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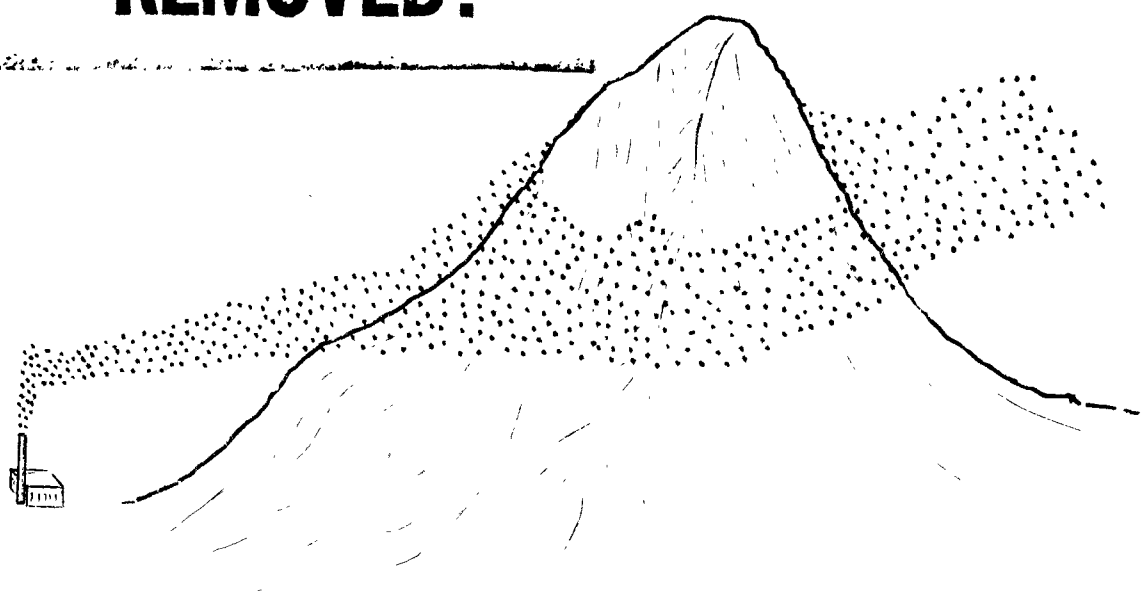

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA-450/2-77-018

VALLEY MODEL USER'S GUIDE

by

Edward W. Burt

Monitoring and Data Analysis Division
Source Receptor Analysis Branch

U S ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

September 1977

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PREFACE

This publication contains information on the techniques and applications of the computer program for the Valley Model which is based on a steady-state, univariate Gaussian formulation. It fulfills the need for a formal discussion to replace a very brief description that has received wide distribution.

The last previous version of the computer code was designated C9M3D. For stable atmospheric conditions the present version provides the same results, but can result in significantly greater concentrations for the limited mixing situation because it uses the multiple-reflection formula of Hales-Bierly-Hewson. Version C9M3D used the interpolation technique of Turner as described in his Workbook of Atmospheric Dispersion Estimates.

The Valley Model is one of the atmospheric dispersion models on the User's Network for Applied Modeling of Air Pollution (UNAMAP) system. The UNAMAP system may be purchased on magnetic tape from NTIS for use on the user's computer system, or may be accessed through phone lines and time-share computer terminals. For information on accessing UNAMAP contact: Chief, Data Management Section, Meteorology and Assessment Division, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Although attempts are made to thoroughly check out computer programs with a wide variety of input data, errors are occasionally found. In case there is a need to correct, revise or update this model, revisions will be distributed to those who complete and return the mailing form on page v. A user can be assured that the latest version of the Valley Model is on the UNAMAP system.

Comments and suggestions regarding this publication should be directed to: Chief, Source Receptor Analysis Branch, Monitoring and Data Analysis Division (MD-14), EPA, Research Triangle Park, NC 27711. However, technical questions regarding execution of the model may be handled by telephone call to the Chief, Modeling Support Section, Source Receptor Analysis Branch in Durham, NC at 919-541-5335 or, using FTS, 629-5335.

ACKNOWLEDGMENTS

Were it not for the technical and administrative support of Mr. Herschel H. Slater, the Valley Model might not be in use today. His efforts under intensive and extensive pressures have provided a basis for improving the air quality in many areas of our country. Messrs. Jerome B. Mersch, Herschel W. Rorex, and David H. Starr contributed to the programming aspects, and largely prepared Section 4. Mr. Donald Henderson, EPA Regional Meteorologist, Denver, provided many useful comments which have improved the clarity and usefulness of this report. This report and a myriad of communications regarding the Valley Model have been typed by Mrs. Barbara M. Stroud; her timely and congenial assistance in these matters over the past several years is greatly appreciated.

Chief, Environmental Applications Branch

Meteorology and Assessment Division (MD-80)

U.S. Environmental Protection Agency

Research Triangle Park, NC 27711

I would like to receive future revisions to the *Valley Model User's Guide*.

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1. MODEL OVERVIEW

1.1 INTRODUCTION

The Valley Model is an analytical technique whose primary use is for estimating the upper limits of 24-hour average pollutant concentrations due to isolated sources in rural, complex terrain. Options are provided which allow multiple sources, flat terrain, urban areas, and long-term averages to be considered also. This manual formally documents the Valley Model and supercedes a brief description of earlier versions which received wide distribution.

A historical overview on the use of Valley and the scope and general data requirements of this model are included in the remainder of Section 1. The assumptions and mathematical formulations are given in Section 2. Specific data requirements are discussed in Section 3, with input format specifications given in Section 4. Four appendices provide an evaluation of model accuracy, a full test run, a program listing, and a simple data set for testing the runstream deck and for obtaining base maps.

1.2 HISTORICAL OVERVIEW

The large non-ferrous smelters in the West posed a particularly difficult problem when State Implementation Plans were being evaluated in 1972 and thereafter. They were known to be large emitters of sulfur dioxide and particulate matter and suspected to be substantial emitters of metals of some toxicity (e.g., arsenic, lead, mercury). Their rates of emissions were not well established. Contaminants were emitted from different processes in different ways at different heights and at different times. The smelters are generally isolated and located in areas of complex mountainous terrain. Their effluents are dispersed and transported initially, at least, by local wind systems determined largely by the orientation and configuration of the nearby terrain, atmospheric radiation (which is a function of time of day and season of the year) and the synoptic weather situation. None of the smelter locations had meteorological data available which was adequately representative of the dispersion and transport factors. Finally, ambient air quality data which were representative of the impact of the smelter on the surrounding air environment did not exist.

Meteorologists attached to the Office of Air Quality Planning and Standards were asked to estimate the likely impact of the smelters on the surroundings. Several had a number of years experience estimating the impact of point sources on ambient air quality, forecasting the weather in the mountainous west, and conducting field sampling studies around large point sources, some of which were in complex terrain. A concensus of their judgments based on their considerable experience and training in dispersion meteorology indicated that a smelter located

in proximity to terrain features in the western mountains would likely cause frequent and greatest threats to an ambient air quality standard under a particular set of meteorological circumstances. The threat was considered to be greatest with light winds, but not calms, when strong inversions with bases at the ground-level, or if elevated, below the crests of nearby ridges, were experienced for several hours of the day. Under these conditions, plumes from smelters were observed to level-off shortly above the stack top and flow in close proximity to elevated terrain in ribbons or sheets. The horizontal spread of the plumes consistently far exceeded the vertical spread. It was anticipated that in complex terrain areas, pollutants emitted from smelter stacks must cause highest ambient 3- to 24-hour average concentrations on the elevated terrain.

Due to large uncertainties in the magnitude, height and timing of emissions, and in the representativeness of the existing meteorological data, it was judged that the threat to the standards could be best represented by an analytical routine that would conveniently calculate a 24-hour concentration on elevated terrain during stable atmospheric conditions with light winds. The algorithm was expected to represent a fanning plume which affects an elevated terrain feature, and to provide a reasonable estimate of the second highest 24-hour concentration that would be experienced during a year.

Careful review of upper air summaries of wind speeds and stability aloft for the western portion of the U.S. provided a basis for the choice of weather parameters. The Briggs plume rise calculations showed

that the heights of the smelter plumes in stable air would likely not exceed 400 m above stack base for the conditions evaluated. Wind speeds of 2.5 m/s, ± 1 m/s, occurred at 300 m above the ground one-third or more of the time at most western upper air observing sites.

The Valley Model does not provide a rigorous mathematical description of the physical circumstances which pertain to flow about a terrain feature. It is an algorithm which describes and associates the meteorological parameters that often prevail when high concentrations are anticipated on elevated terrain.

It is imperative that the user of any model which is purported to estimate the greatest concentrations due to an elevated source in complex terrain realizes that observed meteorological data suitable for calculating these singular events generally do not exist. Hence, the user must generate the meteorological conditions to be used as input to obtain the solution. Needless to say, the user can usually assume a set of reasonably realistic meteorological conditions which will duplicate any observed concentration due to a point source. The real test of a simulation model is an evaluation for several different locations using objective meteorological input data, such as is done in the evaluation herein of the Valley Model (see Appendix D).

1.3 SCOPE OF THE MODEL

The Valley Model is an algorithm which produces output to be used in evaluating the impact of a stationary source or sources on air

quality at ground level. The applicability of the model is bounded by the following operational characteristics:

(1) It is generally recognized that short-term air quality standards are the most difficult for a single source to meet in an area of complex terrain. Assuming constant emissions from an isolated, elevated point source, if the short-term standard is not exceeded then the long-term standard is unlikely to be exceeded by the single facility. Valley was developed with this in mind. The treatment by Valley of plumes in rural, complex terrain was specifically intended for a 24-hour period, a single facility of small areal extent, and particularly for stable conditions which are generally conceded to be the worst situation in complex terrain. However, the program may be executed in the long-term mode for a complex terrain situation. An urban mode is optional, wherein terrain is considered to be flat. Multiple facilities may be evaluated during any run if results are carefully interpreted.

(2) Source emission data is input as an average per source for the period of concern. A user's option allows for a 24-hour analysis or a long-term analysis (e.g., seasonal or annual). The emission and meteorological data are assumed to be uncorrelated with one another when multiple meteorological conditions are input.

(3) The source data array is dimensioned to accept a maximum of 50 sources. Sources may be "point" or "area," and may be input in any order. The point sources may include several specific points of emission from an industrial or residential area. Often, however, emissions from

individual chimneys in residential areas, or specific vents in industrial facilities, cannot be defined except as an average of the multiple emission points. In such cases, the point sources in an area may be grouped for analysis as one or more square area sources.

(4) The computer simulation averages the impact of any non-reactive gaseous, liquid, or solid pollutant for which the deposition rate may be considered negligible. However, a half-life option is available for any pollutant whose concentration decreases exponentially as a function of time (i.e., aside from the decrease due to dispersion).

(5) The program specifies an array of 112 receptors, fixed by the program in a grid internal to the program. The user preassigns the scale of the region to be depicted on the output maps.

(6) The potential ranges of most of the input data are so large as to preclude any meaningful programmed validity checks. For this reason most input data are reproduced on the concentration maps, providing an invaluable aid for post-analysis data verification. Programmed format checks detect and indicate omitted and most erroneously placed input data records; however, they will not detect erroneous ordering within a discrete data subset such as the stability-wind rose (STAR) data.

1.4 GENERAL DATA REQUIREMENTS

General data requirements for the Valley Model are indicated in this section; specifics are discussed in Section 3. It should be noted that data sets prepared for earlier versions of Valley require one simple change to be compatible with the computer program documented in this guide (see MWT under Section 3.1.4).

1.4.1 Meteorological Data

Meteorological data have an important effect on the simulated transport and dispersion of air pollutants. The data required are:

- STABILITY-WIND SUMMARY
- AMBIENT TEMPERATURE
- AMBIENT PRESSURE
- MIXING HEIGHT
- MEAN SPEEDS OF THE WIND SPEED CLASSES

The stability-wind data are the frequencies of occurrence of six wind speed classes by 16 wind directions and by six stability categories for the area and time period of concern. These data define the transport and the degree of dispersion of the pollutant. The mixing height determines the depth through which the pollutant may be mixed before being totally reflected downward. Temperature is used in computing plume rise. Pressure and temperature are used in the optional conversion of concentrations to standard conditions of pressure and temperature.

Meteorological data may be acquired from the National Climatic Center (NCC) at Asheville, North Carolina. The Center is operated by the National Oceanic and Atmospheric Administration. The user must determine whether the available data are representative of the area and period of concern. The NCC will supply summaries of long-term stability-wind data (STAR data) and set the charges for its services. The six-stability deck (Pasquill-Gifford stabilities A through F) should be

specified for use with Valley. STAR data which contain the day/night classifications are not appropriate for use with the model. The stability-wind data for 24-hour analyses must be obtained by other means. (see Section 2.2.2).

1.4.2 Receptor Data

A network of 112 receptors is established by the program. The user controls only two factors relative to the network: (1) the geographic spacing of the receptors, through a scaling factor; and (2) the vertical spacing of the receptors through assignment of the terrain elevation at each receptor. These controllable elements are:

- SCALING FACTOR
- GROUND ELEVATION AT RECEPTORS

1.4.3 Source Data

The source data must include some basic information for each source of concern. Each analysis (one run through the program) is restricted to one pollutant. The required source data elements are:

- IDENTIFICATION
- PHYSICAL CHARACTERISTICS OF SOURCE AND EFFLUENT
- HORIZONTAL COORDINATES OF SOURCE
- GROUND ELEVATION AT SOURCE
- EMISSION RATE

The identification elements have no quantitative value, nor do they control any program options. One such element is available to identify each run through the program, and one is available to identify each source evaluated during the run; these elements are printed at appropriate places on the output pages.

1.4.4 Control Parameters

Several options and controls are available to the user to select the analytical techniques and output of the program. These options and controls specify:

- CONCENTRATIONS IN SITU OR AT STANDARD CONDITIONS
- UNITS OF CONCENTRATION
- REPETITION OF SOURCES FOR SUCCESSIVE RUNS
- OUTPUT DEVICE IDENTIFICATION
- URBAN/RURAL ENVIRONMENT
- POLLUTANT HALF-LIFE
- CONCENTRATION AVERAGING TIME
- FORMAT OF STAR DATA
- TYPE OF SOURCE CONTRIBUTION MAPS

2. TECHNICAL DISCUSSION

The basic treatment of dispersion by the Valley Model is quite similar to that of the Air Quality Display Model (AQDM) and the Implementation Planning Program (IPP); see TRW, Inc. (1969, 1970). However, Valley includes modifications to the techniques used in those models. These modifications include (1) a representation of the effect of terrain on ground-level concentrations, (2) plume rise equations from Briggs (1971, 1972); (3) a different treatment of pollutant reflection from inversions aloft; (4) a rural-area option; (5) a short-term option; and (6) printouts of the spatial distribution of concentrations on equal-area maps. Dispersion equations for Valley and discussions of the assumptions made in the model are presented in this section.

2.1 THE DISPERSION EQUATIONS AND SIMULATION OF COMPLEX TERRAIN EFFECTS

The most important aspect of Valley is its treatment of the effects of terrain on concentration. For stable atmospheric conditions, the model assumes that the plume height above stack base remains constant after final plume rise. Thus, as terrain rises the plume approaches the elevated surface; in effect the plume height decreases. Since the terrain elevations may vary from receptor to receptor, an effective plume height must be calculated for each receptor. All concentrations are then estimated as if the receptors were located at actual ground level at the respective geographical locations. However, it is further assumed that the plume centerline comes no closer than 10 m to the

elevated terrain. If the terrain extends above the original plume height, the plume centerline is adjusted so that it remains 10 m above the ground. Any plume height which is initially within 10 m of the ground during stable conditions is assumed to remain at its initial height above ground, regardless of downwind terrain elevations.

The schematic in the lower half of Figure 2-1 illustrates the treatment of an elevated plume that has encountered terrain during stable conditions. The plume is assumed to be deflected upward and to the side (tending to parallel the axis of the ridge, for example). Any increase in concentration that would occur on the sides of the terrain obstacle due to lateral deflection of the plume beyond the sector of immediate concern is ignored. Therefore, conservation of mass is not accomplished.

Deflection of the plume by terrain during stable conditions is simulated through the attenuation of concentration with height in the sector of immediate concern. This is accomplished by applying a factor based upon the relative elevations of the ground at the receptor and of the centerline of the undisturbed plume, h_0. The factor has a value of unity at and below the elevation of the plume centerline in free air prior to encountering terrain effects, but decreases linearly with increasing height (from plume level) to zero at and above 400 m above the undisturbed plume centerline. The attenuation should not be inferred to represent pollutant decay or penetration into the terrain. This is an empirical scheme intended as a general representation of the blocking

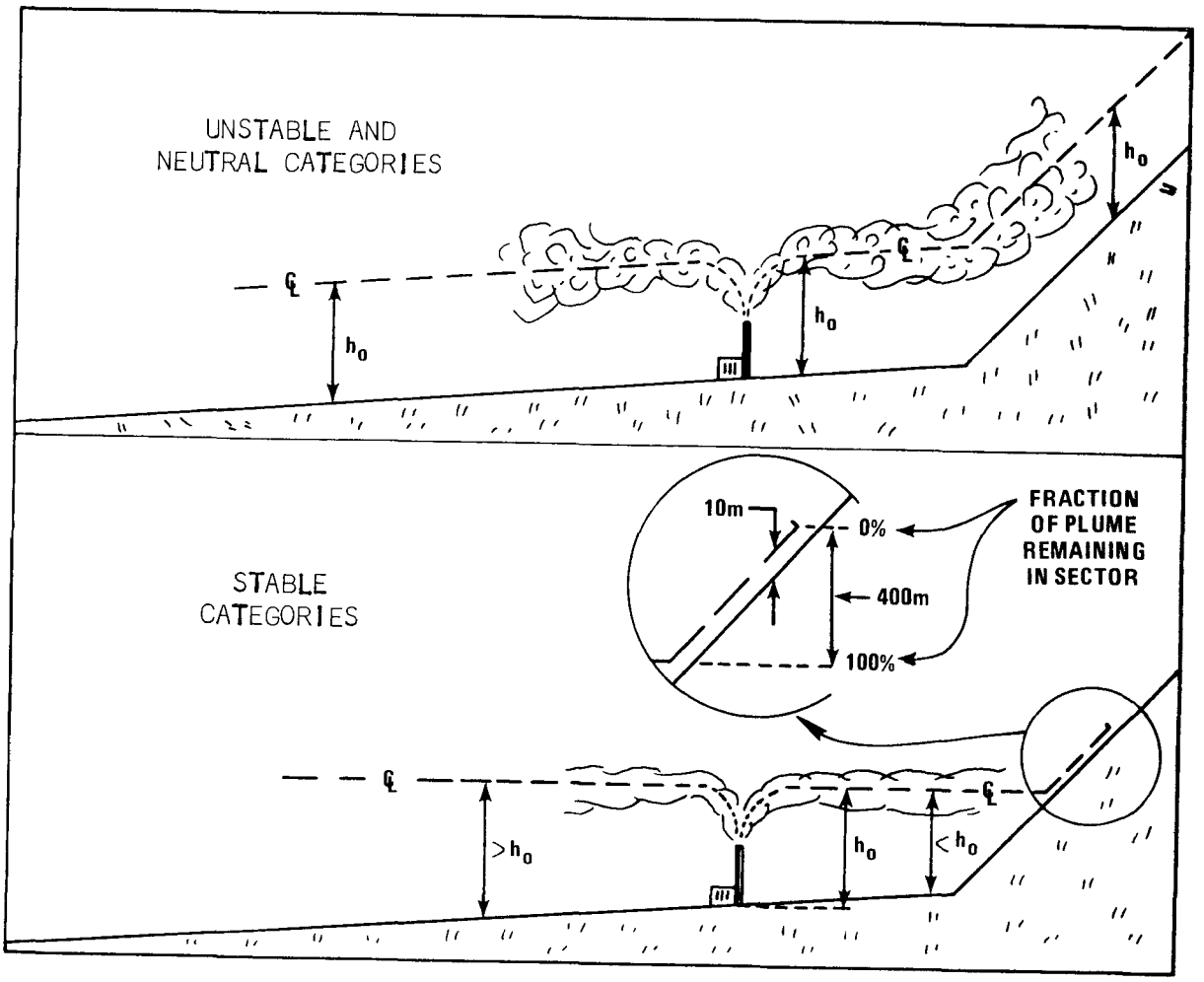


Figure 2-1. Depiction of Plume Height in Complex Terrain, as in the Valley Model. h_o is the Height of the Plume at Final Rise Above Ground for the Unstable and Neutral Cases and Above Stack Base for the Stable Cases. Plume are Shown for Flows Toward and Away from Elevated Terrain.

of air flow by significant terrain features. Therefore, in case of such plume impingement no attempt should be made to utilize the concentrations that will be calculated for the leeward side of a substantial hill or ridge, because the computer program has no memory regarding upwind terrain features.

For unstable/neutral atmospheric stability conditions, the plume is assumed to maintain a constant height above the terrain. The plume parallels the terrain feature by increasing and decreasing its effective height relative to the stack base; this is, in effect, a flat-plane situation as can be visualized from the upper sketch of Figure 2-1. This technique may lead to underestimates of concentration in complex terrain.

The dispersion equations used in Valley are presented below; subsequent sections provide details of the various factors and terms, and their treatment in Valley. The equations have been developed from the familiar bivariate Gaussian formulation which describes the dispersion of a pollutant from a point source (see, for example, Equation 3.1 of Turner (1970)).

One of the two dispersion equations used in the Valley Model is:

$$\chi(x,y,o;h,L) = 2.03 \cdot 10^6 \; Q \; K \; ((c-y)/c) \; ((401-D)/400) \; C$$

$$\cdot \sum_{N=-J}^{+J} \exp\{-0.5 \; [(H+2 \; N \; L)/\sigma_z]^2\}$$

$$\cdot \{\exp[-(0.693 \; x_p)/(3600 \; u \; I)]\}/(\sigma_z \; u \; x) \qquad (2.1)$$

where only Q and u are input by the user, and:

χ is concentration in micrograms per cubic meter ($\mu g/m^3$) or parts per million (ppm), always calculated at ground level (see MWT, Section 3.1.4).

x is the source-receptor distance (m), as projected on the mean wind vector through the source. For area sources, this is the distance from the receptor to the effective point source. Contributions of a point source to a receptor within 20 m of that source are ignored.

y is the crosswind distance (m) of the receptor from a line parallel to the mean wind drawn through the source; $y \leq c$.

H is plume centerline height (m) above the receptor; the receptor is always at ground level. Plume height h_o above the stack base is calculated internally, or assigned by the user, and then may be adjusted for terrain elevation at the receptor to provide H. For nonstable conditions, or over flat terrain, $H=h_o$.

L is mixing height (m) above ground; L remains constant, regardless of topography (see Section 2.1.6).

Q is the pollutant emission rate (g/s) of a given source, averaged over the period of concern. If the actual emission rate varies one must consider its correlation with the meteorological conditions specified in the input data.

c is the crosswind arc length of the 22.5° wind sector implicit in this formulation (see Section 2.1.2).

D is receptor elevation minus plume height, each in meters above mean sea level. The D term simulates the stable-case deflection by terrain of the plume from the sector being evaluated.

$1 \leq D \leq 401$ m {stable conditions}

D = 1 m {neutral and unstable conditions}

C determines the units of χ:

C = 1 {for χ in $\mu g/m^3$; required for nongaseous pollutants}

C = 0.0831 T/(M P) {for gases only, to obtain χ in ppm}

where:

T is ambient air temperature (°K).

M is molecular weight of the gas (grams per mole).

P is ambient air pressure (millibars).

K converts concentrations from on-site to standard conditions of temperature and pressure. $K = 1013.2\ T/(298\ P)$.

$|N|$ represents the number of perfect reflections a parcel of air has undergone before reaching the distance of the receptor (see the next paragraph for a discussion of J).

σ_z is the standard deviation (m) of the vertical (Gaussian) distribution of the pollutant and $\sigma_z = f(x)$ (see Section 2.1.3).

x_p is the distance (m) from the receptor to the point source or to the center of the area source projected to the mean wind direction as was defined for x; for point sources, $x_p = x$.

u is the mean wind speed (m/s) affecting the plume.

I is the half-life (hr), of the pollutant and the exponential containing I is the half-life factor (see Section 2.1.5).

The summation term in Equation 2.1 is a special case of the expression developed by Hales (1956), and independently by Bierly and Hewson (1962), to describe concentrations during conditions of plume trapping (see Section 2.1.6). The limits on N determine the accuracy of the term. In Valley, $J \leq 5$. However, as σ_z becomes large relative to L, this low limit on J can result in serious underestimates of χ. The error can be reduced to insignificance by equating J to a large value, but with a corresponding increase in computation time. Fortunately, a simple approximation to Equation 2.1 exists for these conditions; for distances beyond which $\sigma_z = 2\ L$ the Valley Model utilizes Equation 5.14 from Turner (1970) in the form:

$$\chi(x,y,o;h,L) = 2.55 \cdot 10^6 \; Q \; K \; ((c-y)/c) \; ((401-D)/400) \; C$$

$$\cdot \{\exp[-(0.693 \; x_p)/(3600 \; u \; I)]\}/(L \; u \; x). \qquad (2.1a)$$

This simple equation provides a very good approximation to Equation 2.1 when J is very large and the vertical distribution of pollutants has become virtually homogeneous.

