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COMPUTER ANALYSIS OF AIR POLLUTION FROM HIGHWAYS, STREETS, AND COMPLEX INTERCHANGES

A CASE STUDY: PORTIONS OF THE PROPOSED 3-A SYSTEM IN 1978 BALTIMORE, MARYLAND

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16. Abstract

In connection with Mr. Darling's appearance as an expert on air quality for the Government in the trial of a citizen suit (filed to stop construction of the 3-A System of highways in Baltimore) under the Clean Air Act, the Transportation Systems Center prepared a detailed computer analysis of air quality for a complex highway interchange, using an in-house version of the Environmental Protection Agency's Gaussian Highway Line Source Model. This analysis showed that the levels of air pollution near this interchange in the year 1978 would not exceed established standards.

This analysis is treated as a case study, illustrative of a methodology which is useful for computing air pollution levels associated with many highway configurations. The individual ingredients of the analysis are described in detail, including the handling of road geometry, the calculation of emissions, the estimation of meteorological parameters and the selection of receptor locations. A complete listing of the computer program used in these studies is included.

It is concluded that the air quality analysis methodology developed for this case is an easy-to-use, straightfoward procedure of general applicability. Within the limitations of the model and subject to the accuracy of the input data, this approach can produce reasonable estimates of worst-case pollutant concentrations for comparison with national ambient air quality standards.

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PREFACE

In response to recent legislation requiring that each department of the Government take steps to carefully and systematically consider the environmental effects of its actions, the Office of the Secretary of Transportation initiated a program at the Transportation Systems Center in FY72 to develop unified technological capabilities in air pollution control as part of a family of techniques and capabilities necessary to support the development in the Office of the Secretary, and in the Operating Administrations, of planning procedures related to the environmental impact of transportation systems and facilities.

One aspect of this program is to promote liaison and coordination with the DOT Operating Administrations, the Environmental Protection Agency and other organizations concerned with transportation-generated air pollution. The work reported here was performed as part of this liaison and coordination effort in response to a joint request for support from the Federal Highway Administration and the Justice Department.

The authors are members of the Software Implementation Branch, Information Sciences Division, Technology Directorate of the Transportation Systems Center. In this report all references to work by the Transportation Systems Center (TSC) pertain to the accomplishments of this Branch.

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1. INTRODUCTION

1.1 BACKGROUND

This report is concerned with the analysis of air pollution associated with roadways. The requirement for this kind of analysis is mandated by a number of recent public laws - primarily, the following:

1) The Department of Transportation Act, Title 49, U.S.C. (1970),

2) The National Environmental Policy Act (NEPA) of 1969, PL 91-190,

3) The Clean Air Amendments of 1970, PL 91-604,

4) The Federal-Aid Highway Act of 1970, PL 91-605.

Court decisions interpreting the National Environmental Policy Act of 1969 have made clear:

a) The requirement for agency research (of a broader scope than may have been traditionally within its jurisdiction) into environmental impact,

b) The mandate for a finely tuned and systematic balancing analysis of each proposed project,

c) That agencies are responsible for taking the initiative in probing environmental considerations, and

d) That agencies have the duty to consider less environmentally damaging alternatives.

The aforementioned laws and interpretations constitute the framework within which the process of preparing, reviewing, challenging and approving environmental impact statements is evolving. A typical impact statement will treat an appropriate subset of the following topics: social and economic factors, housing disruption, land use patterns, aesthetic considerations, energy budget, air pollution, water pollution, noise and solid waste disposal.

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In the case of roadways, air pollution is a major factor since motor vehicles produce about 44% of the U. S. total and 86% of the transportation total of all air pollutant emissions in the United States (EPA, 1969). The responsibility for analyzing the environmental impact of highways rests with the cognizant state highway department. A draft impact statement for each proposed project is prepared and submitted to the regional office of the Environmental Protection Agency (EPA) for review. The final statement is reviewed by the regional office of the Federal Highway Administration (FHWA) and then forwarded to FHWA headquarters for final approval.

The Clean Air Amendments of 1970 (Sec. 304) recognize the right of persons to bring a citizen suit, "(1) against any person (including (i) the United States, and (ii) any other governmental instrumentality or agency to the extent permitted by the Eleventh Amendment to the Constitution) who is alleged to be in violation of (A) an emission standard or limitation under this Act or (B) an order issued by the Administrator* or a State with respect to such a standard or limitation, or (2) against the Administrator where there is alleged a failure of the Administrator to perform any act or duty under this Act which is not discretionary with the Administrator. The district courts shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce such an emission standard or limitation, or such an order, or to order the Administrator to perform such act or duty, as the case may be."

The air quality analyses reported herein were performed by TSC in connection with Mr. Darling's testimony as an expert witness for the Government in the trial of such a citizen suit, filed with the intent of stopping the construction of a roadway system in Baltimore, Maryland.

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* In this section the term Administrator means Administrator, Environmental Protection Agency.

