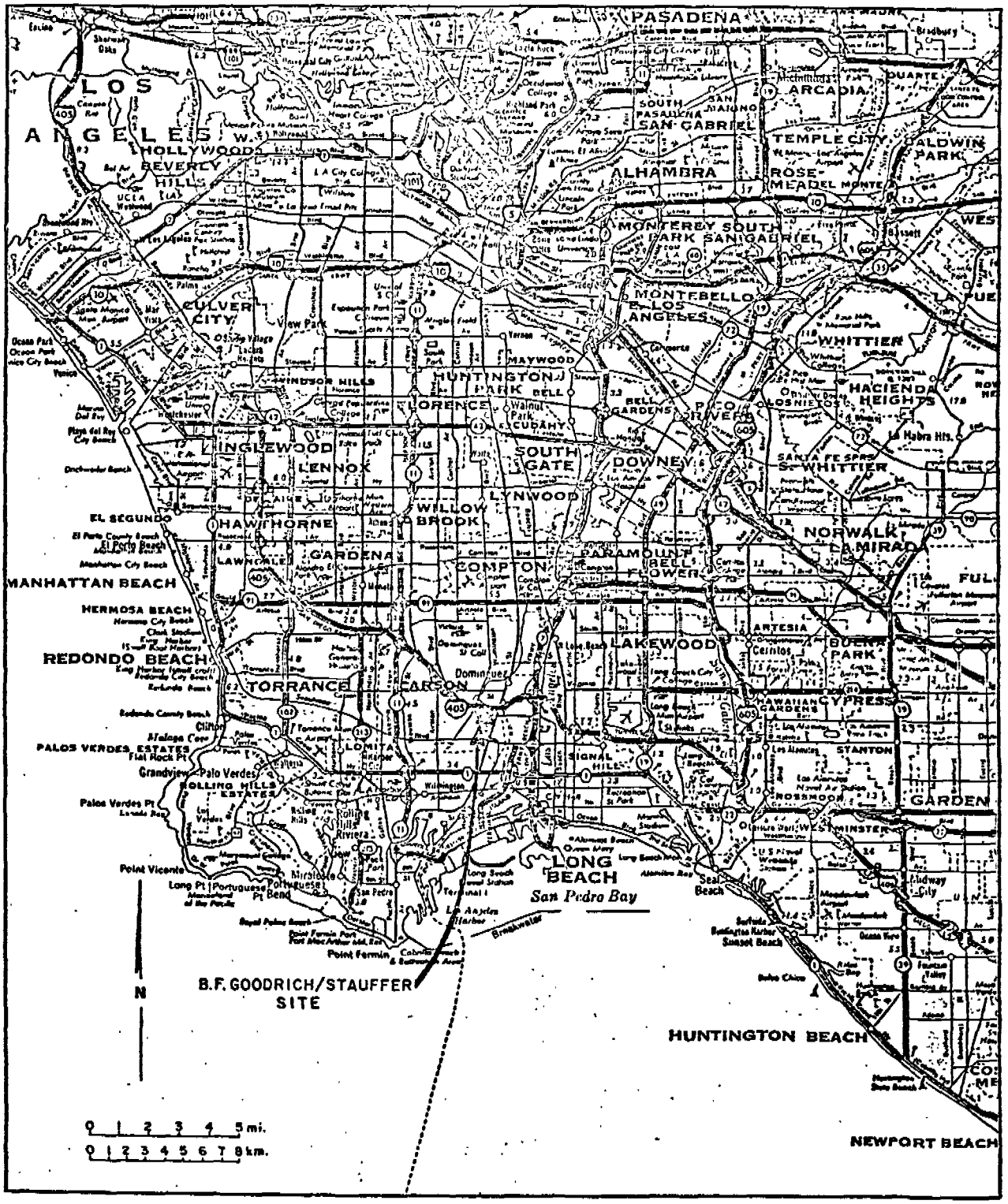

FIGURE 1. GENERAL LOCATION OF THE PLANT SITE.

FIGURE : PHOTOGRAPH OF BF GOODRICH AND STAUFFER VINYL CH RIDE MONOMER AND POLYVINYL CHLORIDE PRODUCTION COMPLEX NEAR LONG BEACH.