2.1.1 Sector Averaging

The constant 2.03 of Equation 2.1 is comprised of the factors $2/(\sqrt{2\pi} \; 2 \; \pi/16)$. This is obtained when the bivariate Gaussian formulation is converted to the cross-sector averaging form for a 22.5° (i.e., $2 \; \pi/16$) sector. Such conversion results in a uniform concentration across the wind sector at a given distance and height.

2.1.2 Cross-Sector Interpolation

To eliminate unrealistic discontinuities in concentration between sectors, which would result when wind frequencies differ in adjacent sectors, the essentially linear interpolation factor $(c-y)/c$ is utilized, where $y \leq c$. The result for wind in a single sector is that the sector-averaged concentration is decreased from 100 percent of its value at the sector centerline to zero about the centerline of the two adjacent sectors.

2.1.3 Vertical Dispersion Coefficient

The values of σ_z calculated by the program are based on the work of Pasquill (1961) as adapted by Gifford (1961). The σ_z required for each stability category is calculated using:

$$\sigma_z = a\ x_p^{\ b} + d \tag{2.2}$$

where a, b and d values are constants for each stability class within three different distance ranges as shown in Table 2-1.

Stability classes S = 5 and 6 are associated with nighttime, surface inversion conditions, and the σ_z values for these cases are the smallest normally used. However, because of the thermal and mechanical influences of urban areas, the lowest part of the typical urban atmosphere is less stable than its rural counterpart. When the urban option is utilized, the σ_z values for S = 4 are always used when the meteorological criteria indicate S = 5 or 6 (see Section 2.3). The σ_z for stacks less than 50 m high, σ_z', is calculated via $\sigma_z' = (\sigma_z^2 + SIGI^2)^{1/2}$ to account for surface effects, where SIGI = (50. - (stack height)) within the limits $0 \leq SIGI \leq 30$ m, during $S \leq 4$.

2.1.4 Plume Height

The plume rise equations used in Valley are taken from Briggs (1971, 1972), and are calculated in subroutine BEH072; the formulations are annotated in the listing presented in Appendix B.

TABLE 2-1 Constants Used in Calculating the Vertical Diffusion Coefficient.

$x_p \geq 1000$ m

STABILITY =	A[1]	B	C	D	E	F
a	.001	.0476	.119	2.61	52.6	33.6
b	1.89	1.11	.915	.45	.15	.14
d	9.6	2.0	0	-25.5	-126.	-75.

100 m $\leq x_p <$ 1000 m

STABILITY =	A	B	C	D	E	F
a	.001	.0476	.119	.187	.1345	.362
b	1.89	1.11	.915	.755	.745	.55
d	9.6	2.0	0	-1.4	-1.1	-2.7

$x_p <$ 100 m

STABILITY =	A	B	C	D	E	F
a	.1742	.1426	.1233	.0804	.06	.0434
b	.936	.922	.905	.881	.854	.814
d	0	0	0	0	0	0

[1] Stability A corresponds to S = 1, stability B corresponds to S = 2, etc.

Plume rise is calculated as a function of stability. However, the user has the option of assigning a fixed plume rise for any source(s). A fixed plume rise is not adjusted for wind speed by Valley; the effective plume height is simply defined as the sum of plume rise and the physical stack height. However, for analyses in complex terrain the plume height may be adjusted for each receptor depending on terrain elevation, as described in Section 2.1. Also, no matter what plume rise is calculated or assigned, maximum plume height is limited to the mixing height in the short-term mode during nonstable conditions (see Section 2.2.2).

2.1.5 Pollutant Decay or Transformation

Through each successive period of travel defined by the half-life, I, the pollutant concentration in a given parcel of air is reduced by 50 percent. This reduction of concentration is due to transformation of the pollutant, and should not be confused with the dilution or diffusion of the pollutant.

2.1.6 Limited Mixing (Plume Trapping)

For N = 0 Equation 2.1 accounts for the impact of a pollutant source on a ground-level receptor as though there were no elevated temperature inversion (i.e., no stable layer aloft) in the atmosphere. The sum for all other values of N accounts for multiple eddy reflections occurring as a result of a plume being trapped between an inversion base and the surface of the earth. The inversion base and earth are considered to be perfect reflectors. This condition is called limited mixing or plume trapping. Equation 2.1a is used when the vertical concentration profile is uniform. See also Sections 2.2.1 and 2.2.2.

A plume with centerline above the mixing layer is ignored by Valley in the long-term mode, but in the short-term mode the program limits the maximum height of the plume to no greater than the mixing height.

For computational purposes the value of L in Equation 2.1 is in effect treated as a very large value by Valley during stable conditions in rural areas, but pollutant dispersion within this layer proceeds only at the relatively slow rate dictated by σ_z for the stable condition being evaluated. The definition of L previously given (i.e., mixing height) may not be considered technically appropriate, nor is Equation 2.1a used, for stable conditions in rural areas.

For both rural and urban analyses, neutral conditions designated by the STAR data are divided by the computer code into two classes. One class (40 percent) is evaluated for nighttime conditions, and the remainder represents daytime conditions. The mixing height for all daytime neutral conditions is assigned the input value of the mean afternoon mixing height. The nighttime neutral mixing height for rural areas is taken as half that value, whereas for urban areas it is taken as the average of the input mean afternoon and nighttime values. The user inputs the nighttime mixing height used for urban, stable cases.

2.2 TIME-AVERAGING OF CONCENTRATION

Concentration averaging time must be specified by the user as either of two options, 24-hour or long-term. The techniques for the

24-hour and long-term concentration estimates obtained with Valley are identical except for adjustments (Section 2.2.2) made to emission rate, plume height and mixing depth made in the 24-hour option. Resulting concentrations are highly dependent upon the stability-wind data supplied by the user.

2.2.1 Long-Term Average Concentration

For a specific receptor (r) and source (s) configuration, a long-term estimate of χ_{rs} is obtained by solving Equation 2.1 or 2.1a for each meteorological condition assigned by the user, then summing all such concentrations after weighting each by its frequency of occurrence. The expression for average concentration at a receptor due to one source is thus:

$$\chi_{rs} = \sum_{d=1}^{16} \sum_{n=1}^{6} \sum_{S=1}^{6} F_{dnS}\, \chi_{dnS} \qquad (2.3)$$

where:

F_{dnS} = normalized frequency (from the STAR data) during the period of interest for a discrete case of wind direction d, wind speed n, and stability class S.

χ_{dnS} = ground-level concentration calculated from Equation 2.1 or 2.1a.

The concentration χ_r at a specific receptor for a given pollutant due to all contributing sources is:

$$\chi_r = \sum_{s} \chi_{rs}. \qquad (2.4)$$

The sum of the STAR frequencies for each long-term analysis (e.g., seasonal or annual) should be very near unity. A 1-hour occurrence of a particular meteorological condition will be included in an annual STAR array as (1 hour/year)/(8760 hours/year) = 0.00011, and in a seasonal (quarter-annual) array as 0.00045. The 24-hour analyses (see Section 2.2.2) require a different concept.

The representative speeds usually assigned to the six climatological wind speed categories (0-3, 4-6, 7-10, 11-16, 17-21 and >21 knots), are 0.67, 2.45, 4.47, 6.93, 9.61, and 12.52 m/s. These are user specified.

The six stability categories (S = 1 through 6 in order of increasing atmospheric stability, 4 being neutral) of the STAR data are defined on the basis of the criteria stated by Turner (1964). The classification is based upon ground-level meteorological observations only (surface wind speed, cloud cover, ceiling), supplemented by solar elevation data (latitude, time of day, and time of year); thus the stability estimates can be obtained for any site at which suitable observations have been made.

The mixing height, L, exhibits marked diurnal (daily) and seasonal variations at many locations as shown by Holzworth (1972). However, since it is impractical to account for all these variations, a simple procedure reflecting only major changes is included in the long-term option of Valley. The procedure determines mixing height by

modifying the average afternoon mixing height value according to the stability class being considered. Stability classes S = 1, 2 and 3 are daytime conditions, with S = 1 corresponding to very unstable conditions. When S = 1, the value of L is assumed to be 50 percent greater than the climatological value that is input. For S = 2 and 3 the climatological value is used. Stability class S = 4 is a neutral stability condition which usually occurs either with high wind speeds or with cloudy conditions. Because neutral conditions can exist in both the daytime and nighttime, in rural or urban areas, the afternoon mixing height values are averaged with the nighttime mixing height for 40 percent of the class S = 4 occurrences; the remaining 60 percent of the class utilizes the climatological value of the mean afternoon mixing height. Mixing height is assigned a very large value for stable conditions in rural areas; in urban areas the user-assigned nighttime value is used, with a default value of 100 m, for stable cases.

For the long-term analysis, Valley ignores a plume which is higher than the mixing height. It is assumed that such a plume will be contained in the stable layer aloft and will not affect ground-level concentrations.

2.2.2 Short-Term Average Concentration

The intended use of this option is to estimate and locate the maximum 24-hour concentration due to a single source in complex terrain under stable conditions. For a frequency of occurrence input

as 1.0 the model assumes that that particular meteorological condition exists for any 6 hours of a 24-hour period. Since the frequency designates a discrete wind sector, a particular source can affect only one sector during those 6 hours. The source contributes nothing to that sector for the remaining 18 hours. This is accomplished within the model by reducing the input emission rate to 6/24 of its actual value.

One must be careful in assigning the mixing height when the short-term option is used, for no plume heights are permitted to exceed the mixing height. If the effective stack height is greater than the mixing height it is automatically reassigned a height equal to the afternoon mixing height. The plume is then treated as though it were fully contained within the mixed layer. The user must construct a special STAR deck for the 24-hour option.

For the case when a stable atmosphere in mountainous terrain is suspected of causing the maximum 24-hour concentration, the STAR frequency distribution is assigned all zero values except those for elements of stability, wind speed and wind direction that are of concern. They are assigned a value of 1.0 . Multiple wind directions may be specified for a given run, but one must be aware that in such cases the resulting concentration at a receptor may result from several sources in different directions if multiple sources are input. This potential problem can be avoided by assigning only one wind direction per run. For example, one might input 1.0 in the STAR deck for stability F (S = 6), a wind speed of 2.5 m/s (n = 2) and a westerly wind direction (d = 13); all other elements of the STAR deck are input as zero. In this case,

finite concentrations occur only to the east (± 22.5°) of the source. Concentrations at all other directions are indicated to be zero. The user should input only single directions for multi-source, 24-hour analyses until the implications of multi-directional analyses are fully understood.

2.3 URBAN-RURAL CONSIDERATIONS

Light winds and clear skies usually produce stable atmospheric conditions at night near ground level in rural areas. The simultaneous stability in adjacent urban areas tends to be more unstable because of the heat-island effect. However, stable conditions can remain aloft over the city. These differences are important in the consideration of pollutant dispersion, and are accounted for in Valley through simple measures.

According to Turner's stability criteria, S = 5 and 6 (stable) can occur only when nighttime conditions are conducive to the formation of a surface-based inversion. A shallow layer of nonstable air has been found to occur in urban areas while adjacent rural areas are stable. Thus, for the long-term option only, the vertical dispersion coefficients of S = 4 (neutral) are substituted in Valley for those of S = 5 and 6 for urban analyses. This change is intended to more closely represent the actual dispersion rate for plumes in the urban area provided the plume remains in the shallow, nonstable layer. The user may assign the depth of this mixed layer, or may rely on the default value of 100 m. The concept of mixed layers was discussed in Section 2.1.6.

The conversion of stable conditions to neutral for urban analyses in turn affects the interpretation of terrain relief by Valley. For neutral atmospheric conditions the plume centerline in Valley is always terrain-following. Hence, Valley output for the urban area option is based on the assumption of flat terrain. This may lead to underestimates of concentration in urban areas with significant terrain features.

2.4 DISPERSION FROM AREA SOURCES

Valley computes area source contributions using Equations 2.1 and 2.1a. The total segment of each area source lying in the sector of concern is converted to an effective point source which lies upwind of the actual source. In the conversion process, both the downwind distance and the resultant source strength are dependent on the particular source-receptor configuration. The following discussion of area sources is adapted from the AQDM manual (TRW, Inc., 1969).

If the total emissions were assumed to be concentrated at the center of an area source, concentrations downwind would be overcalculated, especially for nearby receptors. Since uniform spread of the plume across the sector is assumed, it is logical to proceed a step further and assume an effective point source at such distance upwind that the 22.5° sector subtends an effective area width as illustrated in Figure 2-2. The half-life factor and the vertical spread are calculated using x_p, the downwind distance from the centroid of the fraction of the area source affecting the receptor for a given wind direction. However, the vertex of the horizontal angular spread lies at

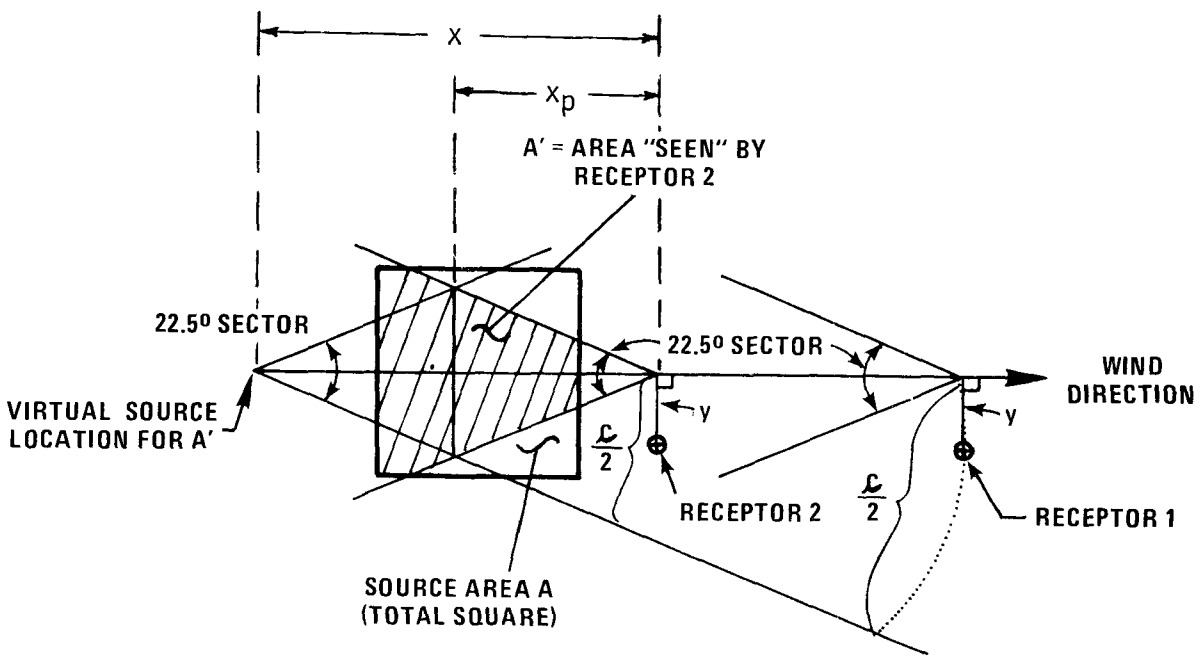


Figure 2-2. Schematic of the Virtual Point Source as Projected from an Area Source (After TRW, Inc., 1969).

distance x from the receptor; that is, at the effective source. This should clarify the need for the two distances, x and x_p, in Equations 2.1 and 2.1a. Note that in these equations x_p assumes the value of x for point source analyses. Also, when the calculated value of x for area sources is less than 100 m, x is reset to 100 m. The geometric treatment of an area source depends on whether the receptor lies within outside but near, or distant from the source area.

When a receptor lies within a source area, only a fraction of the area emissions could affect the receptor for any assigned wind direction. The program determines this fraction and applies it to the concentration calculated using total emissions at the effective point source of the source area subtended by a 22.5° sector with vertex at the receptor. For a given receptor in a given area source, the sum of the fractions for all 16 sectors should be unity; that is, a receptor lying within a ground level area source is never free of the effects of that source.

In a similar manner, nearby receptors are affected by emissions from only a portion of the area source at a given time, and would show excessive concentration values if the total area emission value were used. To correct this, the source emission rate is multiplied by an area utilization factor, Q*, which is the ratio of that portion (A') of the source area lying within a 22.5° sector upwind of the receptor to the total area (A). For example, in Figure 2-2, Receptor 1 would use the total area emission value, Q, while Receptor 2 would use the proportional amount, $QQ^* \propto A(A'/A)$. Note that in this figure the effective

point source for Receptor 2 would be defined by the effective area width. Area sources may be considered in either the flat-plane mode or the complex terrain mode of Valley.

2.5 COMMENTS

Valley should only be applied when competent meteorological advice is available to interpret the techniques of the model. Comments on the model are given next. Many of the limitations are not unique to Valley.

(a) The basis of the model calculations, the Gaussian diffusion formula, was developed to represent the behavior of plumes from point sources. The field data available for development of plume dispersion parameters were primarily obtained from open, flat terrain and for travel distances of no more than a few kilometers. Thus, the model has some potential weaknesses: (1) plume behavior during horizontal transport of more than a few kilometers is not well known; (2) plume behavior in regions of varying thermal and surface-roughness characteristics has not been systematically observed; (3) area sources are only imperfectly simulated by effective point sources; and (4) few real sources are truly point sources.

(b) The climatological data available for long-term calculations are generally obtained from airport weather observing stations. The character of the atmosphere may vary significantly between the meteorological site and the area of concern in the program analysis.

(c) The use of observed surface meteorological data to describe the transport and dispersion of pollutants from elevated sources during stable conditions in complex terrain is likely the greatest source of error in the application of Valley or any other model available today.

(d) The reliability and representativeness of emissions and source data are often overlooked when applying dispersion models. Valley uses average emission rate data. However, significant diurnal and seasonal variabilities in emission rates often occur. Such variabilities may be significantly correlated with the stability and wind data and this can invalidate an analysis made with Valley.

(e) Only 112 receptors are utilized. During stable conditions in complex terrain situations, very large gradients of concentration may exist in the vertical on slopes. The user should be aware that, due to the fixed receptor network, the maximum concentration attainable using Valley may not fall at any of the 112 receptors of a particular run.

(f) If one uses Valley to pinpoint the location of the estimated maximum short-term concentration attainable on a slope, a sampler placed at that location during a period matching the conditions of the simulation may well not record the maximum occurring on the slope at that time. The simplicity of the model does not justify a 1-to-1 comparison of observed and estimated concentrations at a point. Rather, the estimated maximum 24-hour concentration should be used as an indication that during two 24-hour sampling periods of a given year the estimated maximum concentration may be equalled or exceeded in the vicinity of the location of the estimated maximum.

(g) It is generally recognized that if continuous pollutant controls are utilized at a source in order to assure that the 24-hour air quality standard (e.g., for SO_2) is not exceeded as a result of that source alone, then the long-term standard will very likely not be exceeded. Hence, the use of Valley to estimate maximum 24-hour concentrations for complex terrain situations is the most important application of this model.

(h) If the plume height slightly exceeds the terrain in question, even during stable conditions, the pollutants may be drawn downward to the lee of the crest and create a pollution problem at ground level. If the source itself lies in the lee of a hill, a similar result may occur. Valley does not simulate these situations.

(i) Straight-line transport of pollutants is assumed. Hence, curvature of the plume due to pressure gradients induced by topographic features is not simulated.

(j) For Valley Model calculations σ_z is determined from the line of best fit of widely scattered data values obtained over flat terrain. The bulk of interpretations of limited data obtained in complex terrain indicate larger σ_z's than over flat areas, at least during stable conditions. The assumption is utilized in Valley that a statistical average of σ_z for a given stability over flat terrain (i.e., the familiar Pasquill-Gifford values) may be used to represent the lower limit of dispersion in complex terrain, particularly for stable conditions.

(k) Because of assumed plume behavior for nonstable cases, the assumption of flat terrain for urban areas may result in underestimates of concentrations on hillsides in urban areas. The same problem may exist on any elevated terrain during nonstable conditions with elevated plumes.

(l) The description of meteorological conditions by step functions i.e., discrete classes, creates discontinuities in concentration from one meteorological category to the next. These discontinuities are smoothed in Valley across wind-direction classes only.

(m) The model is not appropriate for evaluating atmospheric situations consisting of flow across an urban/rural boundary when the rural area is stable.

(n) The sloping-plume concept of Briggs is used in Valley. In the long-term mode of Valley, when a plume centerline height reaches a point where it exceeds the mixing height the contribution of that plume to all ground-level receptors downwind of that point is considered to be zero. This results in an underestimate of concentration, for some of the pollutant will remain in the mixing layer and affect all downwind receptors within the mixing layer, while the remainder of the pollutant will be transported in or above the stable layer aloft and potentially affect receptors on terrain above the inversion base.

(o) Valley cannot be used to evaluate fumigation. Such conditions can cause high, short-term, ground-level concentrations. In some topographic situations, fumigation can occur with relative regularity.

(p) The impingement of stable plumes on elevated terrain is treated by Valley as though the receptor lies on a slope facing the pollutant source, regardless of the actual orientation of the slope. Hence, concentrations calculated for receptors <u>not</u> located on windward slopes should be ignored.

The limitations of Valley cited in the comments above are not intended to imply that the Valley Model be kept from use. On the contrary, improved models can be developed only when significant experience with present formulations has been achieved, and when data which justify the use of more complex analytical techniques become available.

3. DATA DEFINITIONS

Detailed descriptions of input and output information follow; the variable names used in the program code are shown in capital letters.

3.1 INPUT DATA

3.1.1 Receptor Heights (RECHT)

--RECHT is an array containing the ground elevation (feet above msl) at each of the program-designated receptors. The use of an English unit for this parameter in an otherwise metrically oriented program was chosen so as to be identical with that on the more readily available topographic charts. The 16 records containing receptor elevations must be entered as blanks if a flat-plane analysis is desired. Each record contains the heights for the seven receptors lying on one radial from the center of the output maps, beginning with the radial directed northward from map center. If at least one receptor height is entered as a positive value, a map containing ground elevation differences (in meters) between each receptor and the first source input by the user will be output. The receptor locations are at the decimal point of the concentrations printed on the 16 radials of the output map. Each of the 16 records containing RECHT represents one direction, beginning with north and proceeding clockwise through north-northwest of map center. The first RECHT on each card corresponds to the innermost receptor on the respective radial, and successive values on that card progress outward along the radial.

3.1.2 Pressure and Temperature (P, TEMP, PRESS)

--P is the ambient pressure in millibars (mb) used in the conversion from $\mu g/m^3$ to ppm, and in the conversion from on-site to standard conditions; zero or blank defaults to 960 mb.

--TEMP is the average ambient temperature in degrees Kelvin (°K) used in the plume rise calculation, in the conversion from $\mu g/m^3$ to ppm, and in the conversion from on-site to standard conditions; zero or blank defaults to 293°K.

--PRESS is an option-control parameter.

0 - The concentrations printed will be for on-site conditions of pressure and temperature.

>0 - The concentrations printed will be for standard conditions (1013.2 mb and 293°K), provided the user has called for concentration in units of $\mu g/m^3$. Note that a given concentration expressed in ppm will not change with the temperature and pressure. The concentration of non-gaseous pollutants should not be called for in units of ppm.

3.1.3 Computer Run Identification (TITLE)

--TITLE is an alphabetic title of up to 80 characters which is supplied by the user. This identification label is printed on each map that is output for a given run through the program, with a line feed between columns 20 and 21. Sources are identified individually (see below); TITLE is therefore available for general identification of the analysis performed, but may be blank.

3.1.4 Program Control (GRID, MWT, DMIX, ISOR, DUPSOR, K, IUR, ICONT, DMNI, HLIFE, ISHORT)

--GRID is the required map scaling factor which scales the printed output maps to geographical reality. However, there is no variation in the size of the maps produced. This discussion of map scaling applies to printers with ten characters and six lines per inch. If a printer has a ratio that differs from 10:6, the output maps will not be of equal-area projection. A scale of kilometers is printed on each output map, and one character space always equals GRID (m). Any value of GRID may be used when the flat-plane mode is invoked. However, if the complex-terrain mode is used, GRID must remain constant for all runs of a given computer job or the receptor heights will differ from the actual ground elevations. If the output map is to be overlayed on a topographic chart having dimensionless scale ratio 1:n, then the user must specify GRID as:

$$\text{GRID (meters)} = .002538\ n$$

For example, for a direct overlay of the map on a chart of scale 1:24000, GRID = 60.9 m. A user might wish to obtain better resolution (i.e., more dense receptor network) in a region of complex topography around or near a source in an area for which a topographic chart of suitable scale is not

available. In such cases the user may manually or photographically change the map size (i.e., as output by the program) to a factor p of its original size, overlay the new size map on a chart scale of 1:n to obtain receptor heights, and calculate GRID for use as input data using:

$$\text{GRID (meters)} = .002538\ n\ p.$$

For example, if the overlay map has been reduced to p = 1/2 the size of a computer map, and is overlayed on a chart of scale 1:62500 to obtain receptor heights, then the user must specify the input value of GRID as 79.3. The scale of the output map from such a run is 1 inch = 793 m, or 1:31250, and the map should not be overlayed directly on the topographic chart from which the receptor heights were obtained.