1.2 THIS REPORT

Chapter 2 begins with a summary of the case study in question which involves the 3-A System of roadways in Baltimore, Maryland. The 3-A System is described; the civil suit against the system is outlined; and the contested air quality portion of the environmental impact statement is discussed. The role of the Transportation Systems Center (TSC) in the trial is explained in Chapter 3 with emphasis on the independent air quality analysis performed by the Center. The next two chapters deal with the TSC air quality analysis methodology (utilizing an Environmental Protection Agency (EPA) model of air pollution dispersion from highways) and modifications of the EPA computer program by TSC to accommodate the complex road configurations analyzed here.

Chapter 6 contains a detailed TSC air quality analysis for the Franklin-Mulberry Corridor at City Boulevard for the year 1978. One-hour peak and eight-hour average concentrations of carbon monoxide (CO) are shown for may receptors at the immediate edge of the proposed roadways and at other strategic locations.

Five appendices follow Chapter 7, Summary and Conclusions. Appendices A, B and C contain detailed information pertaining to the civil suit; Appendix D is a listing of the computer program for the TSC-modified EPA model; Appendix E contains four additional air quality analyses prepared by TSC for road segments related to the 3-A System.

2. THE CASE STUDY: THE 3-A SYSTEM, BALTIMORE, MARYLAND

2.1 DESCRIPTION OF THE 3-A SYSTEM

The proposed 3-A System for Baltimore consists of the 22.7 miles of expressways and boulevards shown (as dashed lines) in Figure 1. The following road segments comprise the System:

1) The extension of I-83 south to the Inner Harbor, then east, connecting with I-95 north of the Harbor Tunnel entrance.

2) I-95 from the southwest City Line, across South Baltimore, across the Harbor at Fort McHenry, turning northeastward and connecting with the existing I-95 at the eastern City Line.

3) I-70N from the western City Line, through Leakin Park, turning southeastward and connecting with I-95 in south-west Baltimore.

4) I-170, an expressway spur from I-70N to City Boulevard west of the City Center.

5) I-395, an expressway spur from I-95 northeastward to City Boulevard south of the City Center.

6) City Boulevard, a semi-circle running from the south side of the Inner Harbor and connecting with I-83 north of the City Center.

The 3-A System was designed by the Urban Design Concept Team, a multi-disciplinary group of leading architects, planners and designers. This approach to the planning of the System was approved by the U.S. Department of Transportation on September 24, 1967. In mid-January 1969 the Bureau of Public Roads selected the 3-A System from a group of three candidates proposed by the Concept Team.
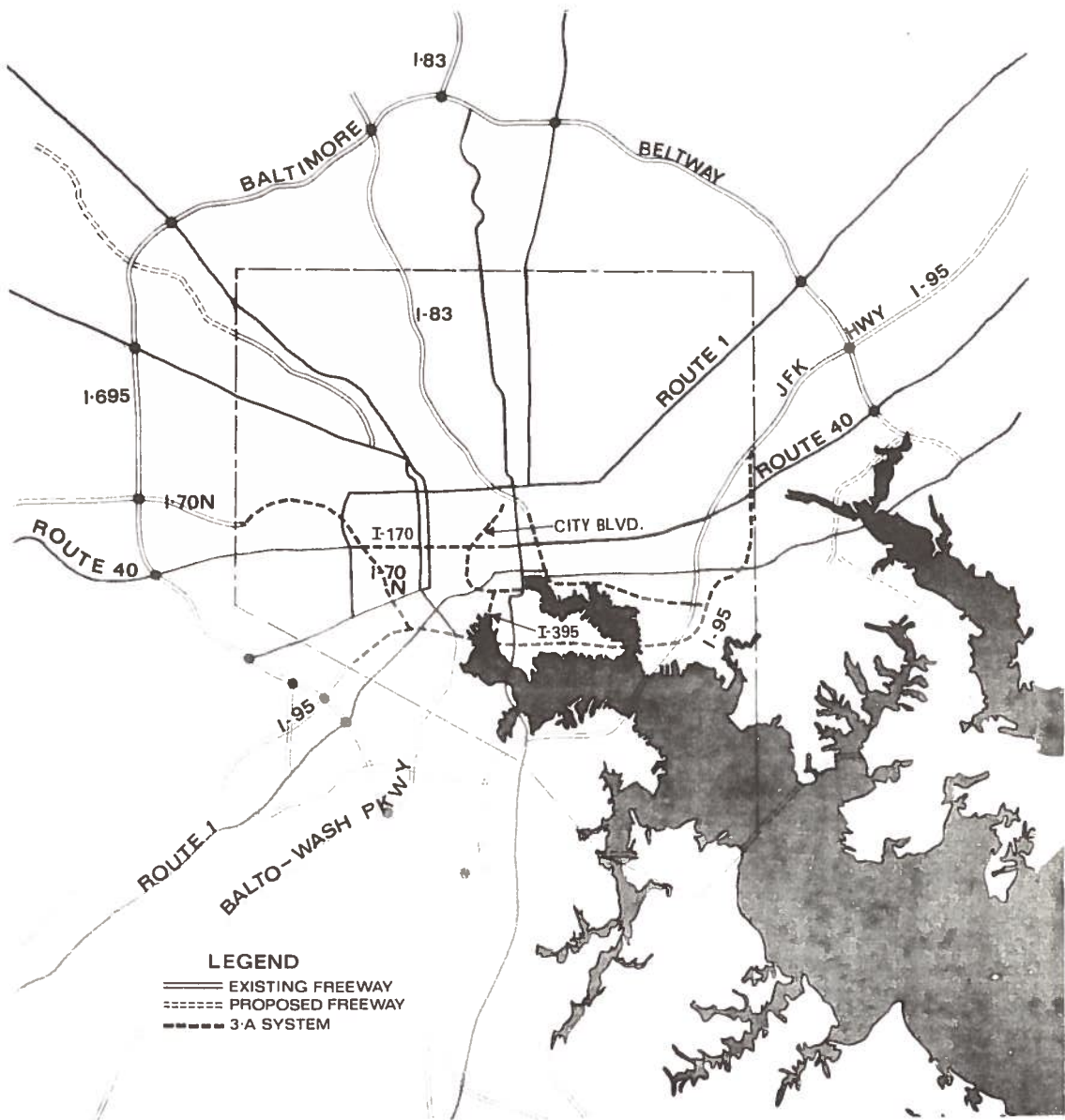
Figure 1. The Proposed 3-A System, Baltimore, Maryland