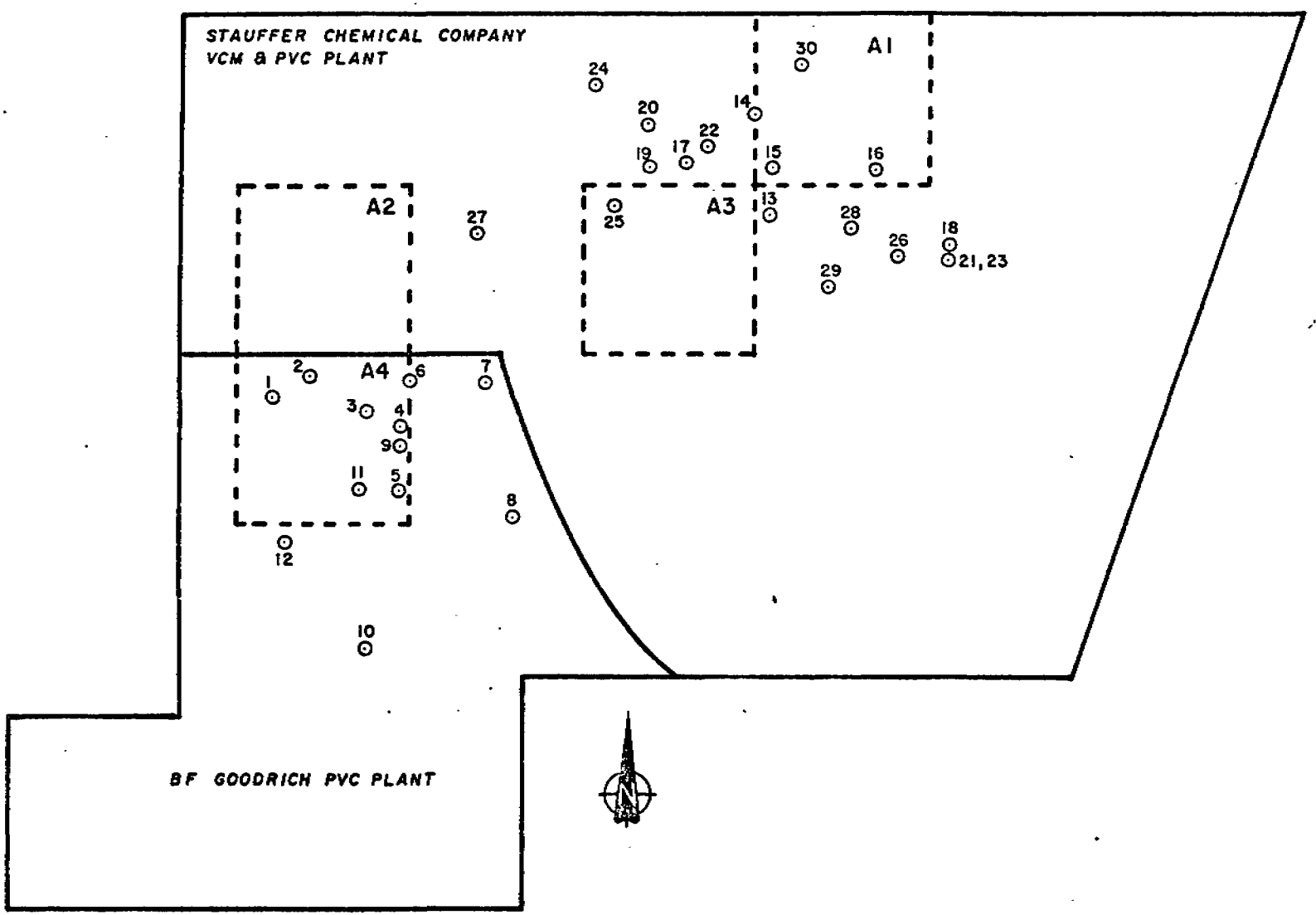

Figure 3. Locations of Point Sources and Area Sources Used in Computer Dispersion Modeling.

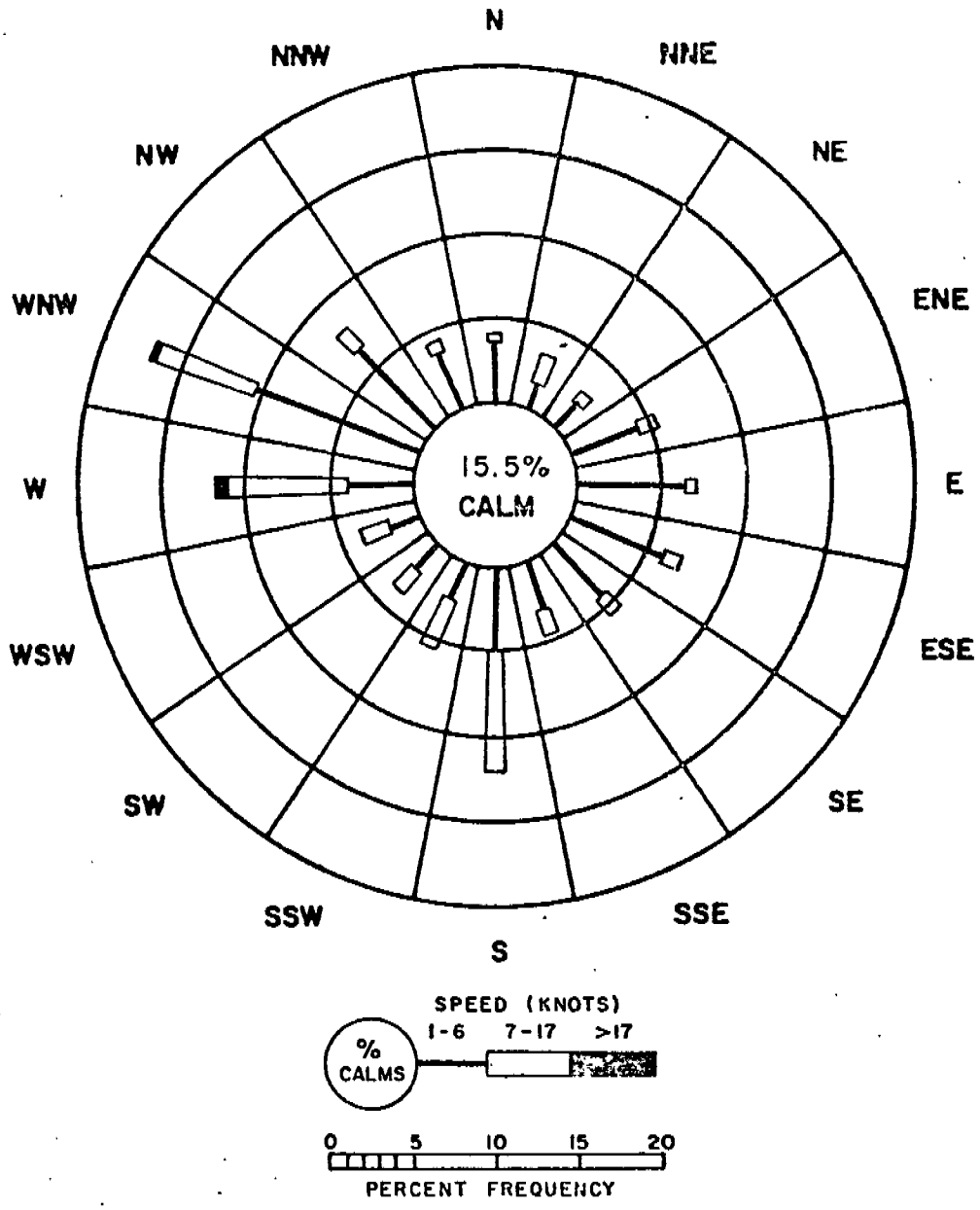

FIGURE 4. ANNUAL WIND ROSE FOR LONG BEACH AIRPORT. 1960-1964 PERIOD OF RECORD.