--MWT determines whether output concentrations (χ) are to be expressed as $\mu g/m^3$ or as ppm.

0 - Indicates that χ will be in $\mu g/m^3$.

>0 - Is accepted by the program as the molecular weight of a gaseous pollutant, and the factor 0.0831 TEMP/(MWT P) is used to convert χ to units of ppm. Users of former versions of Valley (e.g., C9M3D) should note that this is a change from those versions. This modification is the sole reason that data sets prepared for former versions may not be compatible with the requirements of the present version. Unmodified older data sets will be accepted by the present version, but may result in erroneous concentrations.

--DMIX is the required mean maximum afternoon mixing height, in meters, for long-term analyses, or the required mean mixing height for the critical period of concern for short-term analyses. The input mixing height remains constant for the short-term analyses, but is changed internally according to stability for the long-term mode. For the rural mode DMIX is in effect set to a very large value for stable cases. If plume height exceeds DMIX in the short-term mode during nonstable conditions, it is reset to DMIX.

--ISOR is the number of sources, not to exceed 50, to be evaluated during the run. Point and area sources may be intermixed.

--DUPSOR is an option control.

0 - Indicates the user must input a source data set for <u>each</u> run.

>0 - Indicates that a number of STAR data sets will be analyzed in turn using only one source data set.

--K is the numerical indicator of the computer peripheral unit which is to receive the output. The output format is such that when the printer is specified, scaled maps are printed.

--IUR is an option control indicating source environment.

0 - Programmed abort.

1 - Indicates urban.

2 - Indicates rural.

--ICONT is an output control.

0 - Specifies that only the sum of all source contributions is to be output.

1 - Specifies that the individual source contributions and the sum are to be output.

2 - Specifies that only the individual source contributions are to be output.

--DMNI is the night-time mixing height, required only for the urban mode of analysis. Blank or zero defaults to 100 m. This parameter is not used in the rural mode.

--HLIFE is the half-life, in hours, of a pollutant which decays exponentially with time. A zero or blank entry defaults to infinite half-life. A half-life decay should not be confused with the reduction of concentration due to dilution of the pollutant.

--ISHORT is an averaging-time control.

0 - Indicates that the meteorological and source emissions data and resulting concentrations are for a long-term period, say for a season or year.

1 - Indicates the resulting concentrations are for a 24-hour period.

3.1.5 Source Data (INAME); (QSOT, HST, TS, VS, D, VF, SHOT, SVET, SORHT, WT, GT)

--INAME is a 24-character alphabetical array available for each source for identification.

--QSOT is the required emission rate, in grams per second, of each point or area source.

--HST is the required physical height of emission, in meters, of each source. This is the stack height, vent height, etc., above ground.

--TS is the source gas exit temperature, in degrees Kelvin. If plume rise calculations are requested for a given source, and TS $\leq$ TEMP (i.e., a cold plume), the analysis proceeds with plume rise set to zero and a warning is output.

--VS, D and VF are the source effluent exit velocity in meters per second, diameter of exit in meters, and effluent volume flow rate in cubic meters per second, respectively. Each may be input as zero or blank. However, if plume rise calculations are requested by the user (see variable GT below), either VS and D, or VF, must be greater than zero; otherwise, the analysis proceeds with plume rise set to zero, and a warning is output. VF is calculated internally when VS and D are input as non-zero.

--SHOT and SVET are the coordinates of each source, in units of the programmed grid. The location of an area source is defined by the lower left-hand (southwest) corner of the square area. The user's value of GRID determines the scale of the output map of normalized concentrations. The value of GRID (meters) corresponds to 1/10 inch on the face of the map and to one unit of measurement in the coordinate system of the map. Hence, GRID is required to calculate, as follows, the source coordinates to be input by the user:

SHOT (horizontal coordinate) = 460. + (X/GRID)

SVET (vertical coordinate) = 60. + (Y/GRID)

where X and Y (meters) are the east-west and north-south geographic distances, respectively, of the source from the center of the map. Y is negative if to the south of center, and X is negative if to the west of the center of the map. The center of the map lies at SHOT = 460, SVET = 60. For most analyses, the major or only source will likely be

assigned coordinates (460, 60); however, there are no restrictions on source location. There may be situations when the user may wish to obtain better spatial resolution of estimated concentrations than can be obtained by keeping the source location on the map; in such cases, the values of GRID and the source coordinates may be chosen so that the source lies well off the map, with the map representing a small area remote from the source. Receptor locations are program assigned in units of the programmed grid system.

--SORHT is the ground elevation in feet above mean sea level at the location of the source. SORHT has no meaning unless at least one receptor elevation is input as non-zero positive.

--WT is the width in meters of the source. A zero or blank entry signifies that the emissions emanate from essentially a point source. Any non-zero positive entry is interpreted as the length of a side of a square area source; the source is then evaluated using an effective point source technique. There are no restrictions on the sizes of the area sources.

--GT is the assigned fixed plume rise in meters. It is independent of wind speed; however, plume height remains a function of receptor elevation during stable conditions. If zero or blank, the program calculates plume rise via a subroutine. Hence, to evaluate a source with a known plume rise of zero, input for GT any insignificant positive number (e.g., 0.1).

3.1.6 Stability and Wind Related Data (WSA, SCFMT, SC)

--WSA is an array for assigning six wind speeds in meters per second. These speeds are applied respectively to the six frequencies of occurrence of each record in the SC data set (see below). Since the dispersion technique is not appropriate for calm conditions, the program produces zero concentration for each zero value assigned to WSA. Although extremely small wind speeds are acceptable to the program, they may not be appropriate for use with the Gaussian concept of dispersion simulation. The wind speeds usually associated with the six speed categories in the STAR decks are 0.67 2.45, 4.47. 6.93, 9.61 and 12.52 m/s.

--SCFMT is the required user-assigned format of SC and is input as a 72-character array. The program calls for successive SC records on the basis of inferred DO loops in the READ statement. Hence, SCFMT consists simply of six F codes enclosed in parenthesis, with appropriate indications of fields which should be skipped in the available SC records.

--SC is a required 96-record data set of decimal frequencies of occurrence for 576 possible combinations of wind speed, wind direction, and atmospheric stability. Data sets for long-term periods from surface observation sites may be obtained from the National Climatic Center, National Oceanic and Atmospheric Administration, Asheville, N. C. (refer to the STAR program in communications to the Center). Obtain six stability groups; they can be used in the urban or rural mode. Do not obtain the day/night classifications. The frequencies in a data set generated by STAR total about unity.

The long-term STAR data are obtained by an objective interpretation of meteorological data observed at airport weather stations. However, the probability is great that such data will not be representative of the conditions affecting transport and dispersion of pollutants in complex terrain. Even on-site meteorological measurements made at ground level have a high probability of deviating significantly from those that might be made at elevated plume height, particularly during the critical stable conditions in complex terrain. Hence, the emphasis in the development and application of the Valley Model by the EPA has been on the 24-hour average, with meteorological conditions specified objectively as is discussed in Appendix D.

The user must construct an artificial SC data set for short-term analyses to fit the conditions he wishes to evaluate. Valley assumes that the meteorology of the discrete condition represented by the ith entry in the SC array occurs during any 6 SC(i) hours of the day in this mode. For example, for a 24-hour analysis a speed category under one stability class might be assigned a frequency of 1.0 for each of the 16 directions available, with all other SC values zeroed out. In this case, with the source at the center of the map, the concentrations along any single radial could occur on the appropriate day, and the concentrations depicted along all other radials would be invalid for that day. Care must be exercised in summing contributions at a given receptor from multiple sources at different locations when utilizing the type of short-term data described in this example; one can obtain erroneous results (overestimates) by summing contributions which would not occur simultaneously with the single wind direction implied in the short-term mode. In some cases the only alternative is to execute 16 runs, using one wind direction each; often, however, the user can judge in advance which single direction will result in the maximum concentration.

3.2 PROGRAM OUTPUT

With the output unit designated as a printer by the user, the output will be discussed in the next few subsections in the order the information is printed. The program forces overflow of irrelevant data, resulting in asterisks being printed in place of a numerical value for any parameter not used in the respective analysis.

3.2.1 SC Data

The stability-wind rose data (SC) are listed by wind speed for each direction, grouped by the six stability categories. The first 20 characters of the input TITLE are included for identification. The summation of the frequencies for long-term periods (e.g., seasonal and annual) should be approximately 1.0; the short-term sum is dependent upon the intention of the user.

3.2.2 Individual Source Contribution Maps

These maps are output only when requested by the user via the input variable ICONT. Each map contains normalized concentrations at the 112 receptors which are located approximately on 16 radials (seven receptors each) at increments of 22.5° angular separation around the center of the map, beginning at north (toward page top). The decimal point of each printed concentration indicates the receptor location. The receptors along a given radial are not spaced equally, except due east and west, because of the space required for printing concentrations and the impossible matching of three coordinate systems involved (equal area for the internal grid, rectangular-integer for the printer, and 16-direction polar for the desired receptor network).

The concentrations are printed in four-digit (plus decimal point) fixed format. The program normalizes all concentrations on a given map equally, by order of magnitude, so that the maximum concentration printed contains a significant digit in the left-most position of the print area. The order-of-magnitude factor required to reinstate the output concentrations on each map to the proper units is printed on each map. For example, if the maximum concentration is 0.1328 ppm, the number 132.8 will be printed at the appropriate receptor location, and the order-of-magnitude factor 1.0-03 (meaning 10^{-3}) will appear on the map; all concentrations on that map must be multiplied by 10^{-3}.

Each source contribution map includes a good part of the information relevant to that analysis. The important exceptions are the stability-wind data and receptor heights, which are presented elsewhere in the output and discussed elsewhere in this section. The statements and labels on the maps are listed immediately below, in the order they are output. Self-explanatory output is included, but not elaborated.

--RELOCATE 2/3 INCH UP: The outermost concentration on the radial due north of center must be moved northward 2/3 inch (four printer lines) from its printed location. A similar statement applies to the outermost concentration on the south radial (requiring 2/3-inch relocation southward). Otherwise, the decimal point of the concentration value represents the position of the receptor used in the calculations.

--The source identifier (INAME) is printed.

--The run identification (TITLE) is printed, with a line feed following column 20 of the input record.

--HLIFE = ____HRS.

--CONCTR CORRCTD TO STD COND VIA FACTOR___: The concentrations presented have been converted to standard conditions (1013.2 mb, 298°K) via the factor shown. A factor of 1.0 implies no conversion.

--MAX TOWARD__DEG.: Indicates the direction of the maximum concentration from the center of the map.

--NORTH TOWARD TOP

--PLOT___: This is the maximum concentration appearing on the map. It can be used as an abbreviated identifier for the map.

--The center of the programmed receptor network is indicated by a decimal point, and enclosed with asterisks; the center coordinates (460, 60) are listed.

--MULTIPLY PRINTED VALUES BY 1.0 ± ii TO GET CONC. IN (units). In this statement, the multiplier "1.0 ± ii" must be interpreted as "10. to the power ± ii," and must be applied to each concentration. The units will then be in either ppm or $\mu g/m^3$, as specified in the statement.

--SOR ELEV: The input ground elevation at the source.

--COORDX and COORDY: The input coordinates of the source.

--STK HT: The input source emission height above ground.

--Q(GM/SEC): The emission rate, in scientific notation. For example, 2.321+03 is interpreted as 2321.

--FIXED DH: The input fixed plume rise. Asterisks in place of a numerical value indicate the user elected to use plume rises computed via the subroutine.

--BRIG.E and BRIG.F: The plume rises, in meters, for stability E and F, respectively. These are the last values returned by the plume rise subroutine during the source analysis. Hence, they are the calculated rises at the last receptor evaluated, and for the last finite wind speed used.

--DMIX: The input afternoon mixing height for long-term analyses, or the fixed mixing height for short-term analyses.

--DMNI: The input nighttime mixing height for the urban environment. Zero defaults to 100 meters.

--STAR F: The sum of all the input frequencies of the stability-wind data set used in the analysis.

--WIDTH: The input width of the square area source.

--BRIGUN: The calculated plume rise factor for nonstable atmospheric conditions. Divide by wind speed in meters per second to obtain plume rise in meters at the last receptor evaluated.

--P: The input value of pressure, or the default value.

--MWT: Molecular weight of the gaseous pollutant; used in calculating concentration in ppm.

--VV MEAN WIND SPDS VV: The input wind speeds are listed on the next line of output.

--AIR T: The input ambient temperature, or the default value.

--GAS T: The input effluent temperature.

--DIAM: The input stack diameter.

--GAS V: The input effluent exit velocity.

--FLOW: The input effluent volume flow rate, or that calculated by the program, in cubic meters/second.

--A line scale of geographical distances is output.

--RURL MODE or URBN MODE: Indicates the environment option specified by the user, i.e., rural or urban.

--LONG-TERM MODE or SHRT-TERM MODE: Indicates the averaging-time mode specified by the user. SHRT-TERM is intended to represent a 24-hour period.

--SLOPING TERRAIN CONCEPT or FLAT-PLANE CONCEPT: Indicates whether the user had or had not, respectively, input at least one finite, positive value in RECHT. If none was entered, the segment for plume height adjustment during stable conditions was skipped during the analysis.

3.2.3 Map of Total Impact of All Sources

If the user has specified via ICONT that a map be printed of the total impact of all sources, a listing is first provided of all source data (except volume flow rate) and of the plume rises and plume rise factor $u\Delta h$ of each source for the last receptor and meteorological condition evaluated for each source. The program then prints a map entitled "SUM CONC DUE TO ALL SRCS"; this phrase replaces INAME, and indicates the values represent the sum of concentrations due to all sources evaluated during the run through the program. Irrelevant parameters are printed as asterisks, except that Q = 0. Otherwise, the format is the same as the individual source contribution maps.

3.2.4 Terrain Factor Map

A terrain-factor map is output if the user specified as non-zero any receptor elevation. The map is of basically the same format as the concentration maps. However, the height difference between the ground elevation at the first source and each receptor is output in place of the concentration. INAME is replaced in the program by the statement "GROUND ELEVATION DIFFERENCE." Also printed are the statements "NORTH TOWARD TOP. (1/10)((SOURCE HT(1))-(RECPTR HT(N))), HTS IN METERS.", and "MULTIPLY PRINTED VALUES BY 1.0 + 01 (i.e., multiply by 10) TO GET GROUND ELEV DIFF IN M." Irrelevant parameters are printed as asterisks, except Q = 0.

4. COMPUTER USER'S INSTRUCTIONS

4.1 INTRODUCTION

Valley is a single, batch-oriented computer program requiring card input and producing output on standard paper on a line printer. The program consists of a main program and two subroutines (see Appendix B for a program listing).

The main program calls for the input data and calculates concentrations at the 112 receptors whose locations are internally defined. The main program calls the subroutine for calculating plume rise and the subroutine for printing the output maps.

Detailed instructions required for program execution are presented in this section. It is assumed that the user has read the first three chapters of the manual and is familiar with the technical applications of the model as well as the acquisition and significance of the input data required for program execution. A test run is presented in Appendix A.

4.2 OPERATIONS

4.2.1 Description

The generalized program flow diagram given in Figure 4-1 is presented to illustrate the simple operational nature of the program. No peripheral files are required for operation of the program.

Valley is written in Standard FORTRAN and is designed to operate on a UNIVAC 1110. The program requires 56K words of memory and has an execution time of a few seconds per source.

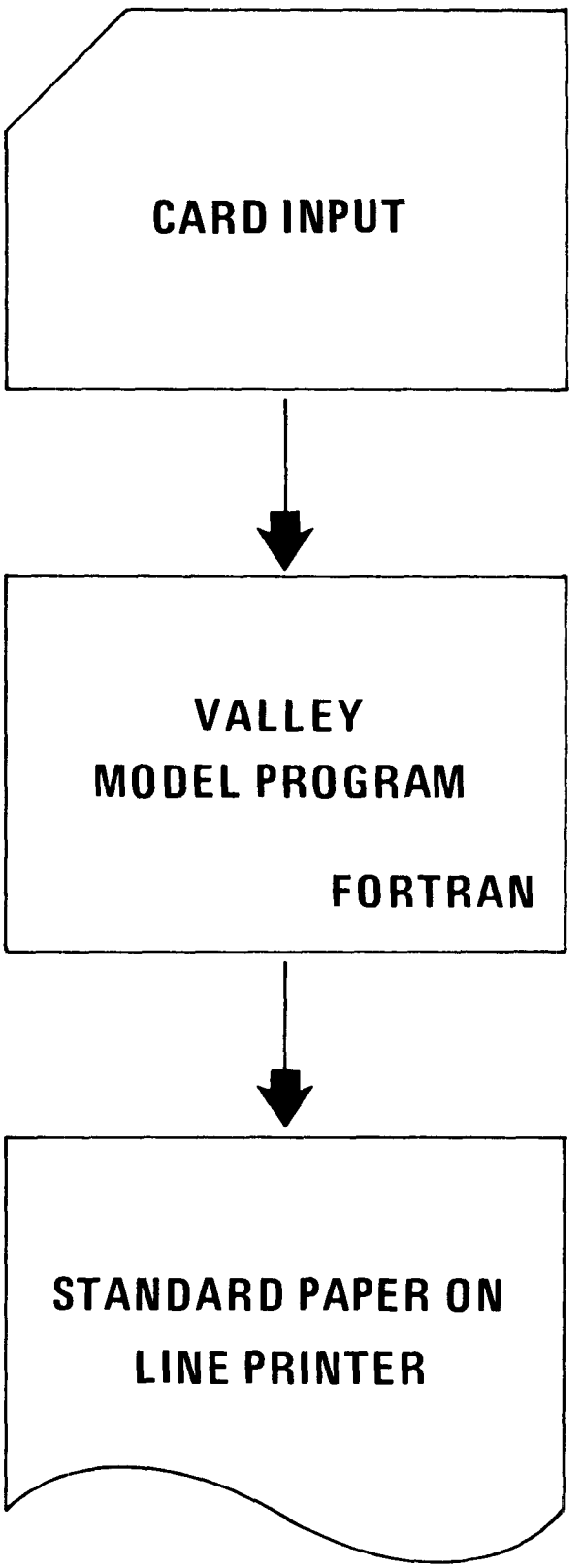


Figure 4-1. General Flow Diagram

The major functions of the program are shown in Figure 4-2. The program is used to calculate the air quality concentrations at 112 receptors resulting from as many as 50 sources of pollutant. These concentrations will be output in their geographically appropriate positions on a line printer as shown in Figure A-2.

4.2.2 Input Data

The data deck layout for the input data, including control data, is shown in Figure 4-3. Note that two cards are required to identify each source along with its stack parameters. Up to 50 sources may be input during a single run. The program also requires 16 receptor height cards for the internally specified 112 receptors. If any receptor elevation is non-zero a map depicting ground level differences between each receptor and the first source input will be output.

Special note must be taken of the Stability Class (SC) Format card and the SC cards. There are 96 SC cards required for each run. There must be six data values on each card. The definition of the data on each card is best described by the output shown in Figure A-2, except no alphabetical characters need appear on the SC data cards. A line of printout represents the data on a single SC input card. If one follows the definitions in this figure and orders the cards in the same manner as shown, the 96 SC cards (6 stabilities times 16 directions) will be properly defined and sequenced. The SC Format card referred to earlier is the FORTRAN format statement which tells the program where the six SC values are located on each card; outer parentheses must be included. Refer to Figure A-1 for an example of this card.

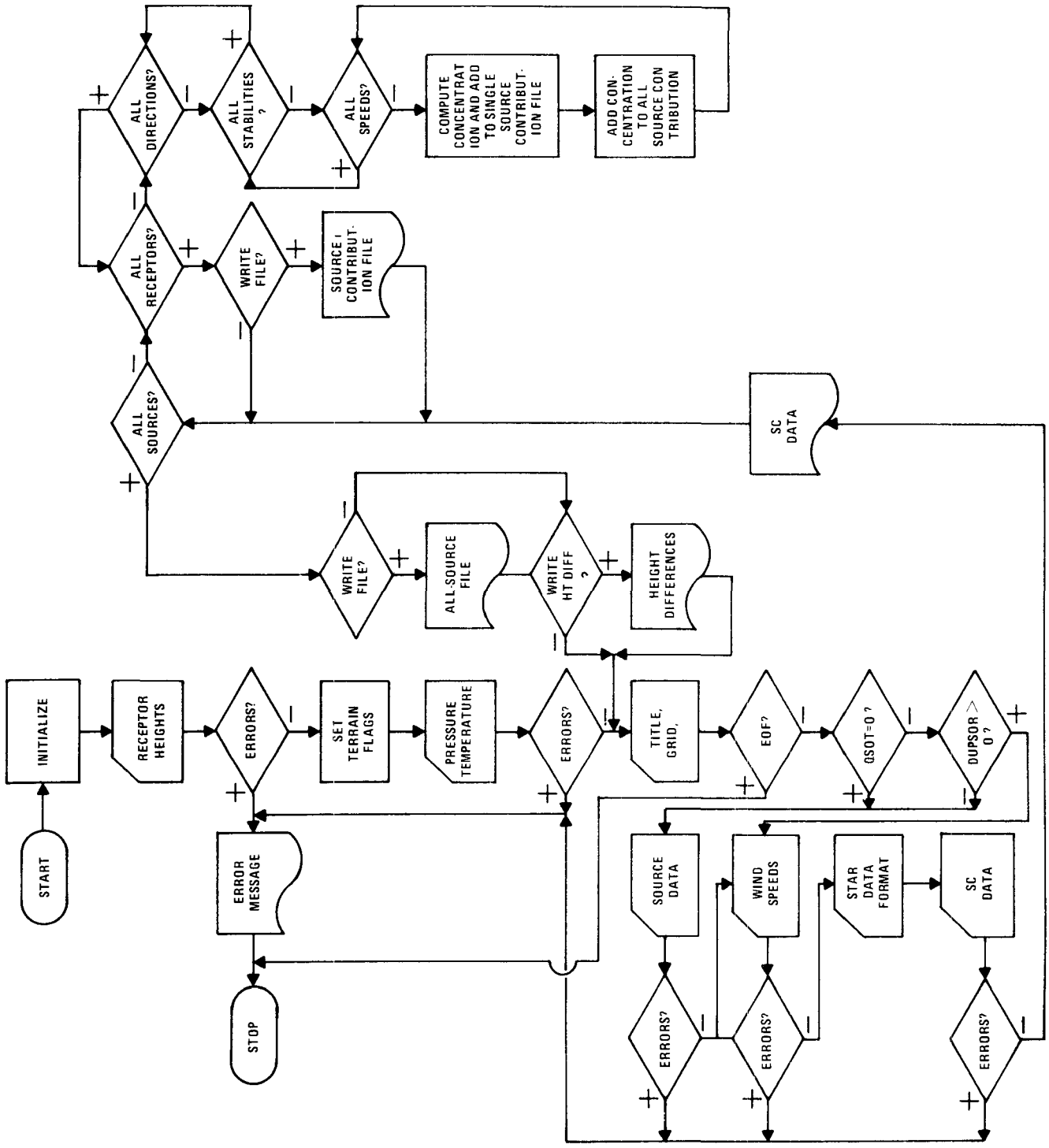


Figure 4-2. Major Program Functions

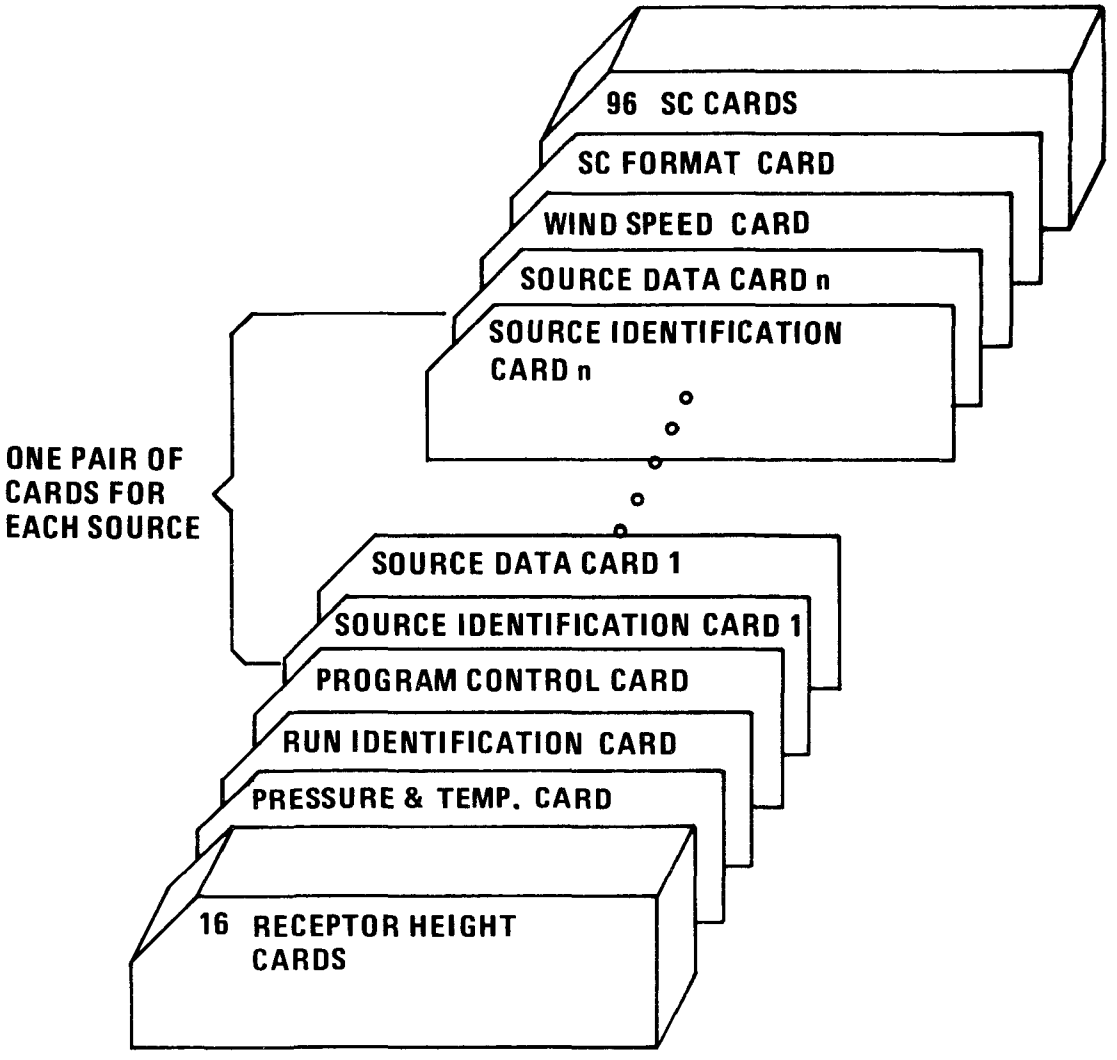


Figure 4-3. Data Deck Layout

Through proper arrangement of the input data cards the program will perform multiple model runs during one execution on the computer. This can be effected by immediately following the 96th SC card with a new Run Identification Card and all succeeding cards down to the last SC card. As many additonal runs as desired may be made following this repetitive scheme. Note that the receptor height cards and pressure/temperature card are input only once per computer execution. An error-free exit from the computer system will occur only if an "end of file" card is read in place of the Run Identification Card.