2.2 CIVIL SUIT AGAINST THE 3-A SYSTEM

Beginning in October 1971 a number of separate civil suits were filed to stop construction of various segments of the 3-A System. Subsequently, in February 1973, it was decided to combine three of these cases into a single suit to be tried in the U.S. District Court for the District of Maryland. The actual trial took place during the period, April 16 through May 11, 1973, and was heard by Judge Roszel C. Thomsen and Judge James R. Miller, without a jury. A plaintiff petition for summary judgement had been denied by both judges on April 2, 1973.

The original plaintiffs* in the case (Civil Action File No. 72-1041M, October 11, 1972, U.S. District Court for the District of Maryland) were five organizations and four individuals, all residents of Baltimore. The defendants named were the Secretary of Transportation, the Administrator of FHWA, the Mayor of Baltimore and the Chief of the Interstate Division for Baltimore City. Each of the defendants was represented at the trial by his own lawyer - none appeared in person. The plaintiffs were represented by a battery of five attorneys.

The complaint alleged that:

1) The provisions of NEPA have been violated because no environmental impact statement was prepared for the 3-A System as a whole and, further, that the impact statements prepared for segments of the System were deficient.

2) In violation of the Federal-Aid Highway Act:

   a) No public hearings were held on the whole 3-A System prior to the decision to go ahead with that System.

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*Movement Against Destruction, South Baltimore Community Council, Western Community Improvement Association, Rosemont Neighborhood Improvement Association, Hunting Ridge Community Assembly, Wallace Gregory, Charles Curtis, Carol J. Sharlip, Mildred Moon. In an amendment dated November 27, 1972, Mildred Moon's name was deleted and five other organizations were added to the above list.

      b)   The approval of the System creates pressure for subsequent Federal appropriations.

      c)   The project is not based upon continuing comprehensive transportation planning involving the State and local community.

   3)   The Clean Air Amendments of 1970 were violated because the EPA Administrator had not reviewed and commented on the environmental impact of the project as required in Sec. 309.

Based upon the above complaint the plaintiffs asked the Court to enjoin the defendants from building the 3-A System.

2.3   AIR QUALITY ANALYSIS FOR THE FRANKLIN-MULBERRY CORRIDOR

One document in contention by the plaintiffs was an environmental impact statement prepared by the Maryland Department of Transportation, Interstate Division for Baltimore City (IDBC), for I-170 between Pulaski and Pine Streets - the so-called Franklin-Mulberry Corridor. TSC became involved in evaluating the air quality portion of this statement in connection with Mr. Darling's appearance* in the trial as an expert witness for the defendants on the subject of air quality.

The Franklin-Mulberry Corridor is oriented in an east-west direction and consists of the existing Franklin and Mulberry Streets (two parallel streets separated by about 300 feet) between Pulaski Street on the west and Pine Street on the east - a distance of about 0.85 miles (see Figure 2). Centered within this corridor it is proposed to build I-170, a divided highway depressed about 30' except at the western and eastern extremities of the Corridor where it rises to grade. At its eastern terminus I-170 overpasses the north-south City Boulevard, another segment of the proposed 3-A System.

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*The request for a Government expert on air quality came from the FHWA Office of the Chief Counsel and from the Justice Department.