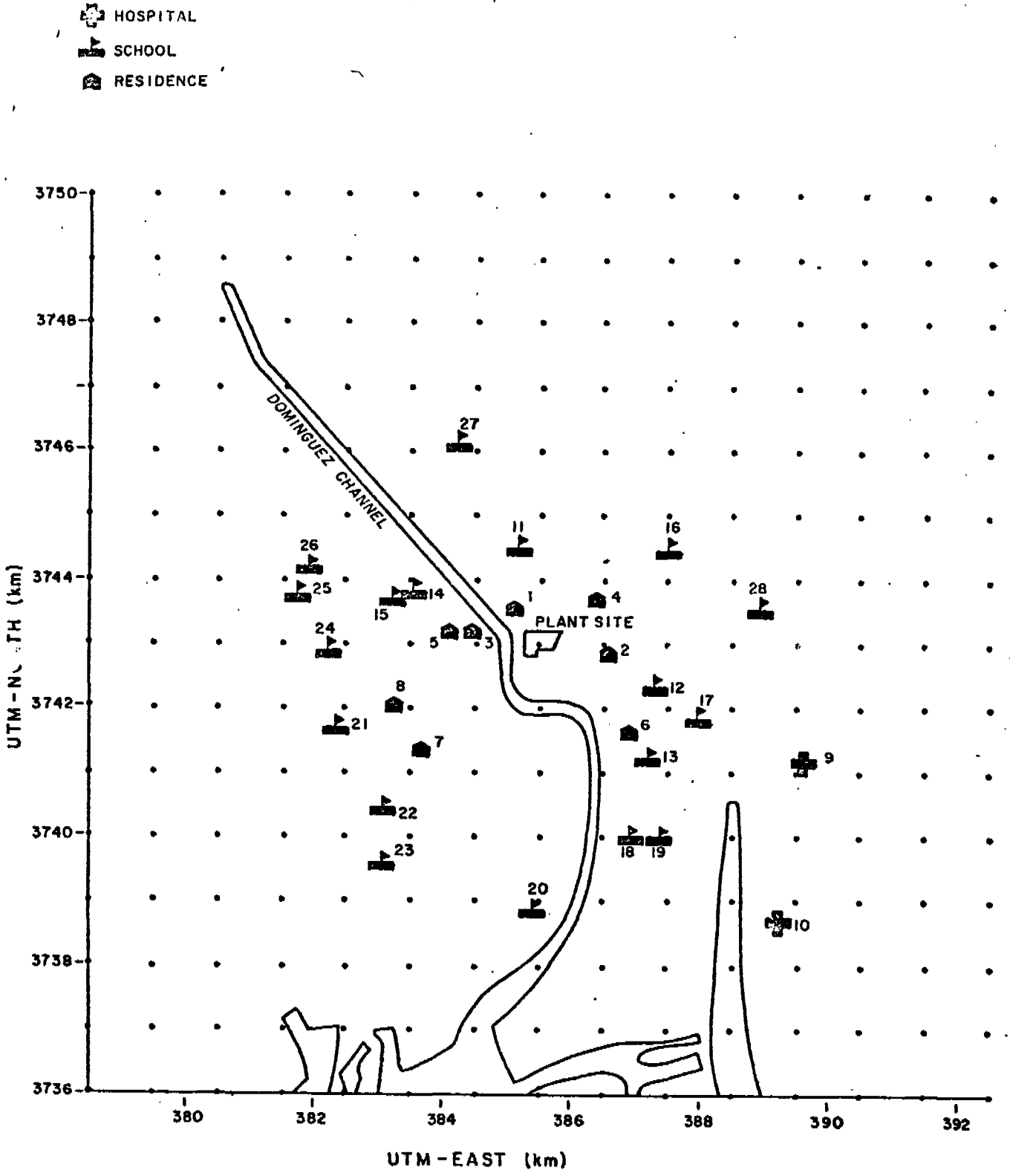

FIGURE 5. LOCATIONS OF THE 28 SENSITIVE RECEPTORS, INCLUDING 8 RESIDENCES, 18 SCHOOLS AND 2 HOSPITALS WITHIN ABOUT 4 KM OF THE SITE.

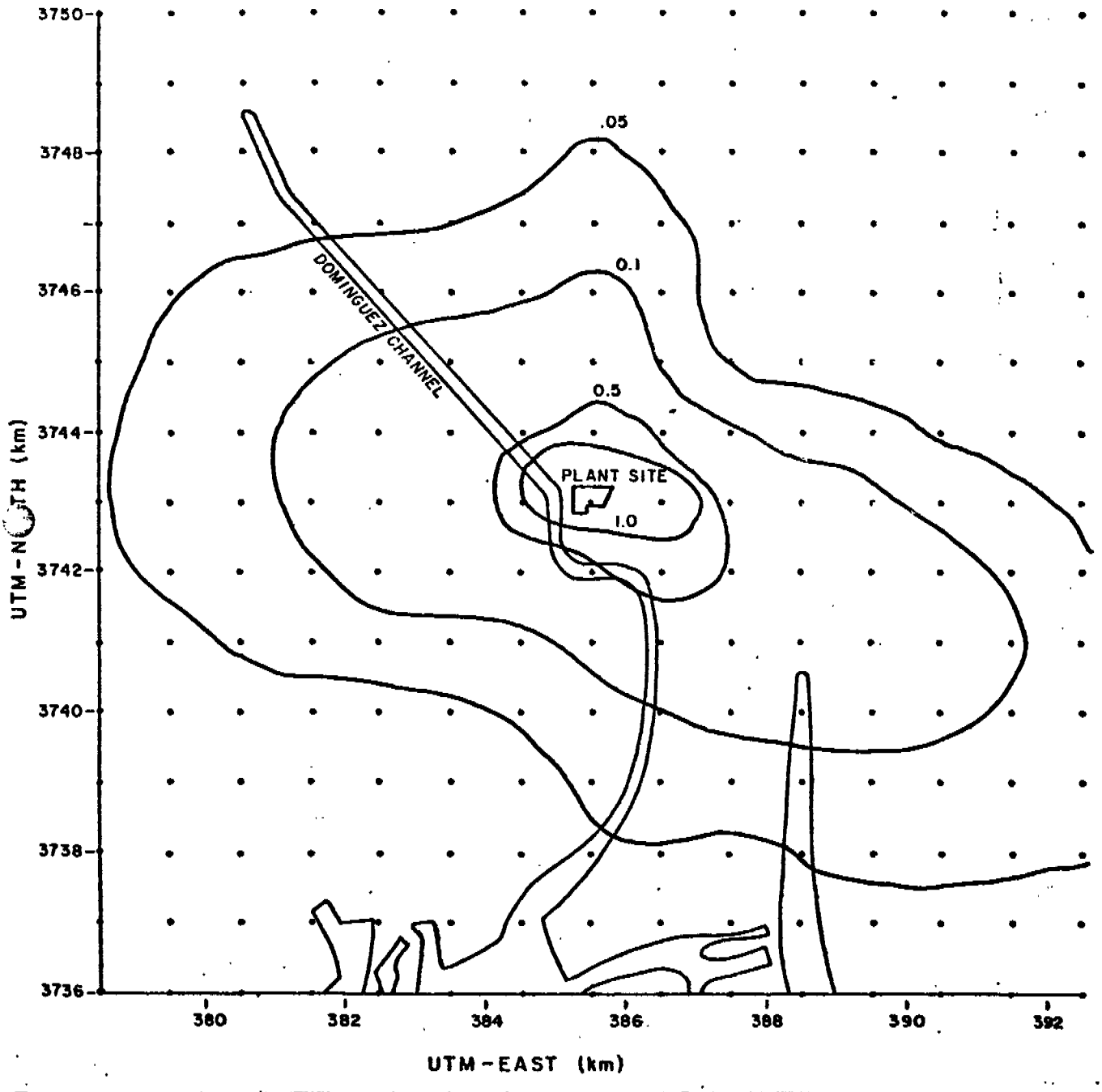

FIGURE 6. ISOPLETHS OF ANNUAL AVERAGE VINYL CHLORIDE CONCENTRATIONS IN PPB FROM AQDM WITH 1 KM GRID. 1960-1964 LONG BEACH DATA. EMISSIONS FROM BF GOODRICH/STAUFFER PLANT AFTER 10/21/78.