For quick reference, Tables 4-1 give the punched card formats for all required input data parameters. The parameter names and descriptions are also given. Decimal points for all numeric data are implied and designated by the symbol ∧ . The 96 SC data cards are not illustrated since they are usually obtained from the National Climatic Center or they are constructed by the user to fit the conditions of the analysis.

Since the input data involves many different formats of punched cards, input forms have been designed to assist the user in the preparation of the input data cards. The forms are illustrated in Figures 4-4. Note that this figure arbitrarily allows for the entry of three sources, but as many as 50 sources may be input per run. No form is presented for SC data, because the user controls the format.

4.2.3 ECL and Deck Setup

The runstream deck required for execution of the Valley Model consists of the Executive Control Language (ECL) cards, the program

TABLE 4-1

Card Input Format

($_\wedge$ designates implied decimal point)

RECEPTOR HEIGHT CARDS

Card Col.	Format	Parameter	Description
1 - 5	XXXXX$_\wedge$	RECHT 1	Ground Level Elev. (ft.) at Receptor 1
6 - 10	XXXXX$_\wedge$	RECHT 2	Ground Level Elev. (ft.) at Receptor 2
11 - 15	XXXXX$_\wedge$	RECHT 3	Ground Level Elev. (ft.) at Receptor 3
16 - 20	XXXXX$_\wedge$	RECHT 4	Ground Level Elev. (ft.) at Receptor 4
21 - 25	XXXXX$_\wedge$	RECHT 5	Ground Level Elev. (ft.) at Receptor 5
26 - 30	XXXXX$_\wedge$	RECHT 6	Ground Level Elev. (ft.) at Receptor 6
31 - 35	XXXXX$_\wedge$	RECHT 7	Ground Level Elev. (ft.) at Receptor 7

PRESSURE & TEMPERATURE CARD

1 - 6	XXXXXX$_\wedge$	P	Pressure (mb)
7 - 12	XXXXXX$_\wedge$	TEMP	Temperature (°K)
13 - 18	XXXXXX$_\wedge$	PRESS	Control Variable for Conversion to Standard Conditions

RUN IDENTIFICATION CARD

1 - 80	80A	TITLE	Alphabetic Identification

TABLE 4-1 (cont.)

Card Input Format

($\wedge$ designates implied decimal point)

PROGRAM CONTROL CARD

Card Col.	Format	Parameter	Description
1 - 5	XXXX$\wedge$X	GRID	Control for Scale
6 - 12	XXXXXXX$\wedge$	MWT	Molecular Weight of Gas; or Zero
13 - 18	XXXXXX$\wedge$	DMIX	Mean Maximum Afternoon Mixing Depth (m)
19 - 21	XXX	ISOR	Number of Sources ($\leq$50)
22 - 24	XXX	DUPSOR	Mode of Operation
25 - 27	XXX	K	Line Printer Designator
28 - 30	XXX	IUR	Urban or Rural
31 - 33	XXX	ICONT	Output Degree
34 - 37	XXXX$\wedge$	DMNI	Night DMIX for Urban Only (m)
38 - 41	XXXX$\wedge$	HLIFE	Half Life of Pollutant (hr)
42 - 44	XXX	ISHORT	Option Control for Averaging Time

SOURCE IDENTIFICATION CARD

1 - 24	24 A	INAME	Alphabetic Source Identification

TABLE 4-1 (cont.)

Card Input Format

($_\Lambda$ designates implied decimal point)

SOURCE DATA CARD

(each such card must be preceded by a Source Identification Card)

Card Col.	Format	Parameter	Description
1 - 7	XXXXXXX$_\Lambda$	QSOT	Emission Rate (gm/s)
8 - 14	XXXXXXX$_\Lambda$	HST	Physical Height of Stack (m)
15 - 21	XXXXXXX$_\Lambda$	TS	Effluent Temperature (°K)
22 - 28	XXXXXXX$_\Lambda$	VS	Effluent Velocity (m/s)
29 - 35	XXXXXXX$_\Lambda$	D	Stack Diameter (m)
36 - 42	XXXXXXX$_\Lambda$	VF	Volumetric Flow Rate (m^3/s)
43 - 49	XXXXXXX$_\Lambda$	SHOT	Easterly Coordinate of Source
50 - 56	XXXXXXX$_\Lambda$	SVET	Northerly Coordinate of Source
57 - 63	XXXXXXX$_\Lambda$	SORHT	Ground Elevation at Source (ft)
64 - 70	XXXXXXX$_\Lambda$	WT	Width of Square Area Source (m)
71 - 77	XXXXXXX$_\Lambda$	GT	Fixed Plume Rise (m)

WIND SPEED CARD

1 - 10	XXXX$_\Lambda$XXXXXX	WSA (1)	Mean Wind Speed (m/s)
11 - 20	XXXX$_\Lambda$XXXXXX	WSA (2)	Mean Wind Speed (m/s)
21 - 30	XXXX$_\Lambda$XXXXXX	WSA (3)	Mean Wind Speed (m/s)
31 - 40	XXXX$_\Lambda$XXXXXX	WSA (4)	Mean Wind Speed (m/s)
41 - 50	XXXX$_\Lambda$XXXXXX	WSA (5)	Mean Wind Speed (m/s)
51 - 60	XXXX$_\Lambda$XXXXXX	WSA (6)	Mean Wind Speed (m/s)

SC FORMAT CARD

1 - 72	72A	SCFMT	Stability Wind Frequency Format

RECEPTOR HEIGHT CARDS

RECHT 1	RECHT 2	RECHT 3	RECHT 4	RECHT 5	RECHT 6	RECHT 7

PRESSURE & TEMPERATURE CARD

P	TEMP	PRESS

RUN IDENTIFICATION CARD

TITLE (Literal for Identification of Analysis)

PROGRAM CONTROL CARD

GRID	MWT	DMIX	ISOR	DUPSOR	K	IUR	ICONT	DMNI	HLIFE	ISHORT

Figure 4-4. Data Card Format

SOURCE IDENTIFICATION CARD

INAME (Alphabetic source identification)

QSOT	HST	TS	VS	D	VF	SHOT	SVET	SORHT	WT	GT

SOURCE DATA CARD

SOURCE IDENTIFICATION CARD

INAME (Alphabetic source identification)

QSOT	HST	TS	VS	D	VF	SHOT	SVET	SORHT	WT	GT

SOURCE DATA CARD

SOURCE IDENTIFICATION CARD

INAME (Alphabetic source identification)

QSOT	HST	TS	VS	D	VF	SHOT	SVET	SORHT	WT	GT

SOURCE DATA CARD

Figure 4-4 (cont.)

WIND SPEED CARD

WSA(1)	WSA(2)	WSA(3)	WSA(4)	WSA(5)	WSA(6)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|---|---|---|---|---

source deck and the data input cards. The data input deck has been explained in the previous section and the program source statements can be found in Appendix B.

The ECL cards required for a compile and execute run are illustrated in Figure 4-5. If the underlined parameters on the first card are not known or understood, the ADP representative for the user's organization should be contacted. All other underlined parameters on subsequent cards may be chosen by the user at his discretion. Once the procedure of Figure 4-5 has been executed, the user then may use the procedure illustrated in Figure 4-6 for all runs using the same file name, FN., and element name, FN.E, chosen when executing the procedure in Figure 4-5.

4.2.4 Output

The output of Valley consists of a stability-wind data listing, various receptor maps, and potentially a listing of all source data used for the simulation. The receptor maps may include individual source contribution maps, a map of the total impact of all sources, and a terrain factor map. Examples of all output formats are shown in Figures A-2 of Appendix A. A simple data set for obtaining base maps that will be of use in acquiring ground elevations at receptor locations is shown in Appendix C. It is emphasized that the only lines of receptors which are equally spaced lie due east and due west of center; the only lines of receptors which do not deviate somewhat from the radials are those in the four cardinal directions.

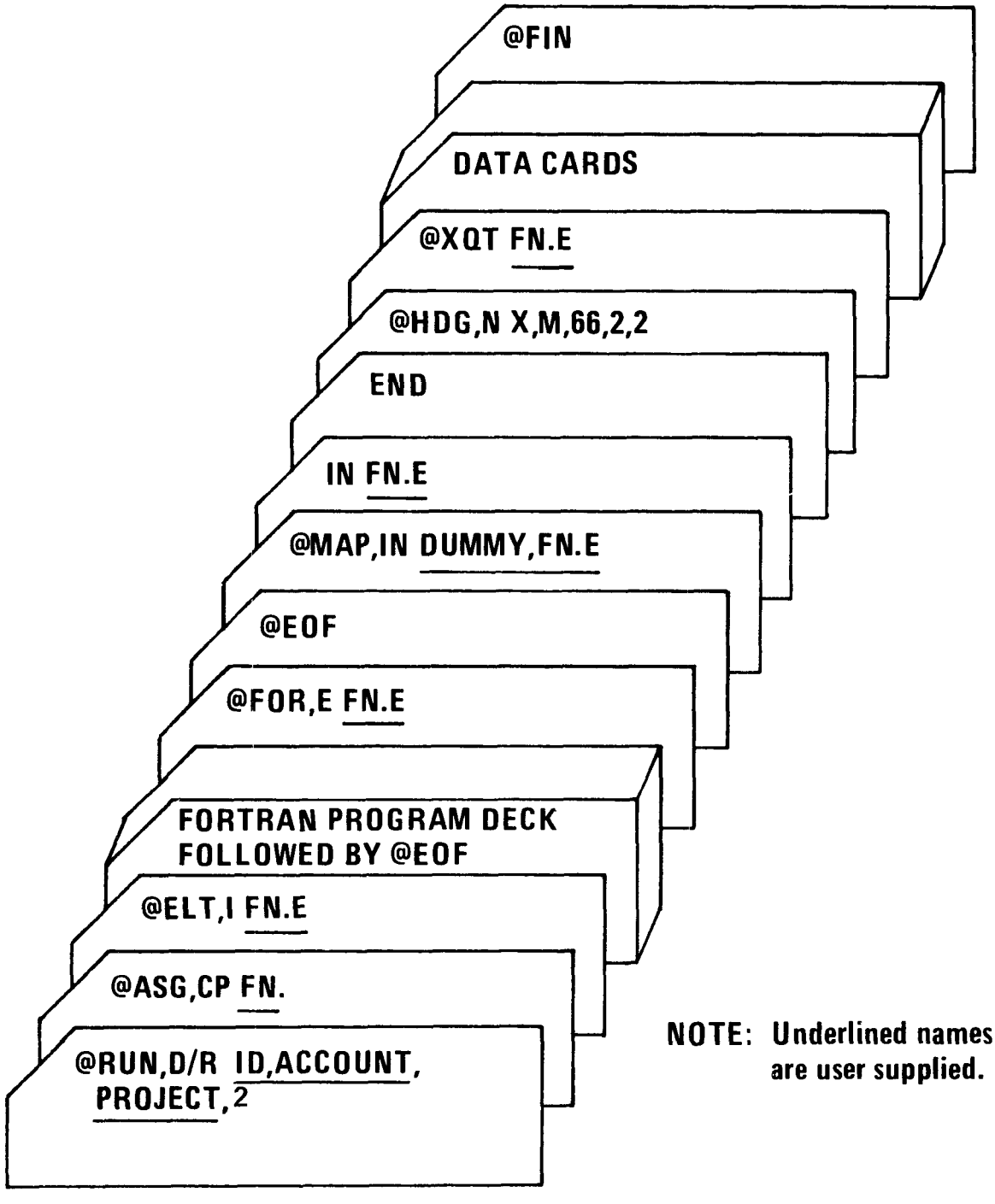
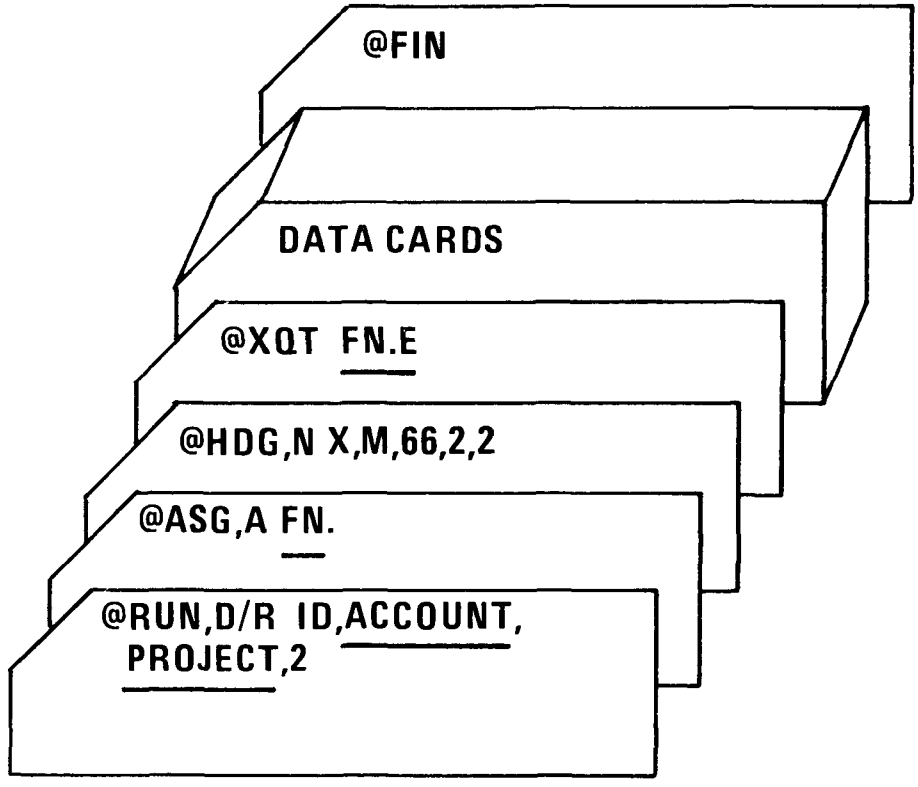


Figure 4-5. ECL Runstream for Compile and Execute



NOTE: Underlined names are user supplied.

Figure 4-6. ECL Runstream for Previously Compiled Program Execution

5. REFERENCES

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APPENDIX A.

TEST RUN

Consider a facility located on a broad, flat area in the countryside near the base of an extended ridge. A particular pollutant is emitted from a stack and a series of relatively low-level vents located in a 20 m x 20 m area surrounding the stack. Vent emissions are about air temperature of 283°K, and are released at very low vertical velocity about 20 m above ground at a rate of 300 g/s; the vents are treated as one area source. The stack is 75 m tall, with an internal diameter of 3.2 m ; the exit velocity is 4.8 m/s, the effluent temperature is 375°K, and the pollutant emission rate is 1200 g/s. The terrain height at the facility is 3800 ft (1158 m) above mean sea level (msl).

The major concern is for air quality on a daily basis. Hence, the Valley model is executed in the short-term (24-hour) mode, using as input stability F (moderately stable atmosphere) and 2.5 m/s for the windspeed. These conditions are assumed by the model to exist for 6 of 24 hours when the short-term mode is specified, and when the frequency of occurrence is input as 1.00.

Since the facility is arbitrarily located at the center of the output map, each line of fixed receptors (located along a given radial from center) is affected by virtually only one wind direction. The analysis for all 16 wind directions can thus be accomplished in one computer run, but each direction represents conditions for one particular day. We can assume this only because the map scale chosen

relegates the area source to essentially a point source as pertains to wind direction effects; however, the area source is still treated as a virtual (or effective) point source by the model.

The source data is input so that the area source effluents (i.e., those from vents) have a fixed plume rise of near zero. The plume rise of the stack effluent is calculated by the model.

The input data listing is shown in Figure A-1. The first column indicates the sequential card number, and is not part of the input data. Note that some records are omitted from the SC subset in the figure to conserve space; those records are blank, but all 96 SC cards are required input. Handwritten notations are added to the data listing and maps for clarification, so as to be distinguishable from the computer output.

Finite frequencies of occurrence of meteorological data have been input for only six wind directions (ENE, E, ESE, WSW, W, and WNW), and only the ground elevations for receptors affected by the sources for those directions have been input. This is sufficient input to permit comparison of the simulated terrain effects (eastward of map center) with a flat-plane situation (due west of map center), and simplifies preparation by any user desiring to duplicate the test case.

The output listing is shown, page per page, in Figure A-2. The entire SC data subset is always listed, but only the non-blank stability category is included here. The SC data are followed in turn by (1) a map of estimated ambient pollutant concentrations due to each source;

324

SEQUENTIAL CARD NUMBER

CARD COLUMN 1

```
 1
 2
 3
 4  3867 4213 4450 4650 5040 5400 4900
 5  3867 4213 4550 4900 5600 5270 4950
 6  3867 4213 4500 4750 5170 5630 5200
 7
 8
 9
10
11
12  3800 3800 3800 3800 3800 3800 3800
13  3800 3800 3800 3800 3800 3800 3800
14  3800 3800 3800 3800 3800 3800 3800
15
16
17 870.  283.  870.
18 TEST RUN -- SO2                          PARTIAL WIND ROSE FOR EASY DUPLICATI
19 60.9                 2     6  2  1      3.  1
20 MAIN STACK
21 1200.  75.    375.   4.8    3.2           460.   60.    3800.
22 VENTS.(AS AREA SRC)
23 300.   20.                                459.84 59.84  3800.  20.    .001
24 2.5
25 (6F2.1)
26
27
 :  } BLANK CARDS
107
108     WIND DIR:
109 1. —ENE
110 1. — E
111 1. —ESE
112                THE LAST 16 CARDS
113                ARE FOR STABILITY F
114
115
116
117 1. —WSW
118 1. —  W
119 1. — WNW
120
121
```

Figure A-1. Test Case Input Data Listing. Notations Are Handwritten to Avoid Confusion with the Data.

(2) a listing of source data; (3) a map of the total contribution due to all sources; and (4) a map of relative terrain elevations at the receptors.

Compare the patterns of concentrations with the pattern of topographic relief sketched on the output maps. Note the concentration isopleths are omitted on the lee of the ridge; calculated concentrations are not appropriate for that area. The area to the west of the facility (to the left of map center) is flat; the ridge crest is oriented north-south and lies to the east of the facility. The differences in concentration at any two radials are due primarily to the simulated effects of terrain; these effects are quite apparent, particularly for the main stack. Some of the difference, particularly for the low-level area source and near the center of the map, can also be due to the fact that receptor spacing may differ from radial to radial. The receptor locations used for the calculations are depicted by the decimal points of the seven concentrations printed along each radial. For the map scale selected, the 20 x 20 m area source representing the multiple vents lies totally within 0.025 inch of the center of the maps.

TEST RUN -- SO2

STABILITY	SPD(MPS) WIND DIR	2.500	.000	.000	.000	.000	.000
A	N	.0000	.0000	.0000	.0000	.0000	.0000
A	NNE	.0000	.0000	.0000	.0000	.0000	.0000
A	NE	.0000	.0000	.0000	.0000	.0000	.0000
A	ENE	.0000	.0000	.0000	.0000	.0000	.0000
.	.						
.	.						
.	.		(ALL ZEROS)				
.	.						
.	.						
E	NW	.0000	.0000	.0000	.0000	.0000	.0000
E	NNW	.0000	.0000	.0000	.0000	.0000	.0000
F	N	.0000	.0000	.0000	.0000	.0000	.0000
F	NNE	.0000	.0000	.0000	.0000	.0000	.0000
F	NE	.0000	.0000	.0000	.0000	.0000	.0000
F	ENE	1.0000	.0000	.0000	.0000	.0000	.0000
F	E	1.0000	.0000	.0000	.0000	.0000	.0000
F	ESE	1.0000	.0000	.0000	.0000	.0000	.0000
F	SE	.0000	.0000	.0000	.0000	.0000	.0000
F	SSE	.0000	.0000	.0000	.0000	.0000	.0000
F	S	.0000	.0000	.0000	.0000	.0000	.0000
F	SSW	.0000	.0000	.0000	.0000	.0000	.0000
F	SW	.0000	.0000	.0000	.0000	.0000	.0000
F	WSW	1.0000	.0000	.0000	.0000	.0000	.0000
F	W	1.0000	.0000	.0000	.0000	.0000	.0000
F	WNW	1.0000	.0000	.0000	.0000	.0000	.0000
F	NW	.0000	.0000	.0000	.0000	.0000	.0000
F	NNW	.0000	.0000	.0000	.0000	.0000	.0000

Figure A-2. Output of Test Case Run.