N

PULASKI STREET

CITY BOULEVARD

PINE STREET

FRANKLIN STREET

I-170

MULBERRY STREET

0.85 mi

———————— Existing Streets

— — — — —. Proposed 3-A System
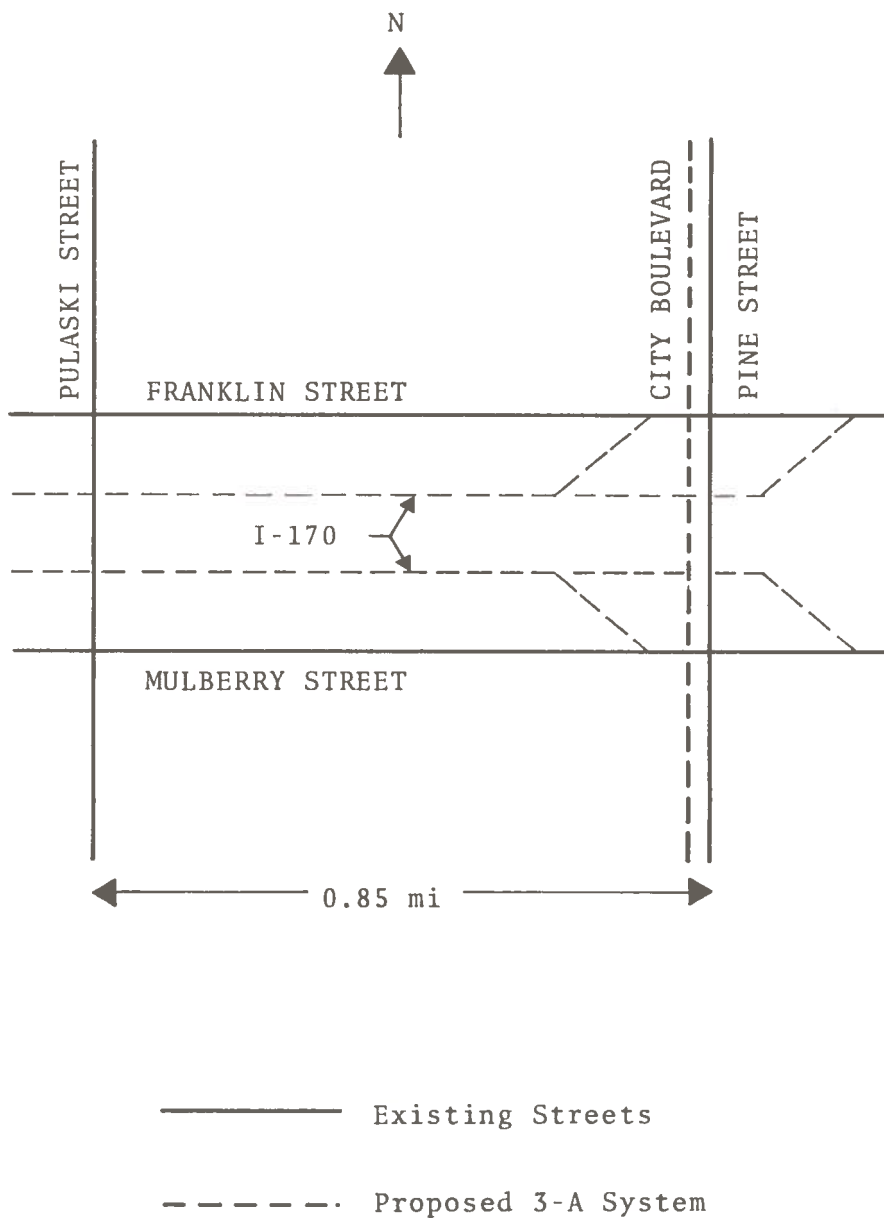
Figure 2. The Franklin-Mulberry Corridor

Following the example of EPA Region III*, the Interstate Division for Baltimore City had used the so called G.E. Model to make air quality calculations for the Franklin-Mulberry Corridor.

2.3.1 The G.E. Model

The model in question was developed by the General Electric Company under a contract with the City of New York.** The purpose of this contract was to produce a model for predicting air quality (i.e. CO concentrations) in the immediate vicinity of various urban roadway configurations. The configurations studied were the following:

> Covered on top, open on one side
> Long tunnel, ventilated
> Shallow Cut
> Short tunnel, unventilated
> Deep cut
> Grade road
> Cantilever cover
> Viaduct
> City street
> Intermittent covered span

The G.E. Model assumes that the decrease in concentration of CO with height can be represented by the following exponential relationship:

$$C = \frac{M\dot{N}}{W(aD+V)} \, e^{-az} \tag{1}$$

where
M = pollutant emissions in mass per vehicle mile
$\dot{N}$ = traffic flow rate in vehicles per hour
a = a constant found to be .015 to .025 ft.$^{-1}$
W = width of the roadway

D = diffusion coefficient

V = wind velocity

z = height above vehicle exhaust plane

C = concentration of CO

If z is replaced by the radial distance ρ then (1) becomes:

$$C = CO_x \ e^{-a\rho} \tag{2}$$

where

$$CO_x = \frac{M\dot{N}}{W(aD+V)}$$

which is the concentration resulting from the xth line source.

ρ = the radial distance between the source and the receptor (the point at which the concentration is calculated).

This model was further refined by defining a vehicular pollution factor ϕ where:

$$\phi = \frac{CO_x}{\dot{N}} = \frac{M}{W(aD+V)} \tag{3}$$

For eight of the ten highway configurations listed above (i.e. all except the tunnels), G.E. discovered that there is a strong linear relationship between ϕ and traffic speed. The regression relationship for the year 1971 was found to be:

$$\phi_i = \left[-0.51 \ T_i + 26.9 \right] \times 10^{-3} \ \frac{ppm\text{-}hr}{vehicle} \tag{4}$$

for 15 mph $\leq T_i \leq$ 49 mph

T_i = average traffic speed in lane i.