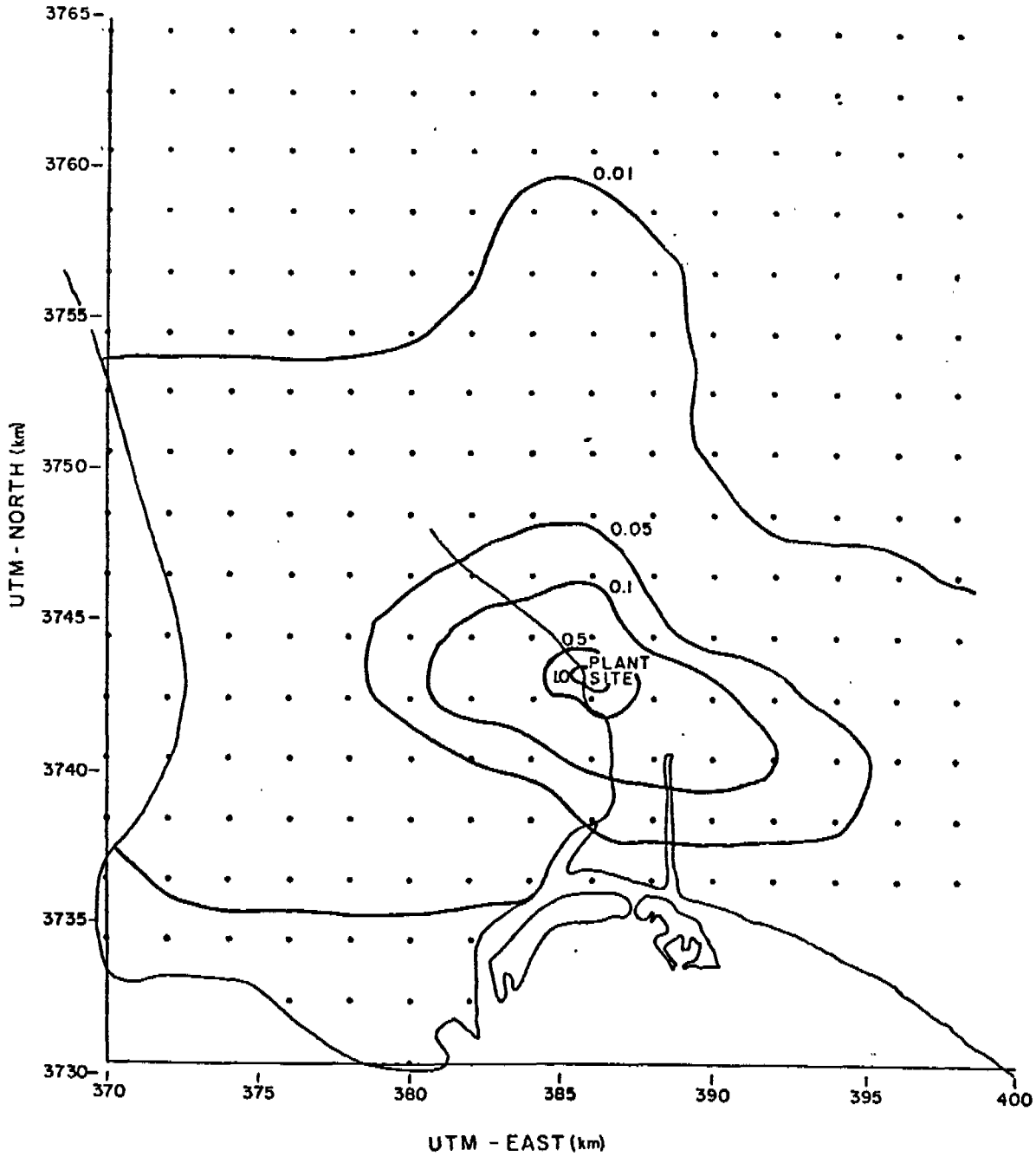

FIGURE 7. ISOPLETHS OF ANNUAL AVERAGE VINYL CHLORIDE CONCENTRATIONS IN PPB FROM AQDM WITH 2 KM GRID. 1960-1964 LONG BEACH DATA. EMISSIONS FROM BF GOODRICH/STAUFFER PLANT AFTER 10/21/78.