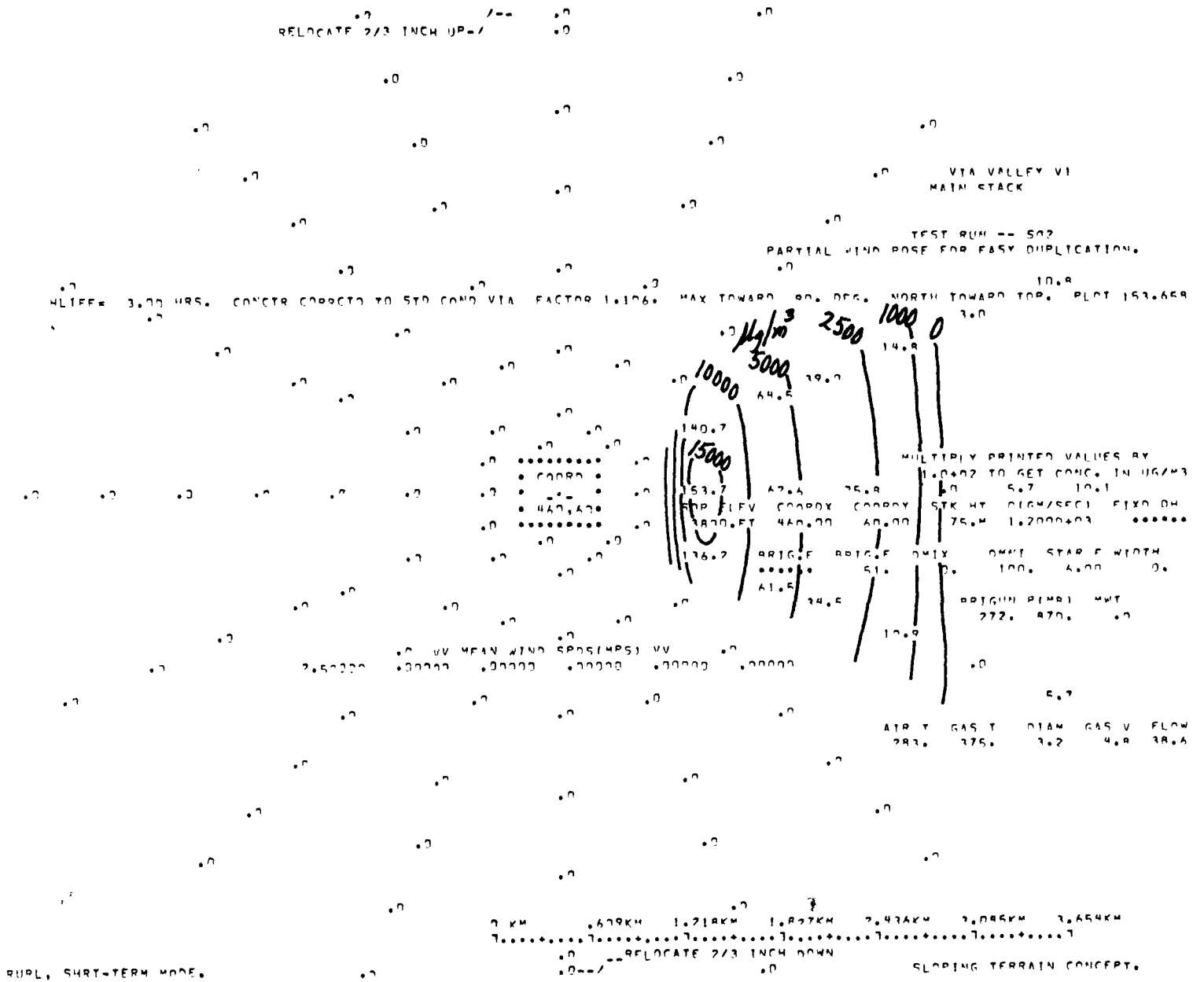

Figure A-2 (cont.)

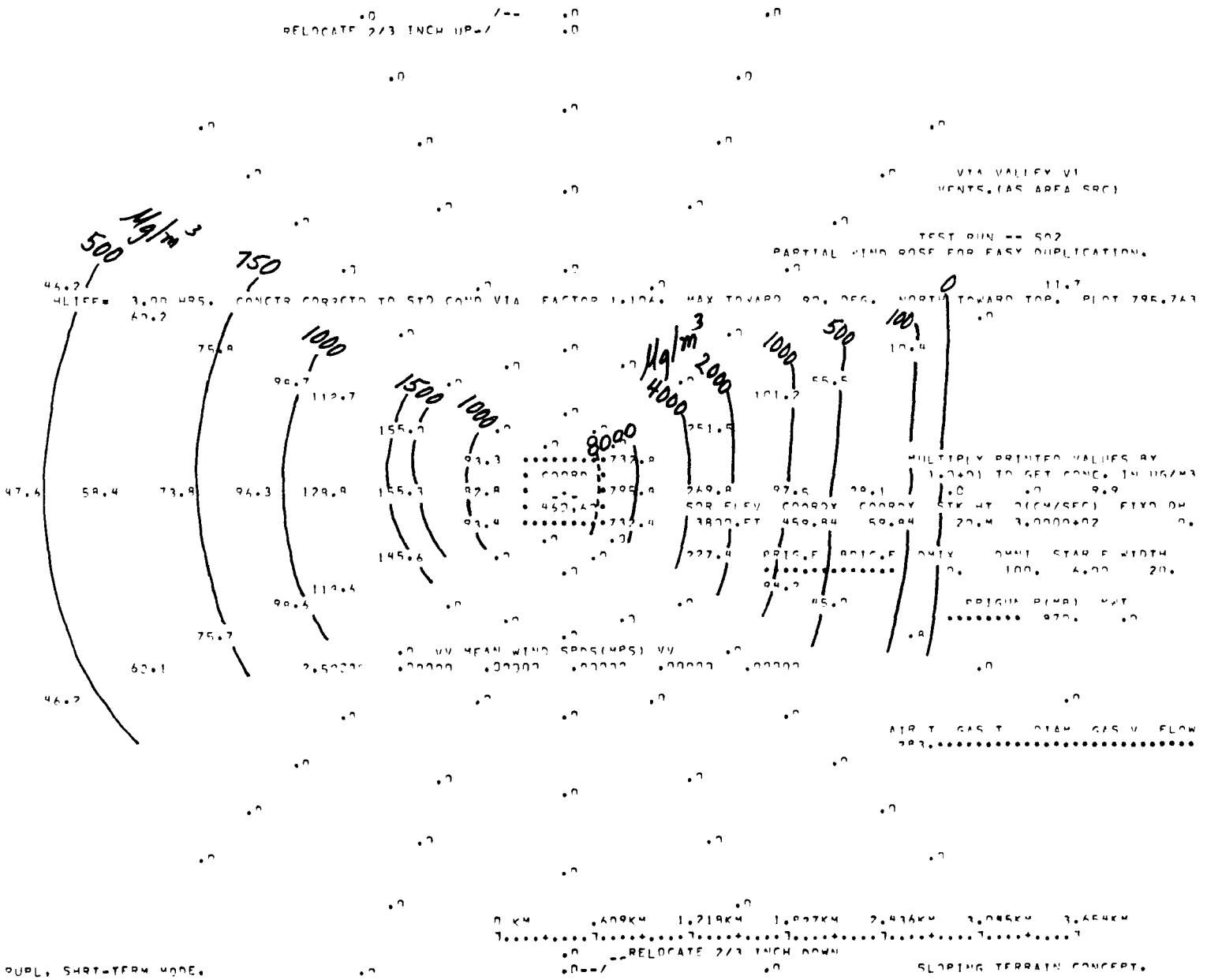

Figure A-2 (cont.)

TEST RUN -- SO2 PARTIAL WIND ROSE FOR EASY DUPLICATION.

SOURCE DATA. PLOT 183.437

SOURCE NAME	COORDX	COORDY	STK HT	EMISS RATE	FIXD DH	SOR W	SOR H	BRIGHN	BRIGF	BRICF	AIR T	GAS T	DIAM	GAS V
1 MAIN STACK	460.00	62.00	75.	1.2000+03	********	0.	3800.	272.	********	51.	283.	375.	3.2	4.8
2 VENTS.(AS AREA SRC)	459.84	59.84	20.	3.0000+02		0.	20.	3800.	**********	**********	283.	****	*****	*****

Figure A-2 (cont.)

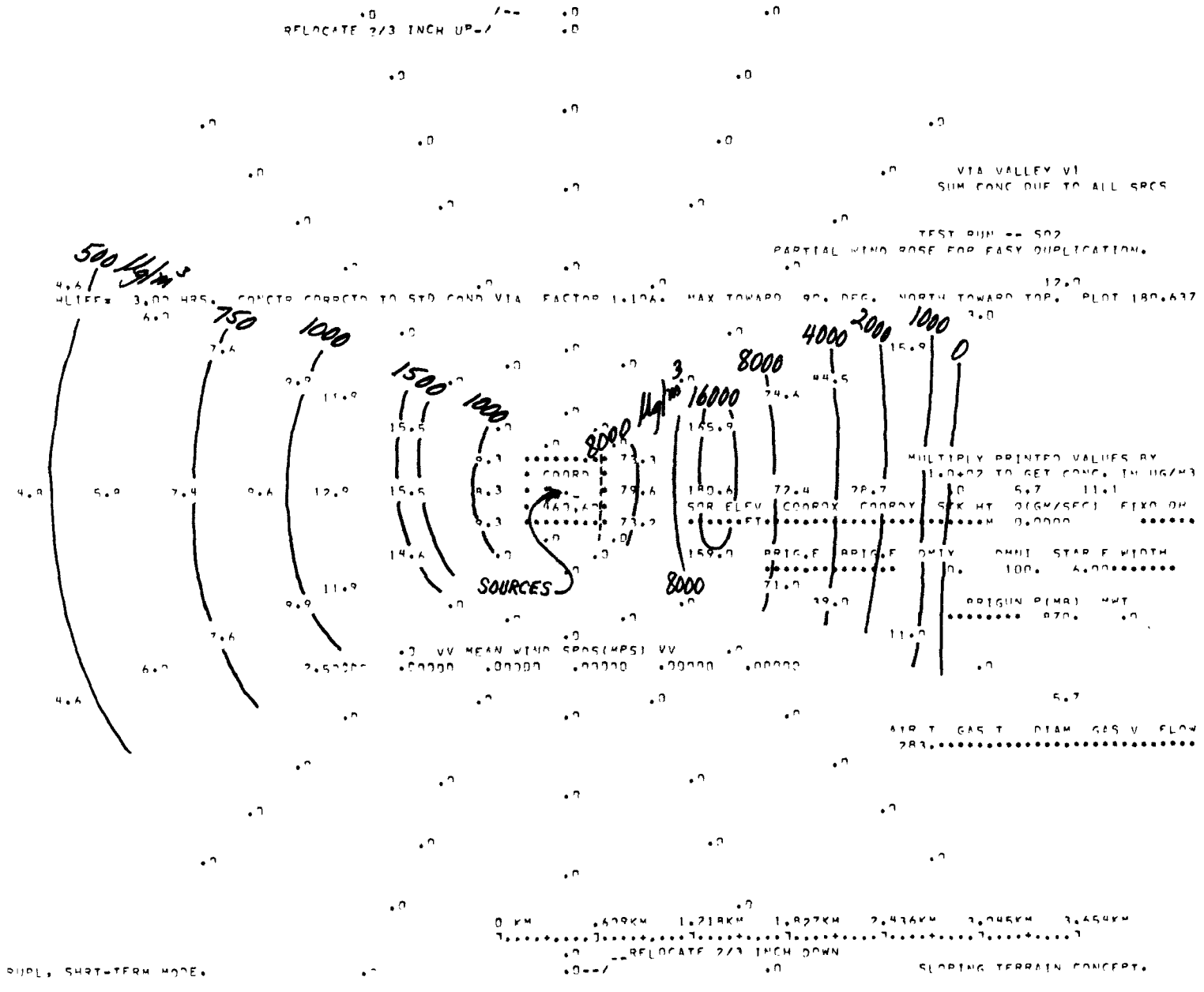

Figure A-2 (cont.)

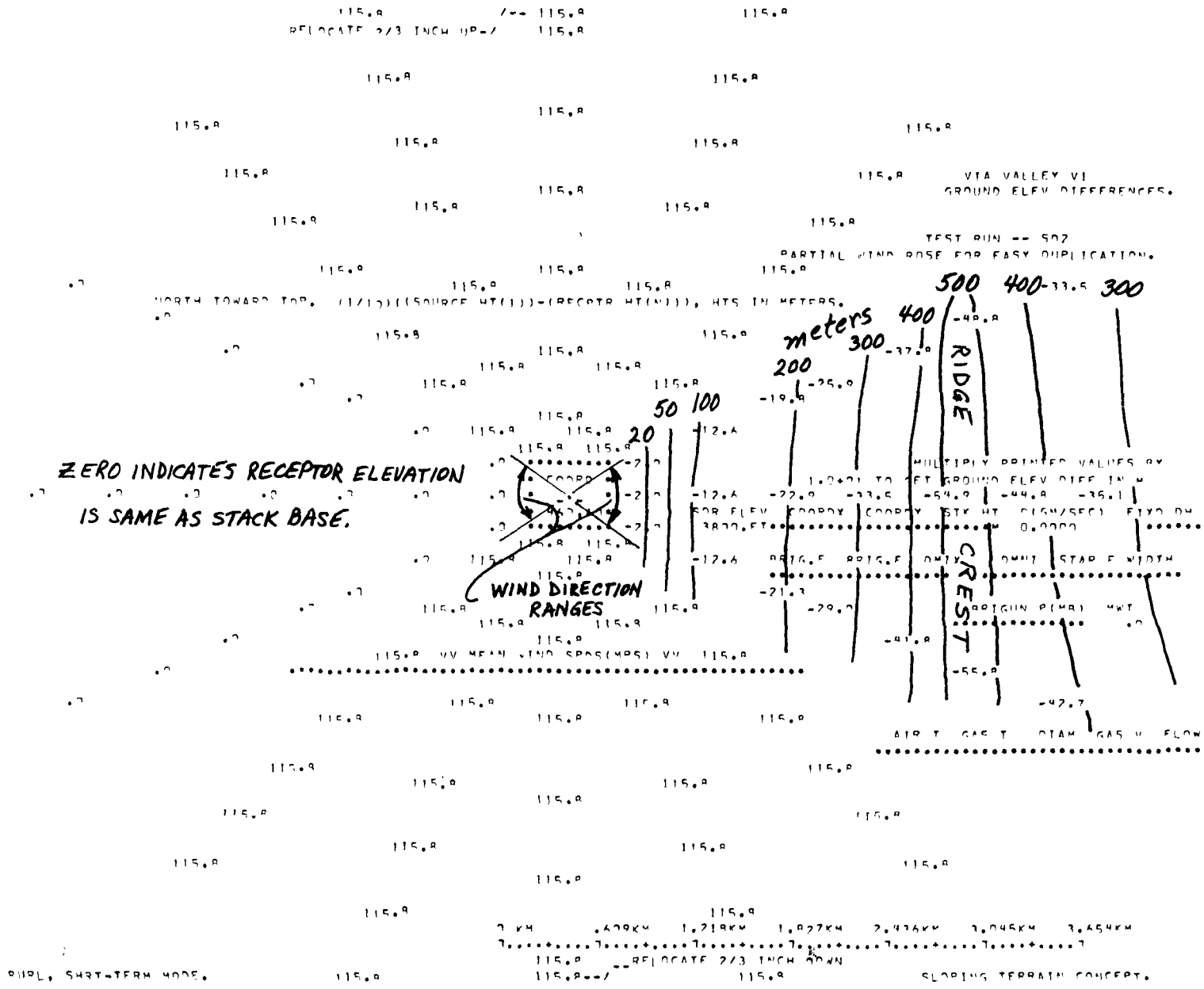

Figure A-2 (cont.)