The total CO concentration at receptor R, CO_R, is then obtained by summing the contribution of the S road lanes:

$$CO_R = \sum_{i=1}^{S} \phi_i \dot{N}_i \ e^{-a\rho_{iR}} \tag{5}$$

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where $\dot{N}_i$ = the traffic flow rate for lane i

ρ_{iR} = radial distance from lane i to receptor R.

2.3.2 Air Quality Analysis Performed by the Interstate Division for Baltimore City (IDBC)

The IDBC used a version of equation (4) derived for the Baltimore traffic situation, namely:

$$\phi_i' = \left[-0.54\ T_i + 29.6\right] \times 10^{-3} \tag{4a}$$

A factor of 0.48 was introduced to account for the decrease in emissions from 1971 to 1978 (the scheduled year of completion for the Franklin-Mulberry Corridor). Calculations were made with the following form of equation (5):

$$CO_R' = \sum_{i=1}^{S} 0.48\ \phi_i'\ \dot{N}_i\ e^{-.02\rho_{iR}} \tag{5a}$$

The 1978 traffic volumes and speeds for the Corridor were estimated by the IDBC.

An air quality analysis was performed for the central part of the corridor, taking into account the pollutant contributions from Franklin Street, Mulberry Street and the depressed I-170. Peak one hour concentrations of CO near Mulberry Street were calculated to be 3-6 ppm -- well below the 35 ppm primary ambient air quality standard. Eight-hour average concentrations were not computed since these could not exceed the 9 ppm standard in view of the fact that the peak hour value was below that level.

2.3.3 The Plaintiff's Air Quality Analysis

Dr. Allan H. Marcus, Professor of Mathematics, Johns Hopkins University, was engaged by the plaintiffs as an expert in air pollution to prepare a counter air quality analysis for the Franklin-Mulberry Corridor. Marcus used a version of equation (2) scaled for Baltimore traffic conditions in 1978. For a hypothetical worst case he calculated a peak hour concentration of 18 ppm.

His computations of the eight-hour average level were in the 4-7 ppm range.

Not satisfied with these results Marcus introduced a number of uncertainty factors which would lead to an increase in his pollution estimates. These factors were: ineffective emission controls, reduced vehicle-induced dispersion, new geometry for Mulberry Street, the effect of atmospheric stagnation, revised traffic estimates and inclusion of the background pollution level. By introducing all these factors and assuming a traffic jam on I-170 eastbound, Marcus calculated the following worst-case values:

Peak hour concentration - 30 ppm
Eight-hour average concentration - 14 ppm

3. THE TSC ROLE

The G.E. Model was judged by TSC to be an inadequate tool for analyzing air quality in the Franklin-Mulberry Corridor because of the following deficiencies:

1) It only considers dispersion of pollutants due to the spread of eddies caused by the mechanical mixing of air induced by vehicle motion. This mechanism is only effective at the immediate edge of the road.

2) The effect of atmospheric turbulence, transport wind and mixing height are not included. These atmospheric parameters govern the dispersion of pollutants from the road edge and must be taken into account when analyzing complex roadways.

3) The model can only be used to calculate pollution in a vertical plane normal to the road and bounded by lines perpendicular to the road edge. It is thus incapable of accommodating the superimposed contribution of line segments of finite length in a complex horizontal configuration of roads.

Furthermore, it was apparent that even if the G.E. model had been suitable, the analysis made did not include the portion of the Corridor where the air pollution would be greatest, namely the I-170/City Boulevard interchange at the eastern terminus. At this interchange all road segments (except the I-170 overpass) are at-grade, hence most of the emissions will originate at ground level and be dispersed directly to the side walks and adjacent buildings along Franklin and Mulberry Streets. It was thus clear at the outset that a separate air quality analysis, using a different model, would have to be made in order to evaluate the impact of this maximum pollution area.

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3.1 THE TSC AIR QUALITY ANALYSIS

As part of the Transportation Air Pollution Control Technology
Project, TSC had acquired a highway line source model from EPA.
This was a Gaussian plume model which represents a highway by a
large number of point sources along a line. The computer program
for this model had been implemented on the TSC IBM 7094 computer
and was in running condition. Being a Gaussian model, atmospheric
parameters could be handled naturally. However, the computer program
supplied by EPA was set up to handle dispersion down wind from a
single highway only. In order to use this model for the problem
at hand, TSC modified the EPA program to handle the superposed
pollution effects of multiple road segments on any receptor. In
this form the program was well suited for analyzing the proposed
I-170/City Boulevard interchange in its full complexity, subject
only to the familiar limitations of the Gaussian model (especially
its inability to handle terrain or buildings).

This TSC version of the EPA program was used to calculate air
pollution at the proposed I-170/City Boulevard interchange for the
year 1978, using traffic data supplied by the Interstate Division
for Baltimore County (IDBC), emission factors from the recent
California Division of Highways manual* and worst case
meteorology. A separate 1978 analysis was made for the same area
for the case where I-170 and City Boulevard are not built. Details
of the TSC analysis methodology may be found in Chapters 4 and 5;
the complete results are presented in Chapter 6. In summary, these
computations show that neither the one-hour peak nor the eight-hour
average national ambient air quality standards would be exceeded in
this maximum pollution area in either the "Build" or "No Build"
case. Furthermore, air pollution levels were calculated to be
somewhat higher in the "No Build" case because of the inadequacy
of existing roads to handle the projected large increase in traffic.