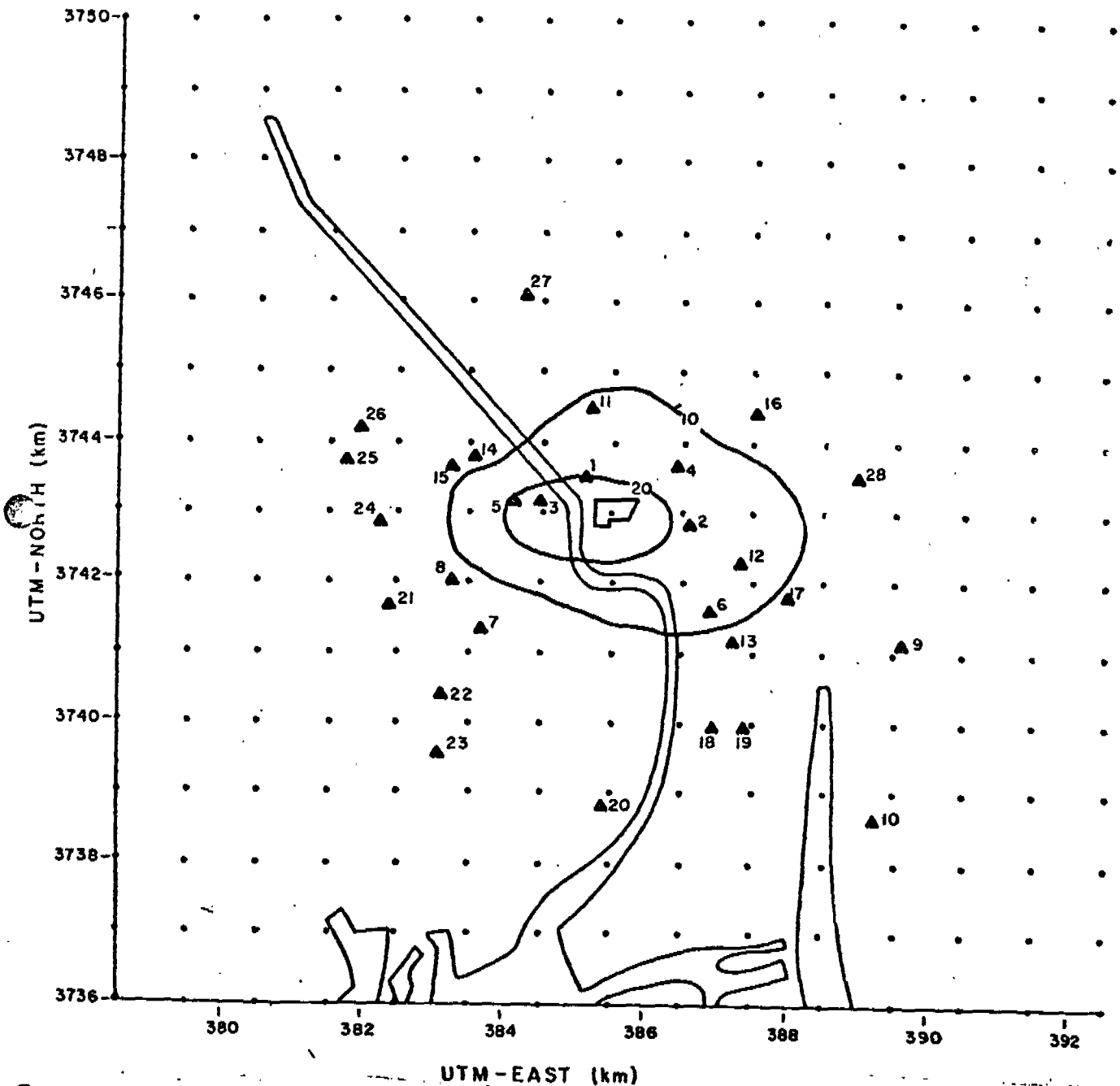

FIGURE 8. ISOPLETHS OF COMPOSITE (NON-SIMULTANEOUS) MAXIMUM 24-HOUR VINYL CHLORIDE CONCENTRATIONS IN PPB FROM RAMFR AT SENSITIVE RECEPTOR LOCATIONS. 1964 LONG BEACH DATA. PLANT EMISSIONS AFTER 10/21/78.

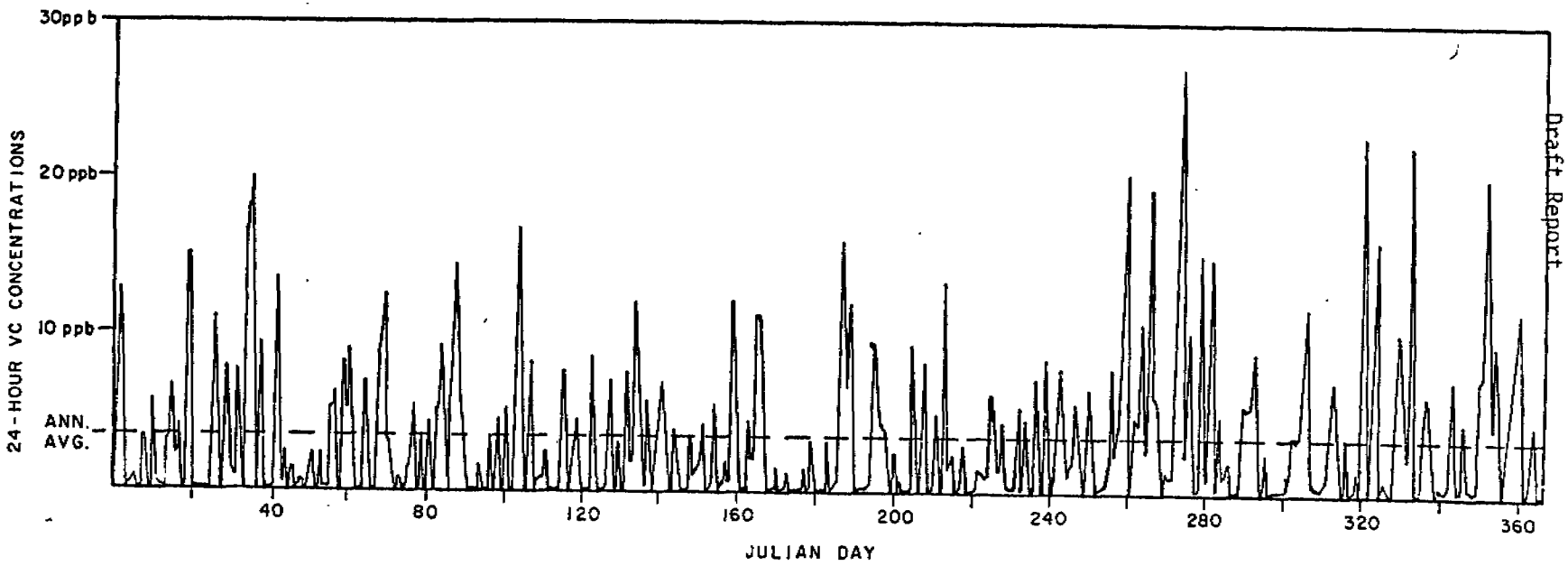

FIGURE 9. SEQUENCE OF DAILY CALCULATED 24-HOUR VC CONCENTRATIONS BY RAMF ON HOURLY 1964 LONG BEACH DATA. EMISSIONS AFTER 10/21/78. RECEPTOR 3.

APPENDIX I

COMPUTER CODES

I.1 INTRODUCTION

Brief descriptions are provided of the EPA computer codes used for the quantitative dispersion modeling performed in this study. The codes are AQDM, the RAM series, CRSTER and PTMAX. The format for the discussion of each code is as follows:

1. Reference
2. Abstract
3. Input
4. Formulation
5. Output

I.2 AIR QUALITY DISPLAY MODEL (AQDM)

Reference: U. S. Department of Health, Education and Welfare, Air Quality Display Model, User's Manual prepared for HEW, Washington, D.C., NTIS PB 189 194, November 1969.

Abstract: Program AQDM is a multiple point and area source dispersion code which calculates annual average concentrations over uniform 15 x 15 square grid with user-specified grid spacing. Modeling is by means of standard Gaussian techniques. The version used in this study incorporated the Briggs plume rise equations.

Input: Up to 1000 point and area sources with specified locations and emissions parameters. Joint frequency distribution of stability/wind speed/wind direction. 15 x 15 regularly spaced grid with specified spacing and up to 12 ad hoc receptor points.

Formulation: Coning dispersion with Pasquill-Gifford (rural) coefficients for classes 1-5. Horizontal sector-averaged concentrations. Briggs plume rise.

Output: Annual average concentrations at each grid point. Partial concentrations by source at 5 highest receptor points.

I.3 REAL-TIME AIR QUALITY SIMULATION MODEL (RAM)

Reference: Turner, D. B., and Novak, J. H., "User's Guide for RAM." Environmental Protection Agency, Research Triangle Park, North Carolina 27711, 1977 (Not yet officially available).

Abstract: RAM is a set of codes incorporating a steady state Gaussian plume model for estimating concentrations of relatively stable pollutants for averaging times from an hour to a day from point and area sources. Level or gently rolling terrain is assumed. Calculations are performed for each hour. Both rural and urban versions are available. RAM (urban and RAMR (rural) are used to run on 24 hours or less of meteorological data. RAMF (urban) and RAMFR (rural) run on a year of data.

Input: Up to 26 point sources and up to 26 area sources with specified source characteristics. Up to specified 60 receptor points.

Formulation: Coning dispersion in accordance with Turner Workbook (rural) coefficients and Briggs equation. Constant horizontal wind field. Perfect reflection from surface and mixing layer, until σ_z = 1.6 times mixing height, then uniform distribution in vertical. Power law vertical wind profile as per DeMarrais, with reference height of 10 m. Chemical reactivity and physical removal treated by separate user-specified half-life values.