APPENDIX B

PROGRAM LISTING

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CC   V1 - JUNE 1977. C9M3D WITH HALES/BIERLY/HEWSON EQN RATHER THAN      MA000100
CC   INTERPOLATION FOR LIMITED MIXING. INPUT VARIABLE ALWT CHANGED       MA000200
CC   TO MWT.                                                             MA000300
CC   C9M3D-NOV. 24,1975. C8M3D WITH FOUR RECEPTOR COORDINATES CORRECTED. MA000400
CC   CALL BRIGGS (STABLE) MOVED TO WIND SPD LOOP. BRIGE AND BRIGF NOW AREMA000500
CC   PLUME RISES (NOT PLUME RISE FACTORS).                               MA000600
CC   C8M3D - SEPT. 17, 1974.  C7M3D WITH PLOTS PRINTED VIA SUBROUTINE.   MA000700
      REAL MWT                                                           MA000800
      DIMENSION TS(50),VS(50),D(50),VF(50),DTDZ(6)                       MA000900
      DIMENSION DIR(16),STAB(6)                                          MA001000
      DIMENSION INAME(300),RECHT(112),SORHT(50)                          MA001100
      DIMENSION TITLE(20),SCFMT(18),RHOR(112),RVER(112)                  MA001200
      DIMENSION SHOT(50),SVET(50),HST(50),QSOT(50),GT(50),WT(50)         MA001300
      DIMENSION SC(6,16,6),A(18),B(18),C(18),WSA(6)                      MA001400
      DIMENSION S(112),V(112),BRIGUN(50),BRIGE(50),BRIGF(50)             MA001500
      COMMON MAXVM,VMAX,V,ICONT,MAXAM,AMAX,S,GRID,NSOR,INAME,TITLE,      MA001600
     A HLIFE,STP,VXDIR,PAGE,ALWT,TFORM,IS3D,G,BRIGUN,TS,D,VS,VF,SORHT,   MA001700
     B SHOT,SVET,HS,QSOT,BRIGE,BRIGF,DMIX,DMNI,STARFR,W,WSA,TEMP,IREC,   MA001800
     C ISOR,GT,HST,WT,VFORM,AXDIR,IUR,ISHORT,NN,MAP,RECHT,HFCTR,K,P,MWT  MA001900
CC   FIXED POTENTIAL TEMP GRADIENTS. 99 IS DUMMY.                        MA002000
      DATA DTDZ/99.,99.,99.,99.,0.02,0.035/                              MA002100
      DATA DIR   /'   N','NNE','  NE','ENE','   E','ESE','  SE',         MA002200
     A 'SSE','   S','SSW','  SW','WSW','   W','WNW','  NW','NNW'/        MA002300
      DATA STAB  /'  A','   B','   C','   D','   E','   F'/              MA002400
CC   RECEPTORS ARE NUMBERED CONSECUTIVELY OUTWARD ALONG EACH RADIAL.     MA002500
CC   1-7 TO NORTH, 8-14 TO NNE, ....., 106-112 TO NNW.                   MA002600
CC   THE CENTER OF THE NETWORK IS AT X=460., Y=60.                       MA002700
CC   HORIZ COORD OF RECEPTORS FOLLOW.                                    MA002800
      DATA RHOR/7*460.,463.,466.,469.,473.,476.,478.,481.,               MA002900
     A 465.,472.,477.,483.,488.,493.,498.,                               MA003000
     B 468.,476.,483.,488.,496.,503.,512.,                               MA003100
     C 468.,476.,484.,492.,500.,508.,516.,                               MA003200
     D 468.,476.,483.,488.,496.,503.,512.,                               MA003300
     E 465.,472.,477.,483.,488.,493.,498.,                               MA003400
     F 463.,466.,469.,473.,475.,478.,481.,7*460.,                        MA003500
     G 458.,454.,451.,447.,445.,442.,439.,                               MA003600
     H 453.,448.,443.,437.,432.,427.,422.,                               MA003700
     I 452.,444.,437.,432.,424.,417.,408.,                               MA003800
     J 452.,444.,436.,428.,420.,412.,404.,                               MA003900
     K 452.,444.,437.,432.,424.,417.,408.,                               MA004000
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     L 453.,448.,443.,437.,432.,427.,422.,                              MA004100
     M 458.,454.,451.,447.,445.,442.,439./                              MA004200
CC  VERT COORD OF RECEPTORS FOLLOW.                                     MA004300
      DATA RVER/68.,75.,83.,92.,100.,108.,117.,                         MA004400
     A 67.,73.,82.,90.,97.,103.,110.,                                   MA004500
     B 65.,72.,77.,83.,88.,93.,98.,                                     MA004600
     C 63.,66.,70.,72.,75.,78.,82.,7*60.,                               MA004700
     D 57.,53.,50.,48.,45.,42.,38.,                                     MA004800
     E 55.,48.,43.,37.,32.,27.,22.,                                     MA004900
     F 53.,47.,38.,30.,23.,17.,10.,                                     MA005000
     G 52.,45.,37.,28.,20.,12.,3.,                                      MA005100
     H 55.,47.,38.,30.,23.,17.,10.,                                     MA005200
     I 53.,48.,43.,37.,32.,27.,22.,                                     MA005300
     J 57.,53.,50.,48.,45.,42.,38.,                                     MA005400
     K 7*60.,63.,66.,70.,72.,75.,78.,82.,                               MA005500
     L 67.,72.,77.,83.,88.,93.,98.,                                     MA005600
     M 65.,73.,82.,90.,97.,103.,110./                                   MA005700
CC  A,B,C ARE FACTORS FOR COMPUTING SIGZ.                               MA005800
      DATA A/.0010,.0476,.119,2.61,52.6,33.6,.001,.0476,.119,.187,      MA005900
     A .1345,.362,.1742,.1426,.1233,.0804,.06,.0434/, B/1.89,1.11,.915, MA006000
     B .45,.15,.14,1.89,1.11,.915,.755,.745,.55,.936,.922,.905,.881,    MA006100
     C .854,.814/,C/9.6,2.,.0,-25.5,-126.,-75.,9.6,2.,0.,-1.4,-1.1,-2.7,MA006200
     D 6*0./                                                            MA006300
  109 FORMAT(1H0,I10,7F10.5)                                            MA006400
  113 FORMAT(20A4)                                                      MA006500
      IN=5                                                              MA006600
      IREC=112                                                          MA006700
      QSOT(1)=0.                                                        MA006800
      HFCTR=0.3048                                                      MA006900
CC  MAP.NE.0 MEANS ELEV CHART WILL BE PRINTED (PROVIDED RCPTR ELEV.NE.0)MA007000
      MAP=1                                                             MA007100
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                        MA007200
CC  READ RCPTR GRND ELEV (INPUT AS ZEROS FOR FLAT PLANE ANALYSIS)       MA007300
CC  RECHT - RECEPTOR HEIGHTS, IN FT MSL FOR COMPATABILITY WITH USGS MAPSMA007400
      READ(IN,74,ERR  =3901) (RECHT(I),I=1,112)                         MA007500
   74 FORMAT(7F5.0,45X)                                                 MA007600
      SUM=0.0                                                           MA007700
CC IS3D IS INDEX FOR WRITING LAST LITERAL IN PLOTS. IS3D=1 FOR FLAT PLNEMA007800
      IS3D=7                                                            MA007900
      DO 76 I=1,112                                                     MA008000
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      SUM=SUM+RECHT(I)                                                  MA008100
   76 CONTINUE                                                          MA008200
      IF(SUM.NE.0.0) GO TO 77                                           MA008300
      IS3D=1                                                            MA008400
      MAP=0                                                             MA008500
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                        MA008600
   77 READ(IN,79,ERR=3903) P,TEMP,PRESS                                 MA008700
   79 FORMAT(3F6.0)                                                     MA008800
CC  P IS AMBIENT AIR PRESSURE(MB) USED IN CONV. CHI TO STANDARD         MA008900
CC    COND. OR TO PPM. ZERO DEFAULTS TO 960.                            MA009000
CC  TEMP IS AIR TEMP (DEG K) USED FOR PLUME RISE CALC AND FOR           MA009100
CC    CONV. CHI TO STANDARD COND. ZERO DEFAULTS TO 293.                 MA009200
CC  PRESS IS A CONTROL - IF EQ. 0, CHI IS AT AMBIENT COND.              MA009300
CC                       IF NE. 0, CHI IS AT STD. COND.                 MA009400
 1000 CONTINUE                                                          MA009500
      VFORM=1.                                                          MA009600
      AMAX=0.                                                           MA009700
      IF(MAP.EQ.2) MAP=0                                                MA009800
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                        MA009900
CC  TITLE - LITERAL FOR I.D. OF DATA THRU NEXT SC DECK.  TITLE IS OUT-  MA010000
CC        PUTTED IN ITS ENTIRETY, WITH LINE FEED AFTER COLUMN 20.       MA010100
      READ(IN,113,END=3900)(TITLE(I),I=1,20)                            MA010200
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                        MA010300
      READ(IN,73,ERR=3905)GRID,MWT,DMIX,ISOR,DUPSOR,K,IUR,ICONT,DMNI,   MA010400
     A HLIFE,ISHORT                                                     MA010500
   73 FORMAT(F5.1,F7.0,F6.0,5I3,2F4.0,I3)                               MA010600
CC  GRID - IN METERS.  EQUIV TO ONE PRINT SPACE ON OUTPUTTED PLOT.      MA010700
CC                FOR PLOT SCALE=     USE GRID=                         MA010800
CC                     1/24000              61.                         MA010900
CC                     1/62500             158.7                        MA011000
CC    PRINTER LINE SPACING MUST BE SET AT (NORMAL) 6 LINES PER INCH     MA011100
CC    TO OBTAIN EQUAL AREA MAP.                                         MA011200
CC  DMIX - MEAN MAXIMUM AFTERNOON MIXING DEPTH (METERS).                MA011300
CC  DMNI - NIGHT DMIX FOR URBAN ONLY. DMNI IS USED ONLY IN THE          MA011400
CC         URBAN CASE(M).                                               MA011500
CC  ISOR - NMBR OF SRCS TO BE READ FOR THIS RUN THRU PROGRAM.           MA011600
CC  DUPSOR =0 INDICATES THAT SOURCE PARAMETERS ARE NOT APPLICABLE TO EACMA011700
CC            TIME PERIOD. THUS, SOURCE CARDS MUST PRECEDE EACH SC() DECMA011800
CC         >0     INDICATES THAT ONLY ONE SET OF (N=ISOR) SOURCE CARDS  MA011900
CC            IS NEEDED FOR ALL THE SC DECKS.                           MA012000
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CC  MWT=0 FOR UG/M3.                                                    MA012100
CC  =MOLECULAR WEIGHT OF GAS WHEN UNITS OF PPM ARE DESIRED(G/MOLE).     MA012200
CC  PROGRAM CONVERTS TO PPM VIA FACTOR 8.31E+04*TEMP/(MWT*P).           MA012300
CC          TEMP - AMBIENT TEMP. (DEG A).                               MA012400
CC          MWT - MOLECULAR WT OF GAS.                                  MA012500
CC          P - AMBIENT PRESSURE (MILLIBARS)                            MA012600
CC K - OUTPUT MACHINE DESIGNATOR  ... 6 FOR 360 PRINTER.                MA012700
CC IUR = 1 FOR URBAN                                                    MA012800
CC     = 2 FOR RURAL                                                    MA012900
CC ICONT = 0 OUTPUTS ONLY SUM OF CHI FOR ALL SOURCES                    MA013000
CC       = 1 OUTPUTS IMPACT OF INDIVIDUAL SOURCES, & SUM.               MA013100
CC       = 2 OUTPUTS ONLY THE IMPACT OF INDIVID SOURCES                 MA013200
CC HLIFE - HALF LIFE OF POLLUTANT (HOURS). DEFAULT VALUE IS INFINITE.   MA013300
CC ISHORT = 0 FOR LONGTERM CHI.                                         MA013400
CC        = 1 FOR 24-HR CHI, BY ASSUMING THE SC CONDTN EXISTS FOR 6 OF TMA013500
CC              24 HRS.  A SPECIAL 24-HR SC DECK IS RQRD. (ISHORT=      MA013600
CC              ISHORT+1  INTERNALLY TO FACILITATE INDEXING FOR WRITE)  MA013700
      ISHORT=ISHORT+1                                                   MA013800
      IF(MWT.EQ.1000000.)WRITE(K,3119)                                  MA013900
 3119 FORMAT(' VALLEY DIAGNOSTIC. CHECK MWT VALUE OF 1000000')          MA014000
      IF(IUR.EQ.1.OR.IUR.EQ.2) GO TO 3122                               MA014100
       WRITE(K,3121)IUR                                                 MA014200
 3121 FORMAT('  IUR HAS ILLEGAL VALUE OF',I5,', SO TERMINATE RUN.')     MA014300
       GO TO 3900                                                       MA014400
 3122 IF(DMNI.EQ.0.) DMNI=100.                                          MA014500
      IF(QSOT(1).EQ.0.) GO TO 3111                                      MA014600
      IF(DUPSOR.NE.0.) GO TO 3112                                       MA014700
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                        MA014800
 3111 READ(IN,106,ERR=3907)(INAME(6*IL-5),INAME(6*IL-4),INAME(6*IL-3),  MA014900
     AINAME(6*IL-2),INAME(6*IL-1),INAME(6*IL),QSOT(IL),HST(IL),TS(IL),  MA015000
     BVS(IL),D(IL),VF(IL),SHOT(IL),SVET(IL),SORHT(IL),                  MA015100
     C WT(IL),GT(IL),IL=1,ISOR)                                         MA015200
  106 FORMAT(6A4/11F7.0)                                                MA015300
CC  INAME - LITERAL I.D. OF EMISSION SOURCES.  PRINTED IN OUTPUT.       MA015400
CC  QSOT - EMISSION RATE (GM/SEC).                                      MA015500
CC  HST - PHYSICAL HEIGHT OF STACK. (METERS)                            MA015600
CC  TS - EFFLUENT TEMPERATURE (DEG K)       TS,VS,D, & VF CAN BE        MA015700
CC  VS - EFFLUENT VELOCITY (MPS)            BLANK WHEN GT > 0.          MA015800
CC  D  - STACK DIAMETER (M)                                             MA015900
CC  VF - VOLUMETRIC FLOW RATE (CU M PER SEC).  COMPUTED INTERNALLY IF   MA016000
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CC     ENTERED AS ZERO, AND VS AND D ARE GIVEN.                          MA016100
CC   SHOT - HORIZ COORD OF SOURCE.  460.0 FOR CENTER OF NETWORK.         MA016200
CC   SVET - VERT COORD OF SOURCE.  60.0 FOR CENTER OF RADIAL NETWORK.    MA016300
CC     EACH UNIT OF THE COORDINATES IS EQUIVALENT TO THE LENGTH OF 'GRID'MA016400
CC   COORDINATES FOR AREA SOURCE ARE AT THE LOWER LEFT-HAND CRNR OF AREA.MA016500
CC       THIS IS THE SOUTHWEST CORNER.                                   MA016600
CC   SORHT - GRND ELEV AT SOURCE (FEET.)                                 MA016700
CC   WT - WIDTH OF SQUARE AREA SOURCE (M).  ZERO FOR POINT SOURCES.      MA016800
CC   GT - FIXED PLUME RISE (M). UNCHANGED THRUOUT CALCULATIONS, EXCEPT   MA016900
CC     FOR TERRAIN ELEVATION EFFECTS.  BRIGGS IS CALCULATED ONLY IF GT=0.MA017000
CC   PLUME RISE IS CALCULATED OR USER ASSIGNED FOR ALL SOURCES.          MA017100
 3112 CONTINUE                                                           MA017200
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                         MA017300
CC   READ IN CLASS-AVERAGE WIND SPEEDS (MPS)                             MA017400
      READ(IN,7,ERR=3909)(WSA(I),I=1,6)                                  MA017500
    7 FORMAT(6F10.6)                                                     MA017600
      IF(WSA(1).GT.99.) GO TO 3900                                       MA017700
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                         MA017800
      READ(IN,2)SCFMT                                                    MA017900
    2 FORMAT(18A4)                                                       MA018000
CC   SCFMT IS FORTRAN FORMAT FOR SC DECK.                                MA018100
CC ###### EXAMPLE  (8X,F5.0,F5.0,F5.0,F5.0,F5.0,F5.0,42X) OR (6F8.0)    MA018200
CC <<<<<<<<<<  DATA IN >>>>>>>>>>                                         MA018300
      READ(IN,SCFMT,ERR=3911)(((SC(M,N,J),J=1,6),N=1,16),M=1,6)          MA018400
CC   SC IS STABILITY,DIRECTION, SPEED ROSE DATA I.E., STAR DECK.         MA018500
CC   FOR LONG-TERM SC DECK, FREQUENCIES NORMALLY TOTAL ABOUT 1.00 .      MA018600
CC   SUM THE STAR FREQUENCIES FOR PRINTOUT.                              MA018700
      STARFR =0.0                                                        MA018800
      DO 3313 J=1,6                                                      MA018900
      DO 3313 N=1,16                                                     MA019000
      DO 3313 M=1,6                                                      MA019100
      STARFR =STARFR +SC(M,N,J)                                          MA019200
 3313 CONTINUE                                                           MA019300
CC   LIST STABILITY, DIR, SPD FREQUENCIES.                               MA019400
      WRITE(K,3116)(TITLE(I),I=1,5)                                      MA019500
 3116 FORMAT('1'/////20X,5A4)                                            MA019600
      WRITE(K,3117)(WSA(J),J=1,6)                                        MA019700
 3117 FORMAT(//T13,'SPD(MPS)',2X,6(F6.3,2X)/' STABILITY   WIND DIR')     MA019800
      DO 3120 M=1,6                                                      MA019900
      WRITE(K,3118) (STAB(M),DIR(N),(SC(M,N,J),J=1,6),N=1,16)            MA020000
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 3118 FORMAT('0',(T4,A4,T14,A4,T21,6F8.4))                              MA020100
 3120 CONTINUE                                                          MA020200
CC  S(M) IS IMPACT OF ALL SOURCES AT RCPTR M.                           MA020300
      DO 1110 M=1,112                                                   MA020400
 1110 S(M)=0.0                                                          MA020500
CC  CALCULATE ALWT(PPM OR UG/M3), AND STP(STD OR AMBIENT COND.).        MA020600
      IF(MWT.NE.0) GO TO 3220                                           MA020700
CC  CHI TO BE IN UG/M3.                                                 MA020800
      ALWT=1000000.                                                     MA020900
      IF(PRESS.EQ.0.) GO TO 3225                                        MA021000
CC  UG/M3 TO BE AT STD. COND.                                           MA021100
      IF(P.EQ.0.) P=960.                                                MA021200
      PRESS=P                                                           MA021300
      STP=1013.2*TEMP/(PRESS*298.)                                      MA021400
      GO TO 3230                                                        MA021500
CC  CHI TO BE IN PPM.                                                   MA021600
 3220 IF(P.EQ.0.) P=960.                                                MA021700
      IF(TEMP.EQ.0.)TEMP=293.                                           MA021800
      ALWT=8.31E04*TEMP/(MWT*P)                                         MA021900
 3225 STP=1.0                                                           MA022000
CC LOOP ON SOURCE                                                       MA022100
 3230 DO 97 IL=1,ISOR                                                   MA022200
      VMAX=0.                                                           MA022300
      BRIGUN(IL)=1.E 10                                                 MA022400
      BRIGE(IL)=1.E 10                                                  MA022500
      BRIGF(IL)=1.E 10                                                  MA022600
      NSOR=IL                                                           MA022700
CC  COMPUTE COORD OF CENTER OF SOURCE, POINT OR AREA.                   MA022800
      SHOR=SHOT(IL)+WT(IL)/(2*GRID)                                     MA022900
      SVER=SVET(IL)+WT(IL)/(2*GRID)                                     MA023000
      HS=HST(IL)                                                        MA023100
      QSO=QSOT(IL)                                                      MA023200
CC QSO IS QRTRD FOR SHORT TERM TO CONVERT 6-HR MEAN TO 24-HR MEAN.      MA023300
CC  ASSUMES STEADY STATE FOR 6 HOURS.                                   MA023400
      IF(ISHORT.EQ.2) QSO=QSOT(IL)/4.0                                  MA023500
      G=GT(IL)                                                          MA023600
      W=WT(IL)                                                          MA023700
CC  SET FLAG ONCE FOR EACH SOURCE, TO SKIP BRIGGS WHEN EFFLUENT CHARACT-MA023800
CC    ERISTICS ARE NOT GIVEN BY USER.  PRINT WARNING.  OR, WHEN FIXED   MA023900
CC    DELTA H IS INPUT.                                                 MA024000
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      IZBRIG=1                                                          MA024100
      IF(G.GT.0.0)GO TO 499                                             MA024200
      TOTAL=VF(IL)+VS(IL)+D(IL)                                         MA024300
      IF(TOTAL.GT.0.0.AND.TS(IL).GE.TEMP) GO TO 500                     MA024400
      BRIGUN(IL)=0.0                                                    MA024500
      BRIGE(IL)=0.0                                                     MA024600
      BRIGF(IL)=0.0                                                     MA024700
      MMM=6*(IL-1)                                                      MA024800
      WRITE(K,498)NSOR,(INAME(MMM+MM),MM=1,6)                           MA024900
  498 FORMAT('1'////////////////T45,'WARNING -- RE SOURCE',I4,', ',6A4/  MA025000
     A 45X,'PLUME RISE FACTORS SET TO 0.0 BECAUSE'/45X,'EFFLUENT FACTORSMA025100
     B ARE NOT SPECIFIED BY USER.')                                     MA025200
  499 IZBRIG=0                                                          MA025300
CC  LOOP ON RECEPTOR                                                    MA025400
  500 DO 115 M=1,IREC                                                   MA025500
      ISBRIG=1                                                          MA025600
CC  V(M) IS IMPACT OF SOURCE IL ON RCPTR M.                             MA025700
      V(M)=0.0                                                          MA025800
      NDIR1=1                                                           MA025900
      NDIR2=16                                                          MA026000
      IF(W.GT.0.0) GO TO 510                                            MA026100
CC  LIMIT APPLICABLE WIND SECTORS TO TWO FOR POINT SOURCES(VIA IPP)     MA026200
      XDIFF=SHOT(IL)-RHOR(M)                                            MA026300
      YDIFF=SVET(IL)-RVER(M)                                            MA026400
CC  PLACE LOWER LIMIT ON PT-SRC/RCPTR DISTANCE(20M).                    MA026500
      SRDIS=GRID*SQRT(XDIFF**2+YDIFF**2)                                MA026600
      IF(SRDIS.LT.20.)GO TO 115                                         MA026700
      NDIR1=IFIX(ATAN2(XDIFF,YDIFF)/0.3927)+1                           MA026800
      IF(XDIFF.LT.0.0)NDIR1=NDIR1+15                                    MA026900
      NDIR2=NDIR1 + 1                                                   MA027000
CC  LOOP ON WIND DIRECTION                                              MA027100
  510 DO 96 ND=NDIR1,NDIR2                                              MA027200
      N=ND                                                              MA027300
      IF(N.EQ.17) N=1                                                   MA027400
CC  LOOP ON STABILITY                                                   MA027500
      DO 98 LOOK=1,7                                                    MA027600
CC  LOOP ON WIND SPEED                                                  MA027700
      DO 99 J=1,6                                                       MA027800
      H=G+HS                                                            MA027900
CC  SKIP TO 9 WHEN APPLICABLE DIR AND STBLTY VRBLS ARE ALREADY COMPUTED.MA028000
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      IF(J.GT.1) GO TO 9                                                MA028100
CC  SKIP TO 132 WHEN APPLICABLE DIR VRBLS ARE ALREADY COMPUTED.         MA028200
      IF(LOOK.GT.1) GO TO 132                                           MA028300
CC  ACTUAL START OF CALCULATIONS BASED ON ITERATION OF WIND DIRECTION.  MA028400
      BB = N                                                            MA028500
      RAD = (BB-1.0) * .3927                                            MA028600
      BSIN=SIN (RAD)                                                    MA028700
      BCOS=COS (RAD)                                                    MA028800
CC  XP IS DISTANCE (VECTOR WITH SIGN) FROM RCPTR TO ACTUAL SRC.         MA028900
      XP=GRID*((SVER-RVER(M))*BCOS+(SHOR-RHOR(M))*BSIN)                 MA029000
CC  WHEN RCPTR TO PT SRC DIST IS SMALL, GO TO NEXT RCPTR.               MA029100
      IF(XP.LT.10.AND.W.EQ.0.0)GO TO 115                                MA029200
CC  X IS DWNWND DIST FROM PT SRC OR VIRTUAL PT SRC TO RCPTR.            MA029300
      X = XP + W/.393                                                   MA029400
CC  IF RCPTR IS UPWIND OF SOURCE, GO TO NEXT DIR.                       MA029500
   18 IF(XP+W/2.)96,96,4                                                MA029600
CC  Y IS CROSSWIND DISTANCE, RECPTR TO SECTOR CENTERLINE AT DSTNC X.    MA029700
    4 Y=ABS(GRID*((SVER-RVER(M))*BSIN-(SHOR-RHOR(M))*BCOS))             MA029800
CC  CX IS SECTOR WIDTH AT DSTNC X.                                      MA029900
      CX = .393 * X                                                     MA030000
CC  IS RECPTR AFFECTED BY SECTOR.                                       MA030100
CC  ARG 2 IS FRACTION OF SECTOR WINDS AFFECTING RECPTR FOR GIVEN SOURCE.MA030200
      IF(CX-Y) 96,96,36                                                 MA030300
   36 ARG2 = (CX-Y)/CX                                                  MA030400
      IF(W.GT.0.0) GO TO 121                                            MA030500
      IF(SHOR.NE.460..OR.SVER.NE.60.) GO TO 13                          MA030600
CC  IF PT SRC AT CENTR (460,60) ARG2 SAYS WHICH LONE SECTOR IS REQUIRED.MA030700
CC    DELETE 2 STMNTS ABOVE AND 3 BELOW IF RCPTRS OTHER THAN ON THE 16  MA030800
CC    RADIALS ARE ADDED AS MODIF., AND ADD 'IF(W.EQ.0.)GOTO13' AT 36+001MA030900
      IF(ARG2.LT.0.5) GO TO 96                                          MA031000
      ARG2=1.0                                                          MA031100
      GO TO 13                                                          MA031200
  121 IF((W/2.)-ABS(XP))122,122,1225                                    MA031300
  122 IF(W-.393*XP)13,13,123                                            MA031400
CC  Q IS FRACTION OF AREA SRC WHICH AFFECTS RCPTR.  FOR PT SRC, Q=1.    MA031500
CC  RECEPTOR INSIDE SOURCE AREA.                                        MA031600
 1225 Q=(.1965*(X-2.04*W)**2)/W**2                                      MA031700
      XP =.707*(XP+W/2.)                                                MA031800
      X=2.0*XP                                                          MA031900
CC  FOR AREA SRC LIMIT RCPTR-TO VIRTUAL PT SRC DIST TO MIN OF 100 M TO  MA032000
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CC      AVOID ARITHMETIC BLOWUP.                                          MA032100
      IF(X.LT.100.) X=100.                                                MA032200
CC   IF AREA SRC DOES NOT AFFECT RCPTR, GO TO NEXT DIRECTION.             MA032300
      IF(Y-(W/2.+0.5))131,131,96                                          MA032400
CC  RECEPTOR OUTSIDE SOURCE AREA, BUT 'NEAR' IT.                          MA032500
  123 Q=(.393*X-W)/W                                                      MA032600
      XP=SQRT((XP*XP)+(W*W/4))                                            MA032700
      X=2.*XP                                                             MA032800
      IF(X.LT.100.) X=100.                                                MA032900
      IF(Y-(W/2.+.393*X)) 131,131,96                                      MA033000
CC  CONTRIBUTION OF POINT SOURCE OR DISTANT AREA SOURCE IS Q=1.           MA033100
   13 Q=1.                                                                MA033200
CC  PLUME RISE FCTRS ARE COMPUTED ONCE PER SOURCE-RECEPTOR FOR            MA033300
CC  NONSTABLE.                                                            MA033400
  131 IF((ISBRIG+IZBRIG).LT.2)GO TO 132                                   MA033500
      ISBRIG=0                                                            MA033600
      XXP=XP/1000.                                                        MA033700
      IT=4                                                                MA033800
      CALL BEH072 (DUM1,DUM2,DUM3,DUM4,DUM5,DUM6,BRIG,HST(IL),            MA033900
     * TS(IL),VS(IL),D(IL),VF(IL),IT,1.0,XXP,DTDZ(IT),TEMP,P)             MA034000
      BRIGUN(IL)=BRIG                                                     MA034100
  132 GO TO (1310,1311),IUR                                               MA034200
CC                                                                        MA034300
CC - LOOK                    1  2  3    4        5    6          7       MA034400
CC                                                                        MA034500
CC - URB. STAB. (STMNT 1310)  A  B  C  D(DAY)   D(NGT)  E     EXIT LOOPMA034600
CC                                                                        MA034700
CC - RUR. STAB. (STMNT 1311)  A  B  C  D(DAY)  D(NGT)  E          F      MA034800
CC  INITIALIZE STABILITY-DEPENDENT FACTORS AND FLAGS.                     MA034900
CC                                                                        MA035000
 1310 GO TO (362,363,364,367,366,365,98),LOOK                             MA035100
 1311 GO TO (362,363,364,367,368,369,370),LOOK                            MA035200
  362 DM=1.5*DMIX                                                         MA035300
      FREQ=1.                                                             MA035400
      L=1                                                                 MA035500
      LLL=1                                                               MA035600
      GO TO 22                                                            MA035700
  363 DM=DMIX                                                             MA035800
      FREQ=1.                                                             MA035900
      L=2                                                                 MA036000
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      GO TO 22                                                          MA036100
  364 DM=DMIX                                                           MA036200
      FREQ=1.                                                           MA036300
      L=3                                                               MA036400
      GO TO 22                                                          MA036500
  365 DM=DMNI                                                           MA036600
      FREQ=1.                                                           MA036700
      L=5                                                               MA036800
      GO TO 22                                                          MA036900
  366 IF(ISHORT.EQ.2) GO TO 98                                          MA037000
      DM=(DMIX+DMNI)/2.                                                 MA037100
      FREQ=.40                                                          MA037200
      L=4                                                               MA037300
      GO TO 22                                                          MA037400
  367 DM=DMIX                                                           MA037500
      FREQ=.60                                                          MA037600
      IF(ISHORT.EQ.2) FREQ=1.0                                          MA037700
      L=4                                                               MA037800
      GO TO 22                                                          MA037900
  368 IF(ISHORT.EQ.2) GO TO 98                                          MA038000
      DM=DMIX/2.                                                        MA038100
      FREQ=.40                                                          MA038200
      L=4                                                               MA038300
      GO TO 22                                                          MA038400
  369 FREQ=1.                                                           MA038500
      DM=10000.                                                         MA038600
      L=5                                                               MA038700
      LLL=2                                                             MA038800
      GO TO 22                                                          MA038900
  370 FREQ=1.                                                           MA039000
      DM=10000.                                                         MA039100
      L=6                                                               MA039200
   22 KKK=L                                                             MA039300
CC  REVERT TO ORIGINAL DMIX WHEN SHORT-TERM AND NONSTABLE.              MA039400
      IF(ISHORT.EQ.2.AND.LLL.EQ.1) DM=DMIX                              MA039500
      IF(IUR.EQ.1.AND.LOOK.GE.6)L=4                                     MA039600
CC  COMPUTE SIGMA Z AS F(DISTANCE,STABILITY).                           MA039700
      LL=L                                                              MA039800
      IF(XP.LT.1000.)  LL=LL+6                                          MA039900
      IF(XP.LT.100.) LL=LL+6                                            MA040000
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      SIGI=50.-HS                                                       MA040100
      IF(LLL.GT.1.OR.HS.GT.50..OR.SIGI.LT.1.0) SIGI=0.0                 MA040200
CC  SIGMA IS INCREASED FOR ALL LOW-LEVEL SRCS XCPT FOR RUR-URB STABLE.  MA040300
      IF(SIGI.GT.30.) SIGI=30.                                          MA040400
      SIGZ=SQRT((A(LL)*ABS(XP)**B(LL)+C(LL))**2 + SIGI**2)              MA040500
CC  ACTUAL START OF CALCULATIONS BASED ON ITERATION OF SPEED CLASS      MA040600
    9 F=SC(KKK,N,J)                                                     MA040700
      IF(KKK.EQ.5.AND.IUR.EQ.1) F=SC(5,N,J) + SC(6,N,J)                 MA040800
      WS=WSA(J)                                                         MA040900
      IF(F.EQ.0.0.OR.WS.EQ.0.0) GO TO 99                                MA041000
      WINDSP=WS                                                         MA041100
      IF(G.NE.0.0) GO TO 15                                             MA041200
      IF(L.LT.5) GO TO 14                                               MA041300
CC  BEH072 RETURNS DELTA H (BRIG) FOR STABLE E OR F, FOR EACH WIND SPD. MA041400
CC    FOR WIND SPD = WS.                                                MA041500
      CALL BEH072(DUM1,DUM2,DUM3,DUM4,DUM5,DUM6,BRIG,HST(IL),           MA041600
     * TS(IL),VS(IL),D(IL),VF(IL),L,WS,XXP,DTDZ(L),TEMP,P)              MA041700
      IF(L.EQ.5) BRIGE(IL)=BRIG                                         MA041800
      IF(L.EQ.6) BRIGF(IL)=BRIG                                         MA041900
      H=HS+BRIG                                                         MA042000
      GO TO 15                                                          MA042100
   14 H=HS+BRIGUN(IL)/WS                                                MA042200
   15 CONTINUE                                                          MA042300
CC  FOR ALL SHORT TERM NONSTABLE, LIMIT H TO DM.  RECALL FOR SHORT-TERM MA042400
CC    RURAL, DM(STBL) >> H.                                             MA042500
      IF(ISHORT.EQ.2.AND.LLL.EQ.1.AND.H.GT.DM) H=DM                     MA042600
CC  GO TO NEXT SPEED  IF PLUME ABOVE LID.                               MA042700
      IF(H.GT.DM) GO TO 99                                              MA042800
      IF(LLL.EQ.1.OR.SUM.EQ.0.0.OR.H.LE.10.0) GO TO 3488                MA042900
CC  THRU 3490, ESTABLSH HT OF PLUME CNTRLNE ABOVE RCTPTR.               MA043000
CC  STABLE                                                              MA043100
      DELEV=(SORHT(IL)-RECHT(M))*HFCTR                                  MA043200
CC  PLHT IS UNADJUSTED PLUME HT AT RECEPTOR.                            MA043300
 3410 PLHT=H+DELEV                                                      MA043400
 3420 IF(PLHT.GT.10.0) GO TO 3491                                       MA043500
CC  ATTENUATE CONC TO ZERO AT 400M ABOVE ORIG PLUME CNTRLINE.           MA043600
      IF(PLHT.LT.-400.0) GO TO 99                                       MA043700
      WS=WS*(400./(401.+PLHT))                                          MA043800
CC  SET MIN PLUME HT AT 10M ABOVE RCPTR FOR STABLE ONLY, IF TERRAIN USEDMA043900
      IF(PLHT.LT.10.0) PLHT=10.                                         MA044000
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CC  PLHT IS NOW THE ADJUSTED PLUME HEIGHT AT THE RECEPTOR.                MA044100
      GO TO 3491                                                          MA044200
CC  UNSTABLE                                                              MA044300
 3488 PLHT=H                                                              MA044400
 3491 H=PLHT                                                              MA044500
      ARG1=(-.5*H*H)/(SIGZ*SIGZ)                                          MA044600
CC  ARG1.LT.-40. ((I.E., EXP(ARG1).LT.4.0E-16)) IS INSIGNIFICANT.         MA044700
      IF(ARG1.LT.-40.) GO TO 99                                           MA044800
      ARG1=EXP(ARG1)                                                      MA044900
      ARG1FR=0.0001*ARG1                                                  MA045000
CC  RATHER THAN INTERPOLATING FOR LID REFLECTION AS IN C9M3D, USE         MA045100
CC  TURNER (WADE) EQN 5.14 FOR HOMOGENEOUS MIX, AND HALES-BIERLY-HEWSON   MA045200
CC  EQN (TURNER EQN 5.8, BUT FOR SECTOR) FOR SHORTER DISTANCES.           MA045300
      XD=X                                                                MA045400
      AJ=0.                                                               MA045500
      IF(SIGZ.GT.(2.*DM))GO TO 75                                         MA045600
CC  NO INVERSION ALOFT FOR STABLE (GO TO 68)                              MA045700
      IF(L.GE.5)GO TO 68                                                  MA045800
CC  NONSTABLE METEO CONDITIONS. HALES-BIERLY-HEWSON.                      MA045900
      DO 65 NJ=1,5                                                        MA046000
      DUM1=2*NJ*DM                                                        MA046100
      DUM2=EXP(-.5*((-H-DUM1)/SIGZ)**2)                                   MA046200
     A +EXP(-.5*((H-DUM1)/SIGZ)**2)                                       MA046300
      IF(DUM2.GT.ARG1FR)GO TO 65                                          MA046400
      AJ=AJ+DUM2                                                          MA046500
      GO TO 68                                                            MA046600
   65 AJ=AJ+DUM2                                                          MA046700
   68 C3=2.03*FREQ*Q*F*ARG2*(ARG1+AJ)/(WS*XD*SIGZ)                        MA046800
      GO TO 78                                                            MA046900
CC  FULLY MIXED IN VERTICAL                                               MA047000
   75 C3=2.55*FREQ*Q*F*ARG2/(DM*WS*XD)                                    MA047100
   78 CONTINUE                                                            MA047200
      C4=C3*QSO*ALWT*STP                                                  MA047300
CC        DISTANCE TO VIRTUAL SOURCE IS EXCLUDED FROM HLIFE CALCULATION.  MA047400
      IF(HLIFE.NE.0.0) C4=C4*EXP(-(XP/WINDSP)*0.693/(3600.*HLIFE))        MA047500
      V(M)=V(M)+C4                                                        MA047600
CC  V IS THE IMPACT OF SOURCE AT RECEPTOR M.                              MA047700
   99 CONTINUE                                                            MA047800
   98 CONTINUE                                                            MA047900
   96 CONTINUE                                                            MA048000
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CC  VMAX IS MAX VALUE OF ALL V'S COMPUTED FOR GIVEN SOURCE.          MA048100
      IF(V(M).LT.VMAX) GO TO 1140                                    MA048200
      VMAX=V(M)                                                      MA048300
      MAXVM=M                                                        MA048400
CC  S IS THE SUM OF IMPACTS OF ALL SOURCES AT RECEPTOR M.            MA048500
 1140 S(M)=S(M)+V(M)                                                 MA048600
      IF(S(M).LT.AMAX) GO TO 115                                     MA048700
      MAXAM=M                                                        MA048800
CC  AMAX IS MAX VALUE OF S(M) IN PLOT TO BE PRINTED.                 MA048900
      AMAX=S(M)                                                      MA049000
  115 CONTINUE                                                       MA049100
      IF(ICONT.EQ.0) GO TO 97                                        MA049200
CC  SET FLAG TO INDICATE FLOW ROUTE THRU PLOTTING SUBROUTINE.        MA049300
      NN=1                                                           MA049400
      CALL EBPLT1                                                    MA049500
   97 CONTINUE                                                       MA049600
      IF(ICONT.EQ.2) GO TO 971                                       MA049700
      NN=0                                                           MA049800
      CALL EBPLT1                                                    MA049900
  971 IF(MAP.NE.1) GO TO 1000                                        MA050000
CC  SET FLAG TO INDICATE FLOW ROUTE THROUGH PLOTTING SUBROUTINE.     MA050100
      NN=2                                                           MA050200
      CALL EBPLT1                                                    MA050300
      GO TO 1000                                                     MA050400
 3901 WRITE(6,3902) I                                                MA050500
 3902 FORMAT('0<<< ERROR IN READ RCPTR HTS.  CARD',I4)               MA050600
      GO TO 3915                                                     MA050700
 3903 WRITE(6,3904)                                                  MA050800
 3904 FORMAT('0<<< ERROR IN READ P,TEMP')                            MA050900
      GO TO 3915                                                     MA051000
 3905 WRITE(6,3906)                                                  MA051100
 3906 FORMAT('0<<< ERROR IN READ GRID')                              MA051200
      GO TO 3915                                                     MA051300
 3907 WRITE(6,3908) IL                                               MA051400
 3908 FORMAT('0<<< ERROR IN READ SOURCE, CARD',I4)                   MA051500
      GO TO 3915                                                     MA051600
 3909 WRITE(6,3910)                                                  MA051700
 3910 FORMAT('0<<< ERROR IN READ WSA')                               MA051800
      GO TO 3915                                                     MA051900
 3911 WRITE(6,3912) M,N,J                                            MA052000
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 3912 FORMAT('0<<< ERROR IN READ SC, STABILITY',I2,'DIR',I3,'SPD',I2)   MA052100
 3915 WRITE(6,3916)                                                    MA052200
 3916 FORMAT('0<<< CHECK OVERALL ORDER OF DATA CARDS BEFORE CHECKING'/  MA052300
     A'       DATA ON CARD REFERRED TO ABOVE'/'      EXECUTION HAS BEEN MA052400
     BTERMINATED DUE TO READ FORMAT ERROR (NOT BECAUSE OF DATA CHECK)') MA052500
3900  CONTINUE                                                         MA052600
      CALL EXIT                                                        MA052700
      END                                                              MA052800
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      SUBROUTINE EBPLT1                                                 PL000100
CC  EBPLT1 IS GEARED TO WRITE OUTPUT PLOTS OF CONCENTRATION AND HEIGHT  PL000200
CC    DIFFERENCES.  IT IS CALLED WITH FLAG NN SET TO ONE OF 3 VALUES....PL000300
CC      0 - WRITE THE SUM OF ALL CONTRIBUTIONS, AND WRITE A HEIGHT      PL000400
CC        DIFFERENCE BEFORE RETURN IF IMAP.EQ.1.                        PL000500
CC      1 - WRITE THE CONTRIBUTION OF ONLY ONE SOURCE.                  PL000600
CC      2 - WRITE ONLY THE HEIGHT DIFFERENCE MAP.                       PL000700
      DIMENSION SHOT(50),SVET(50),HST(50),QSOT(50),GT(50),WT(50)        PL000800
      DIMENSION TS(50),VS(50),D(50),VF(50),RECHT(112)                   PL000900
      DIMENSION VERBL(12),URBRUR(2),THREED(12)                          PL001000
      DIMENSION INAME(300),SORHT(50),TERM(2),SCALE(6),TITLE(20),WSA(6)  PL001100
      DIMENSION S(112),V(112),BRIGUN(50),BRIGE(50),BRIGF(50)            PL001200
      COMMON MAXVM,VMAX,V,ICONT,MAXAM,AMAX,S,GRID,NSOR,INAME,TITLE,     PL001300
     A HLIFE,STP,VXDIR,PAGE,ALWT,TFORM,IS3D,G,BRIGUN,TS,D,VS,VF,SORHT,  PL001400
     B SHOT,SVET,HS,QSOT,BRIGE,BRIGF,DMIX,DMNI,STARFR,W,WSA,TEMP,IREC,  PL001500
     C ISOR,GT,HST,WT,VFORM,AXDIR,IUR,ISHORT,NN,MAP,RECHT,HFCTR,K,P,MWT PL001600
      DATA VERBL/'SUM ','CONC',' DUE',' TO ','ALL ','SRCS',             PL001700
     A           'GROU','ND E','LEV ','DIFF','EREN','CES.'/             PL001800
      DATA URBRUR/'URBN','RURL'/,TERM/'LONG','SHRT'/                    PL001900
      DATA THREED/'FLAT','-PLA','NE C','ONCE','PT. ','    ',            PL002000
     A            'SLOP','ING ','TERR','AIN ','CONC','EPT.'/            PL002100
  810 FORMAT( '1',T39,F5.1,T56,'/--',T60,F5.1,T81,F5.1/T34,'RELOCATE 2/3PL002200
     A INCH UP-/',T60,F5.1///T42,F5.1,                                  PL002300
     B T78,F5.1//T60,F5.1/T22,F5.1,T98,F5.1/T45,F5.1,T76,F5.1//         PL002400
     C T27,F5.1,T93,F5.1,'      VIA VALLEY V1'/T60,F5.1,T102,6A4/       PL002500
     D T47,F5.1,T73,F5.1/T32,F5.1,T88,F5.1/                             PL002600
     E T100,5A4/T65,15A4/T37,F5.1,T60,F5.1,T83,F5.1/T8,F5.1,T51,F5.1,T69PL002700
     F ,F5.1,T112,F5.1)                                                 PL002800
 8102 FORMAT                                                            PL002900
     A(T17,F5.1,T103,F5.1/T43,F5.1,T77,F5.1/T24,F5.1,T60,F5.1,T96,F5.1/ PL003000
     B T54,F5.1,T66,F5.1/T32,F5.1,T48,F5.1,T72,F5.1,T88,F5.1/T37,F5.1,  PL003100
     C T83,F5.1/T60,F5.1/T44,F5.1,4X,F5.1,5X,F5.1,8X,F5.1/              PL003200
     D T58,    F5.1,T65   ,F5.1 /T52,F5.1,                              PL003300
     E T59,9('*'),T68,F5.1,T99,'MULTIPLY PRINTED VALUES BY ')           PL003400
 103  FORMAT(T59,'* COORD *',T99,1PE8.1,' TO GET CONC. IN UG/M3')       PL003500
 104  FORMAT(T59,'* COORD *',T99,1PE8.1,' TO GET CONC. IN PPM')         PL003600
  811 FORMAT(T4,7(F5.1,3X), T59,'*  _._  *',T68,6(F5.1,3X),F5.1/        PL003700
     A T59,'* 460,60*',T76,'SOR ELEV  COORDX  COORDY  STK HT  Q(GM/SEC) PL003800
     B FIXD DH')                                                        PL003900
  812 FORMAT(T52,F5.1,T59,9('*'),T68,F5.1,T76,F6.0,'FT',F8.2,F8.2,F7.0, PL004000
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      A 'M-',1PE10.4,4X,0PF6.0/ T58,F5.1,T65    ,F5.1/T44,F5.1,T53,F5.1,  PL004100
      B T63,F5.1,T76,F5.1,T84,'BRIG.E  BRIG.F  DMIX    DMNI  STAR F WIDTHPL004200
      C'/T60,F5.1,T84,F6.0,F8.0,F7.0,F8.0,F7.2,F7.0/T37,F5.1,T83,F5.1/   PL004300
      D T32,F5.1,T48,F5.1,T72,F5.1,T88,F5.1,12X,'BRIGUN P(MB)  MWT'/     PL004400
      E T54, F5.1,T66,F5.1,T103,F8.0,F6.0,F6.1/T24,F5.1,T60,F5.1,        PL004500
      F T96,F5.1/T43,F5.1,'  VV MEAN WIND SPDS(MPS) VV',T77,F5.1,/       PL004600
      G T17,F5.1,T34,6F9.5,T103,F5.1//T8,F5.1,                           PL004700
      H T51,F5.1,T69,F5.1,T112,F5.1/T37,F5.1,T60,F5.1,T83,F5.1/          PL004800
      I T97,'AIR T  GAS T   DIAM  GAS V  FLOW'/T95,2F7.0,2F7.1,F6.1/     PL004900
      J T32,F5.1,T88,F5.1/T47,F5.1,T73,F5.1/T60,F5.1/T27,F5.1,T93,       PL005000
      K F5.1//T45,F5.1,T75,F5.1/T22,F5.1,T98,F5.1/T60,F5.1//             PL005100
      L T42,F5.1,T78,F5.1/T56,'0 KM',3X,F7.3,5('KM ',F7.3),'KM'/         PL005200
      M T56,6(']....+....'),']'/T60,F5.1,                                PL005300
      N T68,'__RELOCATE 2/3 INCH DOWN',/T5,A4,', ',A4,'-TERM MODE.',     PL005400
      O T39,F5.1,T60,F5.1,'--/',T81,F5.1,T100,6A4)                       PL005500
       MM=NN+1                                                           PL005600
       GO TO(971,10,3800),MM                                             PL005700
   10  AXVM=(MAXVM+6)/7                                                  PL005800
       VXDIR=(AXVM-1.)*22.5                                              PL005900
       IF(VMAX.GE.100000.)   VFORM=0.001                                 PL006000
       IF(VMAX.LT.100000.) VFORM=0.01                                    PL006100
       IF(VMAX.LT.10000.) VFORM=0.1                                      PL006200
       IF(VMAX.LT.1000.) VFORM=1.                                        PL006300
       IF(VMAX.LT.100.) VFORM=10.                                        PL006400
       IF(VMAX.LT.10.)VFORM=100.                                         PL006500
       IF(VMAX.LT.1.) VFORM=1000.                                        PL006600
       IF(VMAX.LT.0.1) VFORM=10000.                                      PL006700
       IF(VMAX.LT.0.01) VFORM=100000.                                    PL006800
       IF(VMAX.LT.0.001) VFORM=1000000.                                  PL006900
C  VFORM AND AFORM SCALE ALL CONCENTR. VALUES.  ALL VALUES ARE SCALED    PL007000
C   BY THE SAME FACTOR ON A GIVEN PLOT SO THAT THE                       PL007100
C   MAX VALUE ON PLOT IS LEFT-JUSTIFIED IN F5.1, AND UNITS               PL007200
C   ARE PROPERLY IDENTIFIED IN OUTPUT.   THUS, THE SCALING FACTOR CAN    PL007300
CC  BE CHANGED FROM PLOT TO PLOT.                                        PL007400
       DO 835 I=1,IREC                                                   PL007500
       V(I)=V(I)*VFORM                                                   PL007600
  835  CONTINUE                                                          PL007700
       TFORM=1.0/VFORM                                                   PL007800
       PAGE=VMAX*VFORM                                                   PL007900
C  TFORM IDENTIFIES IN PRINT STMNT THE UNITS OF CHI PRINTED ON GRAPH.    PL008000
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      GO TO 1153                                                        PL008100
  971 AXAM=(MAXAM+6)/7                                                  PL008200
      AXDIR=(AXAM-1.)*22.5                                              PL008300
      IF(AMAX.GE.100000.)   AFORM=0.001                                 PL008400
      IF(AMAX.LT.100000.) AFORM=0.01                                    PL008500
      IF(AMAX.LT.10000.) AFORM=0.1                                      PL008600
      IF(AMAX.LT.1000.)  AFORM=1.0                                      PL008700
      IF(AMAX.LT.100.) AFORM=10.                                        PL008800
      IF(AMAX.LT.10.) AFORM=100.                                        PL008900
      IF(AMAX.LT.1.) AFORM=1000.                                        PL009000
      IF(AMAX.LT.0.1) AFORM=10000.                                      PL009100
      IF(AMAX.LT.0.01) AFORM=100000.                                    PL009200
      IF(AMAX.LT.0.001) AFORM=1000000.                                  PL009300
      DO 840 I=1,IREC                                                   PL009400
      S(I)=S(I)*AFORM                                                   PL009500
  840 CONTINUE                                                          PL009600
      TFORM=1.0/(AFORM)                                                 PL009700
      PAGE=AMAX*AFORM                                                   PL009800
 1153 DO 805 I=1,6                                                      PL009900
      R=I                                                               PL010000
      SCALE(I)=R*GRID* 0.01                                             PL010100
  805 CONTINUE                                                          PL010200
      IF(NN.EQ.0) GO TO 11538                                           PL010300
CC  WRITE IN MAP FORM THE EFFECTS OF AN INDIVIDUAL SOURCE.              PL010400
      I=NSOR                                                            PL010500
      WRITE(K,810) V(112),V(7),V(14),                                   PL010600
     A V(6),V(111),V(13),V(5),V(105),                                   PL010700
     B V(21),V(110),V(12),V(104),V(20),V(4), INAME(6*I -5),INAME(6*I -4)PL010800
     C ,INAME(6*I -3),INAME(6*I -2),INAME(6*I -1),INAME(6*I ),          PL010900
     D V(109),V(11),V(103),V(19),                                       PL011000
     E (TITLE(I),I=1,5),(TITLE(I),I=6,20),V(102),V(3),V(18),V(98),V(108)PL011100
     F ,V(10),V(28)                                                     PL011200
      IF(HLIFE.EQ.0.0) HLIFE=999.99                                     PL011300
      WRITE(K,803) HLIFE,STP,VXDIR,PAGE                                 PL011400
  803 FORMAT(T10,'HLIFE= ',F5.2,' HRS.  CONCTR CORRCTD TO STD COND VIA  PL011500
     AFACTOR',F6.3,'.  MAX TOWARD',F5.0,' DEG.  NORTH TOWARD TOP.  PLOT'PL011600
     B ,F8.3)                                                           PL011700
      IF(HLIFE.EQ.999.99) HLIFE=0.0                                     PL011800
      WRITE (K,8102) V(97),V(27),                                       PL011900
     A V(101),V(17),V(96),V(2),V(26),V(107),V(9),V(95),V(100),V(16),    PL012000
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```
     B V(25),V(94),V(24),V(1),V(93),V(99),V(8),V(23),V(106),V(15),      PL012100
     C V(92),V(22)                                                      PL012200
      IF(ALWT-1000000.)1141,1142,1141                                   PL012300
 1141 WRITE(K,104) TFORM                                                PL012400
      GO TO 11421                                                       PL012500
 1142 WRITE(K,103) TFORM                                                PL012600
11421 CONTINUE                                                          PL012700
      WRITE(K,811) V(91),V(90),V(89),V(88),V(87),V(86),V(85),           PL012800
     A (V(M),M=29,35)                                                   PL012900
      IIB=IS3D                                                          PL013000
      IIE=IS3D+5                                                        PL013100
      IF(G.EQ.0.0) G=1.E 10                                             PL013200
      IF(BRIGUN(NSOR).EQ.0.0) BRIGUN(NSOR)=1.E 10                       PL013300
      IF(TS(NSOR).EQ.0.0) TS(NSOR)=1.E 10                               PL013400
      IF(D(NSOR).EQ.0.0) D(NSOR)=1.E 10                                 PL013500
      IF(VS(NSOR).EQ.0.0) VS(NSOR)=1.E 10                               PL013600
      IF(VF(NSOR).EQ.0.0) VF(NSOR)=1.E 10                               PL013700
      WRITE(K,812) V(78),V(36),SORHT(NSOR),SHOT(NSOR),SVET(NSOR),HS,    PL013800
     A QSOT(NSOR),G,V(64),V(43),V(79),V(71),V(50),V(37),                PL013900
     B V(57),BRIGE (NSOR),BRIGF (NSOR),DMIX,DMNI,STARFR,W,V(80),V(38),  PL014000
     C V(81),V(72),V(44),V(39),V(65),V(51),BRIGUN(NSOR),P,MWT,V(82),    PL014100
     D V(58),V(40),V(73),V(45),V(83), (WSA(I),I=1,6), V(41),V(84),V(66),PL014200
     E V(52),V(42),V(74),V(59),V(46),TEMP,TS(NSOR),D(NSOR),VS(NSOR),    PL014300
     F VF(NSOR),V(75),V(47),V(67),V(53),V(60),V(76),V(48),              PL014400
     G V(68),V(54),V(77),V(49),V(61),V(69),V(55),(SCALE(N1),N1=1,6),    PL014500
     H V(62),URBRUR(IUR),TERM(ISHORT),V(70),V(63),V(56),(THREED(I),     PL014600
     I I=IIB,IIE)                                                       PL014700
      RETURN                                                            PL014800
CC  WRITE ALL SOURCE DATA ON ONE PAGE IF SUM OF CHI PLOT IS TO BE PRINTDPL014900
11538 DO 11537 I=1,ISOR                                                 PL015000
CC  OVERFLOW INAPPLICABLE VARIABLES FOR PRINTING.                       PL015100
      IF(GT(I).EQ.0.0) GT(I)=1.E10                                      PL015200
      IF(TS(I).EQ.0.0) TS(I)=1.E 10                                     PL015300
      IF(D(I).EQ.0.0) D(I)=1.E 10                                       PL015400
      IF(VS(I).EQ.0.0) VS(I)=1.E 10                                     PL015500
      IF(VF(I).EQ.0.0)VF(I)=1.E 10                                      PL015600
11537 CONTINUE                                                          PL015700
      WRITE(K,111)(TITLE(I),I=1,20),PAGE                                PL015800
      WRITE(K,112)                                                      PL015900
     A  (IL,INAME(6*IL-5),INAME(6*IL-4),INAME(6*IL-3),INAME(6*IL-2),    PL016000
```