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*
J.L. Beaton et al, Air Quality Manual Vol. II. Motor Vehicle
Emission Factors for Estimates of Highway Impact on Air Quality,
Report No. CA-HWY-MR657082S(2)-72-10, Materials and Research
Department, California Division of Highways, April 1972.

Subsequent to our completion of the above analysis, David Wagner, Chief, Environmental Section, IDBC, requested TSC to perform additional air quality analyses in connection with environmental impact statements currently being prepared by the IDBC for four other segments of highway in Baltimore which join, or are part of, the 3-A System. TSC performed these additional analyses as an act of good will and the results are reported in Appendix E.

3.2 MR. DARLING'S TESTIMONY

On the afternoon of May 1, 1973, Mr. Darling appeared on the witness stand for approximately two hours as a Government expert on air pollution. The first hour was occupied by direct examination; the second by cross examination. Mr. Darling's verbatim testimony is recorded in Appendix A; the principal points are summarized below.

Direct Examination

1) TSC's review of air pollution dispersion models has revealed that none of them has been adequately validated due to a lack of data,

2) The G.E. model used by IDBC to analyze air pollution in the Franklin-Mulberry Corridor was a state-of-the-art technique at the time the analysis was done, and

3) The TSC analysis for the I-170/City Boulevard interchange for both the "Build" and "No Build" cases in 1978 was described at great length and the conclusion stated that air pollution standards would not be exceeded in either case, but that pollution levels were estimated to be somewhat higher in the "No Build" case.

Cross-Examination

a) Mr. Darling stated that he is not an expert on traffic analysis. He accepted without question the traffic data provided by the IDBC and used these data in the TSC air quality analysis.

b) Questions about the limitations of the Gaussian model were answered and the opinion advanced that errors of

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60 % to 80% could be expected with this model. This was
offered as the reason for making a "worst case" analysis.

c)   Aspects of the G.E. model were probed and its weaknesses
     cited by Mr. Darling.

d)   An attack on the TSC assumptions about the wind in
     Baltimore was answered.

4. TSC ANALYSIS METHODOLOGY

The Transportation Systems Center performed an Air Quality Analysis for five sites related to the 3-A System in Baltimore. These sites (shown in Figure 3) were:

1. The proposed I-170, City Boulevard Interchange.

2. The proposed City Boulevard, between Druid Hill Avenue and McCulloh Street.

3. The proposed City Boulevard, between Lexington Street and Saratoga Street.

4. Edmondson Avenue, just west of Hilton Parkway.

5. The proposed I-70N through Leakin-Gwynn Falls Park.

For each of these sites, TSC calculated projected pollutant concentrations for 1978 based upon the assumption that pertinent sections of the 3-A System would be built. This was called the "Build" case. For some of these sites TSC also calculated, for comparisons purposes, projected pollutant concentrations for 1978 based upon the assumption that the 3-A System sections would not be built. This was called the "No-Build" case.

The method TSC uses to perform an Air Quality Analysis consists of five steps:

a. ROAD SEGMENTATION: From the road geometry, the locations of a set of linear road segments are found to model the given configuration.

b. EMISSIONS CALCULATION: Based upon traffic estimates for each road segment, the amount of pollutant emitted by each segment is calculated. Calculations are made for two situations: the peak hour and a typical off-peak daytime hour.