Output: Hourly and average (up to 24 hours) concentration at each receptor. Limited individual source contribution list. Cumulative frequency distribution based on 24-hour averages and up to 1 year of data at a limited number of receptors.

I.4 CRSTER (EPA SINGLE SOURCE MODEL)

Reference: Environmental Protection Agency. "User's Manual for Single Source (CRSTER) Model." Publicaton No. EPA-450/2-77-013 (NTIS PB 271360). Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711, July 1977.

Abstract: CRSTER is a steady state Gaussian plume technique thought to be applicable to both rural and urban areas in uneven terrain.. The purpose of the technique is: (1) to determine the maximum concentrations, for certain averaging times between 1-hour and 24-hours, over a one year period due to a single point source of up to 19 stacks, (2) to determine the meteorological conditions which cause the maximum concentrations, and (3) to store concentration information useful in calculating frequency distributions for various averaging times. The concentration for each hour of the year is calculated and midnight-to-midnight averages are determined for each 24-hour period.

Input: Source parameters for up to 19 co-located point sources. Monthly variations in emissions possible. Receptor grid is 180 points specified by 5 input distances and the 36 10° sectors. Meteorological input is one year of hourly values of wind speed and direction, Pasquill stability class, mixing height and temperature.

Formulation: Coning dispersion in accordance with Turner Workbook (rural) coefficients and Briggs equations. Constant horizontal wind field. Perfect reflection from surface and mixing layer, until σ_z = 1.6 times mixing height, then uniform distribution in vertical. Power law vertical wind profile in accordance with exponents of DeMarrais, with reference

height of 10 m. Terrain treated by reduction of calculated effective stack height by elevation differential between plant and receptor point.

Output: Highest and second highest concentrations for the year at each receptor for averaging times of 1-, 3-, and 24-hours, plus a user-selected averaging time which may be 2-, 4-, 6-, 8-, or 12-hours. Annual arithmetic average at each receptor. For each day, the highest 1-hour and 24-hour concentrations over the receptor field. Hourly concentrations for each receptor on magnetic tape.

I.5 PTMAX

Reference: Turner, D. B., User's Guide to UNAMAP, Environmental Applications Branch, Meteorology Laboratory, Mail Drop 80, EPA, Research Triangle Park, NC 27711, 1975.

Abstract: Program PTMAX calculates maximum short-term (approximately 10-minute), ground-level concentrations resulting from the emissions of a single-point source and the distances from the source at which these maxima occur. Rather than using actual meteorological conditions as input, a spectrum of 49 simultaneous combinations of wind speed and stability conditions are tested, so that the resulting calculations of concentration and distance reflect a range of possible atmospheric conditions. PTMAX is based on standard Gaussian dispersion concepts and incorporates diffusion coefficients found in Turner, 1970. Plume rise calculations are made using a form of the Briggs method (Briggs, 1971).

Input: Emissions input consists of stack parameters of a single source. Meteorological input is contained internally within the code, i.e., 49 combinations of wind speed and Pasquill stability class.

Formulation: Coning dispersion in accordance with Turner Workbook coefficients and Briggs equations.

Output: Magnitude and location of maximum 10-minute concentrations and associated effective stack height for each meteorological combination.

APPENDIX II

LISTINGS OF EMISSIONS INPUT DATA

This appendix presents the emissions inventory as used as input data to the computer programs AQDM and RAMFR. Table II-1 lists the input emissions data to AQDM, and Table II-2 lists the input emissions data to RAMFR.

TABLE II-1

EMISSIONS INPUT DATA TO PROGRAM AQDM


```
                    (XVC: FUGITIVES INCREASED BY FACTOR 1.5).
BF GOODRICH CHEMICAL COMPANY (WITH STAUFFER CHEMICAL COMPANY)
VCM-PVC CHEMICAL PLANT COMPLEX, LONG BEACH CA (MET-64)
       VCM
       XVC
 &INDATA
 NSOURCE=37,
 SOURCE(1,1)=385.453,3743.000,0.0000,0.00068,0.00068,24.4,
             385.469,3743.010,0.0000,0.00050,0.00050,06.0,
             385.494,3742.995,0.0000,0.00043,0.00043,18.3,
             385.508,3742.987,0.0000,0.00060,0.00060,15.2,
             385.509,3742.960,0.0000,0.00091,0.00091,09.1,
             385.513,3743.009,0.0000,0.00006,0.00006,15.2,
             385.545,3743.007,0.0000,0.00003,0.00003,15.2,
             385.559,3742.949,0.0000,0.00006,0.00006,18.3,
             385.508,3742.980,0.0000,0.00003,0.00003,12.2,
             385.495,3742.691,0.0000,0.00006,0.00006,24.4,
             385.491,3742.960,0.0000,0.00154,0.00154,05.5,
             385.460,3742.938,0.0000,0.00026,0.00026,05.5,
             385.668,3743.082,0.0000,0.00069,0.00069,33.0,
             385.661,3743.126,0.0000,0.00009,0.00009,11.0,
             385.668,3743.103,0.0000,0.00013,0.00013,11.0,
             385.714,3743.102,0.0000,0.00038,0.00038,11.0,
             385.633,3743.105,0.0000,0.01125,0.01125,09.0,
             385.747,3743.069,0.0000,0.00192,0.00192,09.0,
             385.617,3743.103,0.0000,0.00706,0.00706,03.0,
             385.617,3743.120,0.0000,0.00359,0.00359,07.0,
             385.747,3743.063,0.0000,0.00395,0.00395,15.0,
             385.641,3743.112,0.0000,0.00563,0.00563,10.0,
             385.747,3743.063,0.0000,0.00096,0.00096,10.0,
             385.593,3743.138,0.0000,0.00133,0.00133,22.0,
             385.600,3743.086,0.0000,0.00057,0.00057,22.0,
             385.724,3743.063,0.0000,0.00067,0.00067,22.0,
             385.540,3743.072,0.0000,0.00197,0.00197,14.9,
             385.704,3743.076,0.0000,0.00076,0.00076,13.7,
             385.695,3743.050,0.0000,0.00132,0.00132,15.2,
             385.681,3743.146,0.0000,0.00050,0.00050,05.5,
             385.661,3743.126,0.00,0.0007,0.0007,12.2,
             385.668,3742.103,0.00,0.0017,0.0017,12.2,
             385.453,3743.000,0.00,0.0008,0.0008,12.2,
             385.698,3743.137,0.0056,0.0206,0.0309,06.0,
             385.473,3743.062,0.0056,0.0178,0.0267,06.0,
             385.623,3743.062,0.0056,0.0075,0.0113,06.0,
             385.473,3742.987,0.0056,0.0095,0.0143,06.0,
```