```
     B INAME(6*IL-1),INAME(6*IL),SHOT(IL),SVET(IL),HST(IL),QSOT(IL),     PL016100
     C GT(IL),WT(IL),SORHT(IL),BRIGUN(IL),BRIGE(IL),BRIGF(IL),           PL016200
     D TEMP,TS(IL),D(IL),VS(IL),IL=1,ISOR)                               PL016300
 111  FORMAT('1',                                                       PL016400
     A       6X,20A4/'   SOURCE DATA.  PLOT ',F7.3 /6X,'SOURCE NAME',10XPL016500
     B ,' COORDX COORDY  STK HT  EMISS RATE  FIXD DH  SOR W  SOR H  BRIGPL016600
     CUN  BRIGE  BRIGF  AIR T  GAS T  DIAM  GAS V')                      PL016700
  112 FORMAT(     1X,I2,1X,6A4,F7.2,F7.2,F8.0,1X,1PE10.4,0PF9.0,F7.0,    PL016800
     A F7.0,F8.0,2F7.0,2X,F4.0,3X,F4.0,1X,F5.1,1X,F5.1)                  PL016900
      IVER=1                                                             PL017000
CC OVERFLOW SOURCE HT (SHT) BEFORE WRITING SUM OF ALL SOURCE CONTRIBUTNSPL017100
      SHT=1.E+20                                                         PL017200
CC OVERFLOW IRRELEVANT PRMTRS(XCPT Q) FOR WRITING SUM AND HDIFF          PL017300
11539 QSO=0.0                                                            PL017400
      DUM=1.E+20                                                         PL017500
      IB=IVER                                                            PL017600
      IE=IVER+5                                                          PL017700
CC  WRITE IN MAP FORM THE SUM OF EFFECTS OF ALL SOURCES.                 PL017800
CC  OR, IF S() ARRAY HAS BEEN LOADED WITH HT DIFFS, WRITE THEM.          PL017900
      WRITE(K,810) S(112),S(7),S(14),                                    PL018000
     A S(6),S(111),S(13),S(5),S(105),                                    PL018100
     B S(21),S(110),S(12),S(104),S(20),S(4),(VERBL(I),I=IB,IE),          PL018200
     C S(109),S(11),S(103),S(19),                                        PL018300
     D (TITLE(I),I=1,5),(TITLE(I),I=6,20),S(102),S(3),S(18),S(98),S(108)PL018400
     E ,S(10),S(28)                                                      PL018500
      IF(MAP.EQ.2) GO TO 809                                             PL018600
      IF(HLIFE.EQ.0.0) HLIFE=999.99                                      PL018700
      WRITE(K,803) HLIFE,STP,AXDIR,PAGE                                  PL018800
      IF(HLIFE.EQ.999.99) HLIFE=0.0                                      PL018900
  809 IF(MAP.EQ.2) WRITE(K,8101)                                         PL019000
 8101 FORMAT(T20,'NORTH TOWARD TOP.  (1/10)((SOURCE HT(1))-(RECPTR HT(N)PL019100
     A)), HTS IN METERS.')                                               PL019200
      WRITE (K,8102) S(97),S(27),                                        PL019300
     A S(101),S(17),S(96),S(2),S(26),S(107),S(9),S(95),S(100),S(16),     PL019400
     B S(25),S(94),S(24),S(1),S(93),S(99),S(8),S(23),S(106),S(15),       PL019500
     C S(92),S(22)                                                       PL019600
      IF(MAP.EQ.2) GO TO 11515                                           PL019700
      IF(ALWT-1000000.)1151,1152,1151                                    PL019800
 1151 WRITE(K,104) TFORM                                                 PL019900
      GO TO 11521                                                        PL020000
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 1152 WRITE(K,103) TFORM                                                PL020100
      GO TO 11521                                                       PL020200
11515 WRITE(K,11517) TFORM                                              PL020300
11517 FORMAT(T59,'* COORD *',T86,1PE8.1,' TO GET GROUND ELEV DIFF IN M')PL020400
11521 CONTINUE                                                          PL020500
      IIB=IS3D                                                          PL020600
      IIE=IS3D+5                                                        PL020700
      WRITE(K,811) S(91),S(90),S(89),S(88),S(87),S(86),S(85),           PL020800
     A (S(M),M=29,35)                                                   PL020900
      WRITE(K,812) S(78),S(36),SHT,DUM,DUM,DUM,QSO,DUM,                 PL021000
     A S(64),S(43),S(79),S(71),S(50),S(37),                             PL021100
     B S(57),DUM,DUM,DMIX,DMNI,STARFR,DUM,                              PL021200
     C S(80),S(38),S(81),S(72),S(44),S(39),S(65),S(51),DUM,P,MWT,S(82), PL021300
     D S(58),S(40),S(73),S(45),S(83), (WSA(I),I=1,6),                   PL021400
     E S(41),S(84),S(66),S(52),S(42),S(74),S(59),S(46),TEMP,DUM,DUM,DUM,PL021500
     F DUM,S(75),S(47),S(67),S(53),S(60),S(76),S(48),                   PL021600
     G S(68),S(54),S(77),S(49),S(61),S(69),S(55),(SCALE(N1),N1=1,6),    PL021700
     H S(62),URBRUR(IUR),TERM(ISHORT),S(70),S(63),S(56),(THREED(I),     PL021800
     I I=IIB,IIE)                                                       PL021900
      IF(MAP.NE.1)RETURN                                                PL022000
CC  PREPARE TO WRITE HEIGHT MAP                                         PL022100
 3800 CONTINUE                                                          PL022200
      MAP=2                                                             PL022300
      PAGE=PAGE-100.                                                    PL022400
      DO 3810 I=1,IREC                                                  PL022500
      S(I)=((SORHT(1)-RECHT(I))*HFCTR)/10.                              PL022600
      TFORM=10.0                                                        PL022700
 3810 CONTINUE                                                          PL022800
CC  OVERFLOW IRRELEVANT VRBLS FOR WRITING HDIFF MAP                     PL022900
      DO 3811 I=1,6                                                     PL023000
 3811 WSA(I)=10000.                                                     PL023100
      SHT=SORHT(1)                                                      PL023200
      STARFR=1.E+10                                                     PL023300
      IVER=7                                                            PL023400
      DMIX=1.E+10                                                       PL023500
      DMNI=1.E+10                                                       PL023600
      P=1.E+10                                                          PL023700
      TEMP=1.E+10                                                       PL023800
      MWT=1.E+10                                                        PL023900
      GO TO 11539                                                       PL024000
      END                                                               PL024100
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      SUBROUTINE BEH072   (HF,HX,HMW,F,DELHF,DISTF,DELHX,HP,TS,VS,D,VF, BE000100
     1 KST,U,X,DTHDZ,T,P)                                               BE000200
C        BEH072   (BRIGGS EFFECTIVE HEIGHT)   OCTOBER 1972              BE000300
C         THIS DIFFERS FROM THE AUGUST 1972 VERSION IN STATEMENT 24 + 1:BE000400
C          THE CONSTANT 2.4 PREVIOUSLY WAS 2.9, AND IN STATEMENT 27:    BE000500
C          THE CONSTANT 3.14159 PREVIOUSLY WAS 2.4 .                    BE000600
C        D. B. TURNER, RESEARCH METEOROLOGIST* MODEL DEVELOPMENT BRANCH,BE000700
C         DIVISION OF METEOROLOGY, ENVIRONMENTAL PROTECTION AGENCY.     BE000800
C           ROOM 314B, NCHS BUILDING, RTP. PHONE (919) 549-8411 EXT 4564BE000900
C          MAILING ADDRESS- DM, EPA, RESEARCH TRIANGLE PARK, NC 27711   BE001000
C         * ON ASSIGNMENT FROM NATIONAL OCEANIC AND ATMOSPHERIC         BE001100
C               ADMINISTRATION, DEPARTMENT OF COMMERCE.                 BE001200
C         FROM A SINGLE SOURCE IS BASED ON:                             BE001300
C        THIS VERSION OF BRIGGS EFFECTIVE HEIGHT TO CALCULATE PLUME RISEBE001400
C           1) BRIGGS,GARY A., 1971: SOME RECENT ANALYSES OF PLUME RISE BE001500
C               OBSERVATION. PP 1029 - 1032 IN PROCEEDINGS OF THE SECONDBE001600
C               INTERNATIONAL CLEAN AIR CONGRESS, EDITED BY H. M. ENGLUNBE001700
C               AND W. T. BEERY. ACADEMIC PRESS, NEW YORK.              BE001800
C           2) BRIGGS, GARY A.,1972: DISCUSSION ON CHIMNEY PLUMES IN    BE001900
C               NEUTRAL AND STABLE SURROUNDINGS. ATMOS. ENVIRON. 6, 507 BE002000
C               - 510. (JUL 72).                                        BE002100
C         OUTPUT VARIABLES ARE...                                       BE002200
C           HF     FINAL EFFECTIVE PLUME HEIGHT (METERS)                BE002300
C           HX     EFFECTIVE PLUME HEIGHT FOR DISTANCE X (METERS)       BE002400
C           HMW    HEAT OUTPUT OF SOURCE (MW)                           BE002500
C           F      BUOYANCY FLUX (M**4/SEC**3)                          BE002600
C           DELHF  FINAL PLUME RISE (METERS)                            BE002700
C           DISTF  DISTANCE OF FINAL PLUME RISE FROM SOURCE (KM)        BE002800
C           DELHX  PLUME RISE AT DISTANCE X (METERS)                    BE002900
C         INPUT VARIABLES ARE...                                        BE003000
C           HP     PHYSICAL STACK HEIGHT (METERS)                       BE003100
C           TS     STACK GAS TEMPERATURE (DEG K)                        BE003200
C           VS     STACK GAS EXIT VELOCITY (M/SEC)                      BE003300
C           D      INSIDE STACK DIAMETER (METERS)                       BE003400
C           VF     STACK GAS VOLUMETRIC FLOW RATE (M**3/SEC)            BE003500
C           KST    STABILITY (CLASS), SEE PAGE 209 OF PASQUILL,         BE003600
C                   ATMOSPHERIC DISPERSION.  CLASSES DEFINED BY...      BE003700
C                     1 IS PASQUILL STABILITY CLASS A                   BE003800
C                     2 IS PASQUILL STABILITY CLASS B                   BE003900
C                     3 IS PASQUILL STABILITY CLASS C                   BE004000
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C                 4 IS PASQUILL STABILITY CLASS D                       BE004100
C                 5 IS PASQUILL STABILITY CLASS E                       BE004200
C                 6 IS PASQUILL STABILITY CLASS F                       BE004300
C          U      WIND SPEED (M/SEC)                                    BE004400
C          X      DOWNWIND DISTANCE (KM)                                BE004500
C          DTHDZ  POTENTIAL TEMPERATURE LAPSE RATE (DEG K/METER)        BE004600
C          T      AMBIENT AIR TEMPERATURE (DEG K)                       BE004700
C          P      AMBIENT AIR PRESSURE (MB)                             BE004800
C       THANKS TO DALE COVENTRY FOR HIS HELPFUL DISCUSSION ON           BE004900
C        PROGRAMMING PLUME RISE, TO ROGER THOMPSON FOR THE COMMENT      BE005000
C        CARDS, AND TO RUSS LEE WHO REVISED THIS ACCORDING TO REFERENCEBE005100
      IF(T)1,1,2                                                        BE005200
C       T = 0. MEANS NO AMBIENT TEMPERATURE GIVEN.  USE T = 293.        BE005300
    1 T = 293.                                                          BE005400
    2 IF(P)3,3,4                                                        BE005500
C       P = 0. MEANS NO AMBIENT AIR PRESSURE GIVEN.  USE P = 960.       BE005600
    3 P = 960.                                                          BE005700
C       IF VF IS NOT GIVEN, CALCULATE IT FROM STACK DATA.               BE005800
    4 IF(VF)5,5,6                                                       BE005900
    5 VF = 0.785398*VS*D*D                                              BE006000
C       THE CONSTANT 0.785398 = PI/4                                    BE006100
    6 F = 3.12139*VF*(TS-T)/TS                                          BE006200
C       THE CONSTANT 3.12139 IS THE ACCELERATION DUE TO GRAVITY / PI.   BE006300
      HMW = 0.00011217*F*P                                              BE006400
C       THE CONSTANT 0.00011217 = PI TIMES THE SPECIFIC HEAT OF AIR AT  BE006500
C        CONSTANT PRESSURE (0.24 CAL/GM*DEG K) TIMES MOLECULAR WEIGHT   BE006600
C        OF AIR (28.966 GM/GM.MOLE) DIVIDED BY IDEAL GAS CONSTANT       BE006700
C        (0.0831 MB*M**3/GM.MOLE*DEG K) AND ACCELERATION DUE TO GRAVITYBE006800
C        (9.80616 M/SEC*SEC) AND THEN MULTIPLIED BY (4.1855E-06 MW/CAL BE006900
C        PER SEC) TO CONVERT THE ANSWER TO MEGAWATTS.                   BE007000
C       GO TO APPROPRIATE BRANCH FOR STABILITY CONDITION GIVEN.         BE007100
C       IF UNSTABLE OR NEUTRAL GO TO 7, IF STABLE GO TO 20.             BE007200
      GO TO (7,7,7,7,20,20),KST                                         BE007300
C       DETERMINE APPROPRIATE FORMULA FOR CALCULATING XST, DISTANCE AT  BE007400
C        WHICH TURBULENCE BEGINS TO DOMINATE.  THE FORMULA USED DEPENDSBE007500
C        UPON BUOYANCY FLUX. STATEMENTS 8 AND 9 ARE EQUATION (7).       BE007600
7     IF(F-55.)8,9,9                                                    BE007700
8     XST=14.*F**.625                                                   BE007800
      GO TO 10                                                          BE007900
9     XST=34.*F**.4                                                     BE008000
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#321