c. RECEPTOR LOCATION: Locations for receptors at which pollutant levels will be calculated are chosen.
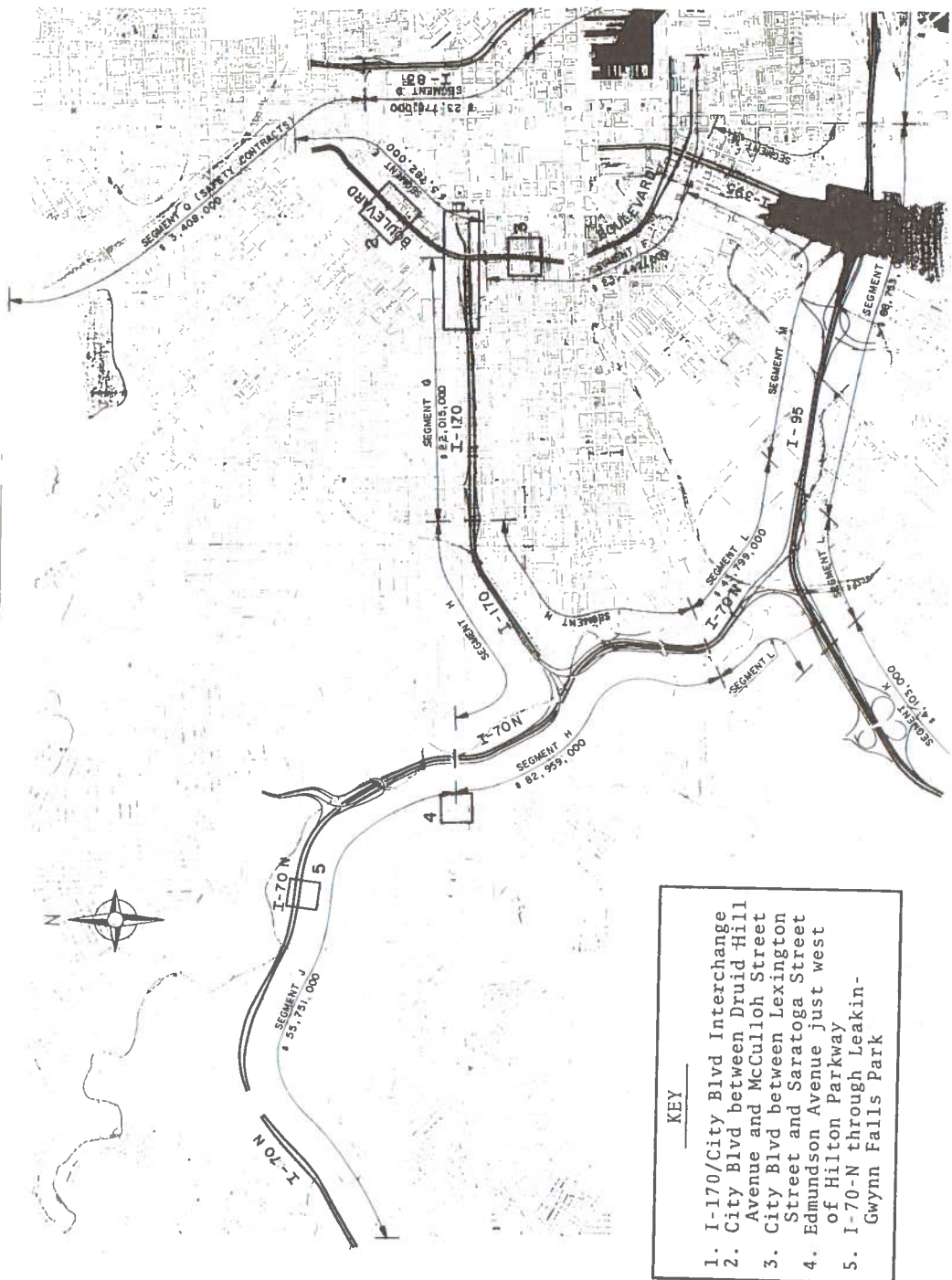
KEY

1. I-170/City Blvd Interchange
2. City Blvd between Druid Hill
   Avenue and McCulloh Street
3. City Blvd between Lexington
   Street and Saratoga Street
4. Edmundson Avenue just west
   of Hilton Parkway
5. I-70-N through Leakin-
   Gwynn Falls Park

Figure 3. The Five Sites Related to the 3-A System where
Air Quality Analyses Were Prepared

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d.   PEAK HOUR CONCENTRATION COMPUTATION: The concentrations
     of pollutant at each receptor are computed for the peak
     hour, based upon the peak hour emissions. The computation
     is done using a vehicle-source air pollution dispersion
     model.

e.   EIGHT-HOUR AVERAGE CONCENTRATION COMPUTATION: Using the
     dispersion model, the concentrations of pollutant at each
     receptor are computed for an average off-peak hour, based
     upon off-peak hour emissions. Then, an eight-hour aver-
     age concentration is calculated using a weighted average
     of the peak and off-peak hour concentrations.

This Chapter of the report will discuss these five steps of
analysis in detail. The dispersion model used is a TSC-modified
version of the EPA Highway Line Source Model. This is described
in Chapter 5. The analysis and results for Site 1 (which were the
subject of testimony at the trial) are presented in Chapter 6.
Air quality analyses for Sites 2-5 may be found in Appendix E.

4.1   ROAD SEGMENTATION

When an Air Quality Analysis is to be prepared for a given
site, the first step is to produce a set of linear road segment
line sources which can be used to model the geometry of the roads
of interest. A road configuration is modeled as a set of hori-
zontal line sources. Each segment of a road to be modeled that
has distinct emissions characteristics (i.e., traffic counts or
speeds) is modeled as a separate line source. For convenience,
if a two-way road has different characteristics for each direction
it is modeled as two distinct line sources. In the analysis, if
no lane-traffic data is available, the traffic on a road segment
is equally divided by lanes and the given, or calculated, road
traffic speed is used for all lanes.

For each road configuration to be analyzed, a diagram showing
the line sources used to model the roads is drawn, and a set of
coordinate axes is superimposed on the diagram. Then a table such
as the one shown in Figure 4 is filled in. For each model line
source, the following is entered in the table:

HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES

Figure 4. Road Section Table

1. The Line Source Endpoints: (X1,Y1) and (X2,Y2).

2. The Source Height: This was set to 3 feet for at-grade
    sources and to 3+H feet for elevated sources of roadway
    height H.

3. The Highway Width: The distance between the edges of the
    outermost traveled lanes (including the center strip,
    if any).

4. The Center Strip Width: (Note that if a two-direction
    highway is modeled as two distinct segments then the
    center strip width for each segment is zero).