TABLE II-1

(Continued) Page 2 of 2

```
PLUME(1,1)=14.33,0.76,294.0,
           00.00,4.69,310.9,
           15.33,0.62,322.0,
           33.09,0.68,360.9,
           21.16,0.95,360.9,
           01.07,0.89,294.0,
           01.07,0.63,294.0,
           01.07,0.89,294.0,
           01.07,0.63,294.0,
           01.07,0.89,294.0,
           7.93,10.20,295.7,
           01.10,0.60,294.0,
           43.64,0.20,310.9,
           05.83,0.25,327.6,
           05.83,0.25,327.6,
           10.36,0.48,327.6,
           08.74,0.22,355.4,
           08.74,0.13,355.4,
           06.78,0.84,338.7,
           11.44,1.54,338.7,
           24.27,0.61,338.7,
           00.20,0.25,336.7,
           00.15,0.20,336.7,
           00.85,0.74,294.0,
           00.85,0.49,294.0,
           00.85,0.53,294.0,
           7.93,12.80,300.0,
           07.93,6.40,300.0,
           07.93,9.10,300.0,
           01.10,0.60,294.0,
           26.0,0.07,333.2,
           26.0,0.07,333.2,
           26.0,0.07,333.2,
```

TABLE II-2

EMISSIONS INPUT DATA TO PROGRAM RAMFR

BF GOODRICH, STAUFFER VCM-PVC PLANT COMPLEX, LONG BEACH CA

30 4 3 2

0.075 1.0

BFG STK	01	385.453	3743.000	0.0072	9.9	24.4	310.0	0.76	14.33
BFG CENT	02	385.469	3743.010	0.0053	9.9	06.0	310.9	4.69	00.00
BFG BLTK	03	385.494	3742.995	0.0045	9.9	18.3	322.0	0.62	15.33
BFG DRY	04	385.508	3742.987	0.0063	9.9	15.2	360.9	0.68	33.09
BFG DRY	05	385.509	3742.960	0.0096	9.9	09.1	360.9	0.95	21.16
BFG SILO	06	385.513	3743.009	0.0006	9.9	15.2	310.0	0.89	01.07
BFG SILO	07	385.545	3743.007	0.0003	9.9	15.2	310.0	0.63	01.07
BFG SILO	08	385.559	3742.949	0.0006	9.9	18.3	310.0	0.89	01.07
BFG SILO	09	385.508	3742.980	0.0003	9.9	12.2	310.0	0.63	01.07
BFG SILO	10	385.495	3742.891	0.0006	9.9	24.4	310.0	0.89	01.07
BFG CT	11	385.491	3742.960	0.0162	9.9	05.5	310.0	10.20	07.93
BFG LAB	12	385.460	3742.938	0.0027	9.9	05.5	310.0	0.60	01.10
SVC OXY	13	385.668	3743.082	0.0001	9.9	33.0	310.9	0.20	43.69
SPV NO1	14	385.661	3743.126	0.0009	9.9	11.0	327.6	0.25	05.83
SPV NO2	15	385.668	3743.103	0.0014	9.9	11.0	327.6	0.25	05.83
SPV NO3	16	385.714	3743.102	0.0040	9.9	11.0	327.6	0.48	10.36
SPV BLTK	17	385.633	3743.105	0.1184	9.9	09.0	355.4	0.22	08.74
SPV BLTK	18	385.747	3743.069	0.0202	9.9	09.0	355.4	0.13	08.74
SPV DRY2	19	385.617	3743.103	0.0743	9.9	03.0	338.7	0.84	06.78
SPV DRY3	20	385.617	3743.120	0.0378	9.9	07.0	338.7	1.54	11.44
SPV DRY4	21	385.747	3743.063	0.0416	9.9	15.0	338.7	0.61	24.27
SPV CENT	22	385.641	3743.112	0.0592	9.9	10.0	338.7	0.25	00.20
SPV CENT	23	385.747	3743.063	0.0101	9.9	10.0	338.7	0.20	00.15
SPV SILO	24	385.593	3743.138	0.0140	9.9	22.0	310.0	0.74	00.85
SPV SILO	25	385.600	3743.086	0.0060	9.9	22.0	310.0	0.49	00.85
SPV SILO	26	385.724	3743.063	0.0070	9.9	22.0	310.0	0.53	00.85
SPV CT1	27	385.540	3743.072	0.0207	9.9	14.9	310.0	12.80	07.93
SPV CT2	28	385.704	3743.076	0.0080	9.9	13.7	310.0	6.40	07.93
SPV CT3	29	385.695	3743.050	0.0139	9.9	15.2	310.0	9.10	07.93
SPV LAB	30	385.681	3743.148	0.0053	9.9	05.5	310.0	0.60	01.10

END POINTS

385.660	3743.099	0.075	0.2163	9.9	6.0
385.435	3743.024	0.075	0.1869	9.9	6.0
385.585	3743.024	0.075	0.0794	9.9	6.0
385.435	3742.949	0.075	0.1003	9.9	6.0

APPENDIX III

LISTINGS OF METEOROLOGICAL INPUT DATA

This appendix presents meteorological data sets which were used as input to the computer programs AQDM and RAMR. Table III-1 lists the data used for AQDM. Table III-2 lists the twenty-four hours of meteorological data for the day (day 274 of 1964) on which the highest 24-hour concentration was predicted for the site referred to in the main body of this report as Receptor 3.