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10    DISTF=3.5*XST                                                     BE008100
      DELHF=1.6*F**0.333333*DISTF**0.666667/U                           BE008200
      IF(X)29,29,32                                                     BE008300
C        IF X = 0.0, CALCULATE FINAL RISE ONLY, IF X IS GREATER THAN    BE008400
C         0.0, CALCULATE RISE FOR DISTANCE = X ALSO.                    BE008500
   32 XM = 1000.* X                                                     BE008600
C        XM IS X IN METERS.                                             BE008700
C        STATEMENT 14 IS EQUATION (6), REFERENCE 1.                     BE008800
   14 DELHX = 1.6*F**0.333333*XM**0.666667/U                            BE008900
      IF(DELHX.GT.DELHF)DELHX=DELHF                                     BE009000
      GO TO 30                                                          BE009100
   20 IF(DTHDZ)21,21,24                                                 BE009200
C        IF DTHDZ IS NEGATIVE OR ZERO ASSIGN TO IT A VALUE OF 0.02 OR   BE009300
C         0.035 IF STABILITY IS SLIGHTLY STABLE OR STABLE, RESPECTIVELY.BE009400
   21 GO TO (7,7,7,7,22,23),KST                                         BE009500
   22 DTHDZ = 0.02                                                      BE009600
      GO TO 24                                                          BE009700
   23 DTHDZ = 0.035                                                     BE009800
   24 S = 9.80616*DTHDZ/T                                               BE009900
C        THE CONSTANT 9.80616 IS THE ACCELERATION DUE TO GRAVITY.       BE010000
C        S IS A STABILITY PARAMETER.                                    BE010100
C        CALCULATE PLUME RISE ACCORDING TO EQUATION (4), REFERENCE 1.   BE010200
      DHA = 2.4*(F/(U*S))**0.333333                                     BE010300
C        CALCULATE PLUME RISE BY EQUATION (5), REFERENCE 1 FOR LIGHT    BE010400
C         WIND CONDITIONS ACCORDING TO MORTON, TAYLOR, AND TURNER.      BE010500
      DELHF = 5.0*F**0.25/S**0.375                                      BE010600
      IF(DHA-DELHF) 25,25,27                                            BE010700
   25 DELHF = DHA                                                       BE010800
C        DISTANCE TO FINAL PLUME RISE IS GIVEN BY THE FOLLOWING         BE010900
   27 DISTF = 3.14159*U/S**0.5                                          BE011000
C        IF X = 0.0, CALCULATE FINAL RISE ONLY, IF X IS GREATER THAN    BE011100
C         0.0, CALCULATE RISE FOR DISTANCE = X ALSO.                    BE011200
C        IF X IS ZERO OR LESS, GO TO 29 AND SET PLUME RISE AND DIST. TO BE011300
C         MAXIMUM PLUME RISE EQUAL TO ZERO.                            BE011400
      IF(X)29,29,33                                                     BE011500
   33 XM = 1000.*X                                                      BE011600
C        XM IS X IN METERS.                                             BE011700
C        IF XM IS GREATER THAN THE DISTANCE TO THE POINT OF FINAL PLUME BE011800
C         RISE, SET PLUME RISE EQUAL TO FINAL PLUME RISE, OTHERWISE,    BE011900
C         CALCULATE PLUME RISE FROM EQUATION (6),REFERENCE 1.           BE012000
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      IF(XM-DISTF)14,14,28                                              BE012100
   28 DELHX = DELHF                                                     BE012200
      GO TO 30                                                          BE012300
   29 DELHX = 0.                                                        BE012400
      HX = 0.                                                           BE012500
      GO TO 31                                                          BE012600
C        CALCULATE EFFECTIVE HEIGHT AT DISTANCE X.                      BE012700
   30 HX = HP + DELHX                                                   BE012800
C        CALCULATE FINAL EFFECTIVE HEIGHT.                              BE012900
   31 HF = HP + DELHF                                                   BE013000
      DISTF = DISTF/1000.                                               BE013100
      RETURN                                                            BE013200
      END                                                               BE013300
```

APPENDIX C

SIMPLE ACQUISITION OF BASE MAPS

The following data set will produce three maps that can be used for transferring the fixed receptor sites of the program to their geographical locations on topographical charts for acquiring terrain elevations at the receptors.

CARD	DATA
1-18	blank
19	col. 1-3: 10.
	col. 21: 3
	col. 27: [user's printer code]
	col. 30: 2
	col. 33: 1
20-26	blank
27	col. 1-7: (6F1.0)
28-123	blank
124	end-of-file or finish

APPENDIX D

EVALUATION OF THE VALLEY MODEL

by

Edward W. Burt and Herschel H. Slater

This paper, with appendix, is contained in the Preprint Volume for the Joint AMS/APCA Conference on Applications of Air Pollution Meteorology, November 29-December 2, 1977. Salt Lake City, Utah

EVALUATION OF THE VALLEY MODEL

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1. BACKGROUND

The large non-ferrous smelters in the West posed a particularly difficult problem for air pollution control agencies when State Implementation Plans were being evaluated in 1972 and thereafter. They were known to be large emitters of sulfur dioxide (SO_2) and particulate matter and suspected to be substantial emitters of metals of some toxicity (e.g., arsenic, lead, mercury). Their rates of emissions were not well established. Contaminants were emitted from different processes in different ways at different heights and at different times. The smelters were generally isolated and located in areas of complex, mountainous terrain. Their effluents were dispersed and transported, initially at least, by local wind systems determined largely by the orientation and configuration of the nearby terrain, thermal radiation and the synoptic weather situation. None of the smelter locations had meteorological data available which adequately represented the dispersion and transport factors. Finally, ambient air quality data which were representative of the maximum impact of the smelters on the surrounding air environment did not exist.

2. METEOROLOGICAL RATIONALE

Meteorologists attached to the Office of Air Quality Planning and Standards, EPA, were asked to estimate the likely impact of the smelters on ambient air quality. Several of them had a number of years experience estimating the impact of point sources on ambient air quality, forecasting the weather in the mountainous West, and conducting field sampling studies around large point sources, some of which were in complex terrain. A concensus of their judgments, based on their considerable experience and training in dispersion meteorology, indicated that a smelter located in proximity to terrain features in the western mountains would likely cause frequent and greatest threats to an ambient air quality standard under a particular set of meteorological circumstances. The threat was considered to be greatest on days with a fanning plume. It was judged that the greatest threat to the ambient air quality standards was likely to occur on nearby elevated terrain during inversion conditions with light winds. In these circumstances the plumes from smelters were observed to level-off shortly above stack top and to flow toward, around or over elevated terrain in ribbons or sheets.

Due to the complexity of the terrain, there were large uncertainties in the representativeness of the available meteorological data. Similarly, the magnitude, height and timing of the emissions were poorly specified. Further, the short-term 24-hr primary standard for SO_2 was most likely the controlling standard. The 3-hr secondary standard for SO_2 did not apply to the evaluation of the Plans at the time, because attainment dates were not specified. A computer program used in an earlier study in complex terrain by EPA (1972a) was modified to represent the short-term impact of polluting facilities, and to include the plume rise formulations recommended by Briggs (1971). The program became known as the Valley Model [EPA (1977)].

Careful review of upper air summaries of wind speeds and stability aloft for the western portion of the U.S. provided a basis for the choice of weather parameters to be used in the analyses undertaken by EPA (1972b). The Briggs plume rise calculations showed that the heights of the smelter plumes in stable air would not exceed 400 m above stack base for the conditions evaluated. Wind speeds of 2.5 mps, $\pm$ 1 mps, occurred at 300 meters above ground one-third or more of the time at most western upper air observing sites. On an annual basis, ground-based inversions occur in the morning in the Rocky Mountain area over 75% of the time. Most

of them are at least 250 meters deep [EPA (1973)]. The critical wind speed was chosen to be 2.5 mps. The vertical dispersion coefficient was selected to represent moderately stable circumstances. The smelter plumes were assumed to be constrained horizontally by the terrain and terrain influenced flow and to be uniformly distributed horizontally in a 22.5 degree pie-shaped sector. It was arbitrarily assumed that the plume centerline (with respect to the vertical) would not approach nearer than 10 meters to a terrain feature. Based on peak-to-mean concentrations derived from the work of Montgomery, et al. (1971) and later supported by Mills and Stern (1975) and by Martin and Reaves (1977), the 24-hr estimate was assumed to be one-fourth the shorter-term estimate. This may be interpreted as an indication that the plume affects an area for 6 hr, not necessarily continuous, of a 24-hr period. Finally, the half life of SO_2 was assumed to be 3 hr.

It was expected that the estimates derived by the technique would provide a reasonable estimate of the threat to the 24-hr ambient air quality standard for SO_2; i.e., the second highest SO_2 concentration that would occur during a year. The analytical routine was not proposed as a rigorous mathematical description of the physical circumstances which pertain to flow about a terrain feature.

3. COMPARISONS OF ESTIMATED AND OBSERVED DATA

The model was expected to provide estimates of maximum credible threats to 24-hr standards. It was not intended for short-term, day-by-day or hour-by-hour comparisons between estimated and observed concentrations. It is only appropriate to compare estimates of the model with maximum concentrations observed at locations near the height of an elevated stabilized plume. However observed air quality data which enable an unqualified comparison with estimated concentrations in complex terrain situations are difficult to acquire. Past studies suffer from two shortcomings: limited duration, and a limited number of monitoring sites. The data in Table 1 compare the estimated and the highest and second highest observed 24-hr SO_2 concentrations at sites on elevated terrain near large emission sources. All sites were at heights above the stack tops and near the estimated plume heights expected during light wind, stable meteorological conditions.

The monitoring at the Crusher, Phelps Mine and Jones Ranch sites was performed under the auspices of the EPA. The data are stored in the EPA AEROS data bank. The Lake Point data were furnished by Heaney (1975, 1976), of the Kennecott Copper Corporation. The Navajo data are available in a report by Rockwell International, Inc. et al. (1975). Only the Navajo Generating Station emissions were well documented.

The Crusher and Lower Lake Point sites were located on the steep slopes of the Oquirrh Mountains. The bearings of the sites from the source differ by 125°. Data were also furnished EPA

Table 1. The Estimated and the Highest and Second Highest Observed 24-Hr SO_2 Concentrations in the Vicinity of Large Sources Located in Complex Terrain.

Site	Source	Site-Source Dist. (km)	Period	Concentration* Est.	Observed Max	Observed 2nd High
Crusher	Garfield Smelter, Utah	6.4	4/15/73-1/31/75	2480	2564	2473
			2/1/74-1/31/75	2480	6130	3130
Lower Lake Pt	Garfield Smelter, Utah	4.5	3/8/75-12/16/75	1.18	2.66	1.20
			1/1-25/76	1.18	2.71	2.14
#106	Navajo Gen Stn, Arizona	22.8	10/1/74-2/17/75	36	32	19
#107	Navajo Gen Stn, Arizona	23.2	10/1/74-2/17/75	25	30	15
Phelps Mine	Morenci Smelter, Arizona	4.7	1975	15490	2547	2416
Jones Ranch	Miami Smelter, Arizona	2.9	1974	8610	2042	1760
			1975	8610	2642	1548

*Concentrations in $\mu g/m^3$, except those underscored are in ppm.

from another site called Upper Lake Point which was within 1 km of Lower Lake Point but 250 meters higher in elevation. The maximum observed 24-hr concentration at Upper Lake Point during the period cited was only 0.02 ppm (vs. 2.71 ppm at Lower Lake Point), apparently as a result of a stratified atmosphere. The calculated value for Upper Lake Point was similarly small.

Navajo sites #106 and # 107 were located at the top of the Vermillion Cliffs in northern Arizona, west of the Navajo Generating Station. The Cliffs face the facility and are extremely steep. Some of the terrain between the Cliffs and the generating station dips significantly below the stack bases. Several other samplers at the top of the Cliffs and elsewhere at comparable elevations, as well as in a network of sites on the sloping plain on which the power plant is located, did not record such high values of concentration. Site #106 was at the southern end of the line of samplers on the Cliffs, and recorded the highest concentration during the study.

Some air quality data from near a Montana smelter were expected to be reasonably representative of the circumstances to which the analytical procedure was designed to apply. Unfortunately, the data were found to contain uncertainties which could not be resolved.

4. OTHER OBSERVATIONS

Some observations exist which can be used only qualitatively to indicate that stable, elevated plumes can approach very close to elevated terrain as is assumed in the Valley Model. Hewson and Gill (1944) depict concentrations of SO_2 across the Columbia River Valley near Trail, B.C., Canada; the measurements were obtained by aircraft down-valley of a smelter, and depict well-defined smelter plume centers not infrequently lying very near the mountainside.

Scorer (1973) cites observations in three countries of stable elevated plumes either visually impinging on mountainsides or causing damage to vegetation on mountainsides.

The high quality data of Start, Dickson, and Wendell (1973) are often cited as evidence that dispersion rates observed over flat terrain during moderately stable conditions result in overestimates of 1-hr concentrations by a factor of 15 when applied in the complex terrain of Huntington Canyon, Utah. This conclusion is drawn from four 30- to 60-minute ground-level tracer releases, and ground-level sampling, made during a 48-hr period. However, the ratios of concentrations estimated using the bivariate Gaussian formulation (with the flat-terrain dispersion rate) to the maximum concentration observed at each sampling arc (distances 2.12, 2.8, 4.2, and 6.2 km) are 0.95, 1.1, 2.6, and 1.0; this is a very good relationship, considering the limited tests. The Valley Model uses the concept that the average vertical dispersion coefficients for flat terrain can be used for calculating the upper limit of concentrations in complex terrain, but the model results cannot be compared directly with these Huntington Canyon data because of the differences in averaging times and the brevity of the field study.

5. CONCLUSIONS

At four of six sites on mountainous terrain near the height that plumes from major facilities stabilize, it has been shown that the Valley Model provides maximum 24-hr SO_2 concentration estimates which are within a factor of two of the second-highest observed concentrations. It is concluded that the Valley Model is a useful screening procedure for identifying potential threats to the 24-hr ambient air quality standard for SO_2 in complex terrain.

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16. ABSTRACT

The Valley Model is a steady-state, univariate Gaussian plume dispersion model designed for multiple point- and area-source applications. It calculates pollutant concentrations for each frequency designated in an array defined by six stabilities, 16 wind directions, and six wind speeds for 112 program-designated receptor sites on a radial grid of variable scale. The output concentrations are appropriate for either a 24-hour or annual period, as designated by the user. The model contains the concentration equations, the Pasquill-Gifford vertical dispersion coefficients and the Pasquill stability classes, as given by Turner. Plume rise is calculated according to Briggs. Plume height is adjusted according to terrain elevation for stable cases. Technical details of the program are presented, with descriptions of data requirements. Flow diagrams and input data forms are presented. Four appendices include a complete test-case analysis, a complete program listing and a paper in which estimated and observed data are compared at several sites for 24-hour periods during which the upper limits of concentrations were observed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Turbulent diffusion Meteorology Mathematical models Computer models Sulfur dioxide Complex terrain	Dispersion Air Quality Simulation Model	

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