TABLE III-1

METEOROLOGICAL INPUT DATA TO AQDM


```
WNDFRQ(1,1)=0.0001,0.0000,0.0000,0.0000,0.0000,0.0000,
            0.0001,0.0000,0.0000,0.0000,0.0000,0.0000,
            0.0002,0.0000,0.0000,0.0000,0.0000,0.0000,
            0.0001,0.0001,0.0000,0.0000,0.0000,0.0000,
            0.0001,0.0000,0.0000,0.0000,0.0000,0.0000,
            0.0001,0.0001,0.0000,0.0000,0.0000,0.0000,
            0.0005,0.0003,0.0000,0.0000,0.0000,0.0000,
            0.0007,0.0005,0.0000,0.0000,0.0000,0.0000,
            0.0017,0.0013,0.0000,0.0000,0.0000,0.0000,
            0.0009,0.0007,0.0000,0.0000,0.0000,0.0000,
            0.0010,0.0008,0.0000,0.0000,0.0000,0.0000,
            0.0009,0.0005,0.0000,0.0000,0.0000,0.0000,
            0.0009,0.0005,0.0000,0.0000,0.0000,0.0000,
            0.0005,0.0004,0.0000,0.0000,0.0000,0.0000,
            0.0001,0.0000,0.0000,0.0000,0.0000,0.0000,
            0.0001,0.0000,0.0000,0.0000,0.0000,0.0000,
            0.0023,0.0013,0.0001,0.0000,0.0000,0.0000,
            0.0007,0.0004,0.0000,0.0000,0.0000,0.0000,
            0.0011,0.0006,0.0000,0.0000,0.0000,0.0000,
            0.0016,0.0009,0.0001,0.0000,0.0000,0.0000,
            0.0022,0.0008,0.0001,0.0000,0.0000,0.0000,
            0.0017,0.0017,0.0001,0.0000,0.0000,0.0000,
            0.0015,0.0021,0.0009,0.0000,0.0000,0.0000,
            0.0014,0.0024,0.0025,0.0000,0.0000,0.0000,
            0.0027,0.0056,0.0120,0.0000,0.0000,0.0000,
            0.0016,0.0033,0.0067,0.0000,0.0000,0.0000,
            0.0012,0.0025,0.0037,0.0000,0.0000,0.0000,
            0.0017,0.0028,0.0017,0.0000,0.0000,0.0000,
            0.0018,0.0033,0.0021,0.0000,0.0000,0.0000,
            0.0024,0.0038,0.0034,0.0000,0.0000,0.0000,
            0.0019,0.0016,0.0004,0.0000,0.0000,0.0000,
            0.0014,0.0009,0.0002,0.0000,0.0000,0.0000,
            0.0009,0.0028,0.0010,0.0000,0.0000,0.0000,
            0.0004,0.0011,0.0003,0.0000,0.0000,0.0000,
            0.0005,0.0008,0.0002,0.0000,0.0000,0.0000,
            0.0008,0.0021,0.0005,0.0000,0.0000,0.0000,
            0.0013,0.0030,0.0004,0.0000,0.0000,0.0000,
            0.0009,0.0025,0.0008,0.0000,0.0000,0.0000,
            0.0007,0.0018,0.0011,0.0001,0.0000,0.0000,
            0.0003,0.0015,0.0039,0.0004,0.0000,0.0000,
            0.0010,0.0035,0.0216,0.0054,0.0000,0.0000,
            0.0004,0.0012,0.0100,0.0024,0.0000,0.0000,
            0.0005,0.0015,0.0041,0.0006,0.0000,0.0000,
            0.0004,0.0014,0.0027,0.0005,0.0000,0.0000,
            0.0008,0.0024,0.0109,0.0025,0.0001,0.0000,
            0.0014,0.0041,0.0153,0.0018,0.0000,0.0000,
            0.0009,0.0028,0.0029,0.0004,0.0000,0.0000,
```

TABLE III-1 (Continued)


```
0.0009,0.0023,0.0008,0.0000,0.0000,0.0000,
0.0039,0.0061,0.0010,0.0004,0.0001,0.0000,
0.0019,0.0024,0.0003,0.0002,0.0000,0.0000,
0.0029,0.0045,0.0013,0.0006,0.0001,0.0000,
0.0057,0.0106,0.0033,0.0024,0.0005,0.0002,
0.0074,0.0162,0.0047,0.0016,0.0008,0.0002,
0.0071,0.0173,0.0069,0.0014,0.0001,0.0000,
0.0053,0.0120,0.0063,0.0020,0.0002,0.0000,
0.0037,0.0090,0.0067,0.0021,0.0001,0.0000,
0.0054,0.0143,0.0176,0.0082,0.0002,0.0000,
0.0019,0.0054,0.0065,0.0042,0.0001,0.0000,
0.0015,0.0036,0.0041,0.0019,0.0000,0.0000,
0.0016,0.0029,0.0047,0.0060,0.0005,0.0001,
0.0023,0.0053,0.0163,0.0240,0.0027,0.0005,
0.0056,0.0131,0.0135,0.0102,0.0006,0.0001,
0.0035,0.0082,0.0036,0.0033,0.0005,0.0003,
0.0019,0.0044,0.0012,0.0005,0.0002,0.0001,
0.0086,0.0087,0.0009,0.0000,0.0000,0.0000,
0.0026,0.0022,0.0003,0.0000,0.0000,0.0000,
0.0049,0.0041,0.0007,0.0000,0.0000,0.0000,
0.0101,0.0115,0.0012,0.0000,0.0000,0.0000,
0.0149,0.0142,0.0010,0.0000,0.0000,0.0000,
0.0121,0.0140,0.0009,0.0000,0.0000,0.0000,
0.0075,0.0084,0.0006,0.0000,0.0000,0.0000,
0.0032,0.0042,0.0010,0.0000,0.0000,0.0000,
0.0046,0.0077,0.0028,0.0000,0.0000,0.0000,
0.0018,0.0024,0.0011,0.0000,0.0000,0.0000,
0.0014,0.0024,0.0009,0.0000,0.0000,0.0000,
0.0038,0.0046,0.0031,0.0000,0.0000,0.0000,
0.0090,0.0133,0.0144,0.0000,0.0000,0.0000,
0.0301,0.0453,0.0190,0.0000,0.0000,0.0000,
0.0188,0.0246,0.0066,0.0000,0.0000,0.0000,
0.0108,0.0130,0.0017,0.0000,0.0000,0.0000,

UPTHMX=800.0,
UPTHMXM=500.0,
Te=293.15,PA=1000.0,

IBRIGGS=3$
```

TABLE III-2

TWENTY-FOUR HOUR METEOROLOGICAL INPUT DATA TO RAMR FOR DAY OF HIGHEST PREDICTED CONCENTRATION

[illegible] / STAUFFER CHEMICAL COMPANY VC [illegible] COMPLEX

[illegible] 274
INPUT MET DATA 64/ 274

HOUR	WIND DIR THETA (DEG)	WIND SPEED (M/S)	MIXING HEIGHT (M)	AMBIENT TEMP (DEG-K)	STABILITY CLASS
1	99.00	1.54	600.00	285.93	6
2	99.00	1.00	600.00	285.93	5
3	77.00	1.00	800.00	285.37	6
4	94.00	1.00	800.00	284.82	6
5	97.00	1.00	800.00	284.82	5
6	99.00	1.00	15.90	284.82	5
7	96.00	1.00	114.64	285.93	4
8	17.00	2.57	212.72	287.60	4
9	314.00	2.57	310.50	289.82	3
10	284.00	2.57	408.44	292.59	3
11	225.00	4.63	506.38	294.21	3
12	242.00	2.06	604.24	295.93	3
13	306.00	4.12	702.12	297.04	3
14	323.00	5.66	800.00	296.49	4
15	297.00	5.14	800.00	296.49	4
16	307.00	6.69	800.00	294.82	4
17	301.00	4.63	800.00	293.15	4
18	297.00	4.12	800.00	291.93	4
19	284.00	2.57	800.00	289.82	5
20	259.00	1.00	800.00	289.82	5
21	294.00	1.00	800.00	289.26	5
22	84.00	2.57	800.00	288.71	5
23	121.00	3.09	800.00	288.15	5
24	100.00	3.09	800.00	288.71	5

[illegible] MET CONDITIONS

WIND DIRECTION= 304.02
AVERAGE WIND SPEED= 2.73
WIND PERSISTENCE= .432

RESULTANT WIND SPEED= 1.16
AVERAGE T, P= 290.05
MODAL STABILITY= 6

UCC
024047

APPENDIX IV

Not yet available.