5. The Number of Lanes.

4.2 EMISSION CALCULATION

The second step of the TSC Air Quality Analysis is the cal-
culation of the carbon monoxide emissions due to each model line
source. To aid in the calculation, a table such as the one shown
in Figure 5 is filled in. For a given case (i.e., "Build or "No
Build") and for a given hour (i.e., peak hour or average off-peak
hour), the number of vehicles per hour on each road section and
the average speed of the vehicles are obtained from estimates made
by highway engineers. For the five Baltimore sites, these esti-
mates were obtained from Mr. D.A. Wagner, Chief of the Environ-
mental Section, Maryland State Highway Administration, Interstate
Division for Baltimore City. The number of vehicles per hour per
lane is then obtained for each road section.

Based upon the vehicle speed for each road section, the car-
bon monoxide emission factors are found from the emission factor
graphs shown in Figures 6 and 7. These figures are taken from
Motor Vehicle Emission Factors for Estimates of Highway Impact on
Air Quality. Air Quality Manual CA-HWY-MR657082S(2)-72-10, Mater-
ials and Research Department, California Division of Highways,
April 1972. Figure 6 gives the carbon monoxide emission factors
for freeways and Figure 7 gives the emission factors for city
streets. The percent of heavy duty vehicles (i.e., trucks and

EMISSIONS

HIGHWAY SECTION	veh/hr	$\dfrac{\text{veh/hr}}{\text{lane}}$	SPEED	19 EMISSION FACTOR for CO % HDV $\dfrac{\text{gm/mi}}{\text{veh}}$	$\dfrac{\text{gm/mi}}{\dfrac{\text{hr}}{\text{lane}}}$	$\dfrac{\text{gm/m}}{\dfrac{\text{sec}}{\text{lane}}}$

Figure 5. Emissions Table
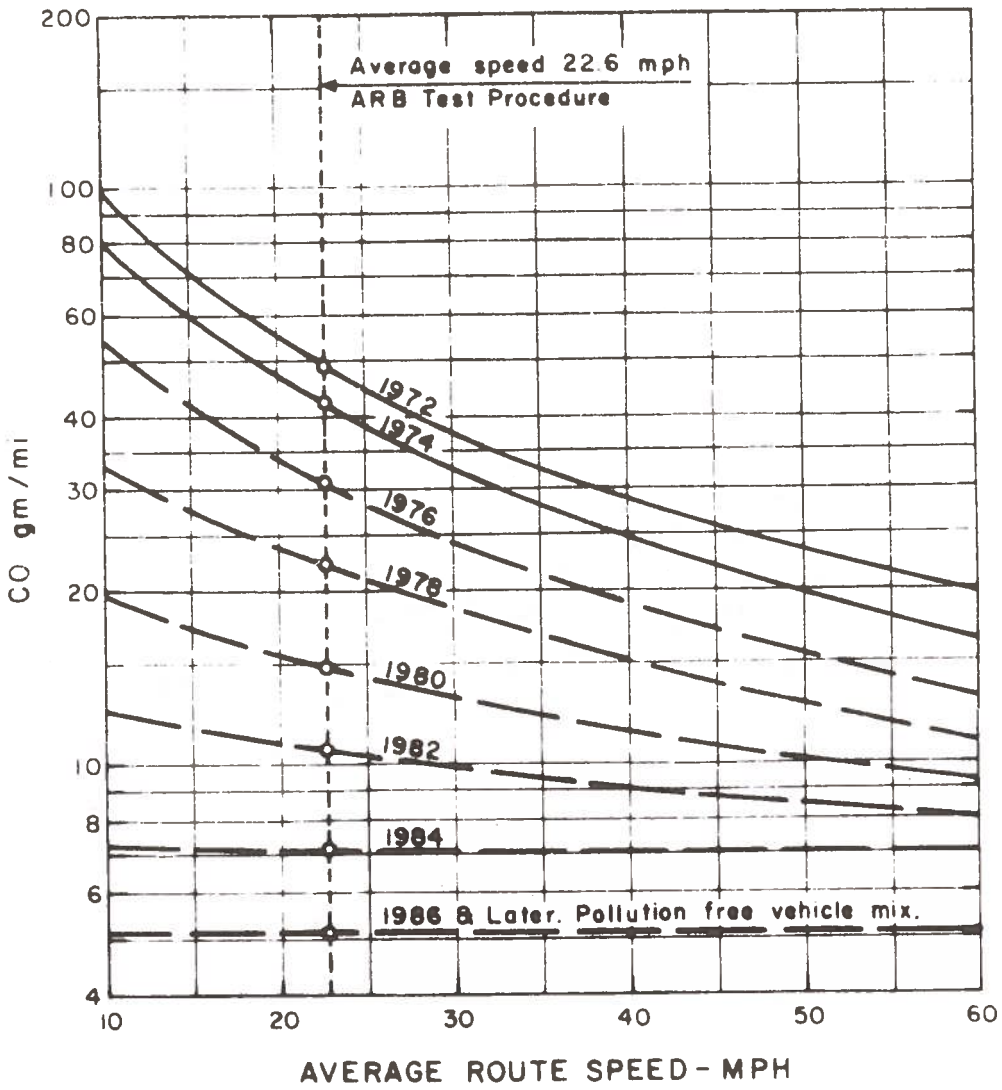
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Reference: Air Quality Manual CA-HWY-MR65708S(2)-72-10,
California Division of Highways, April 1972

Figure 6. Emission Factors for Freeways
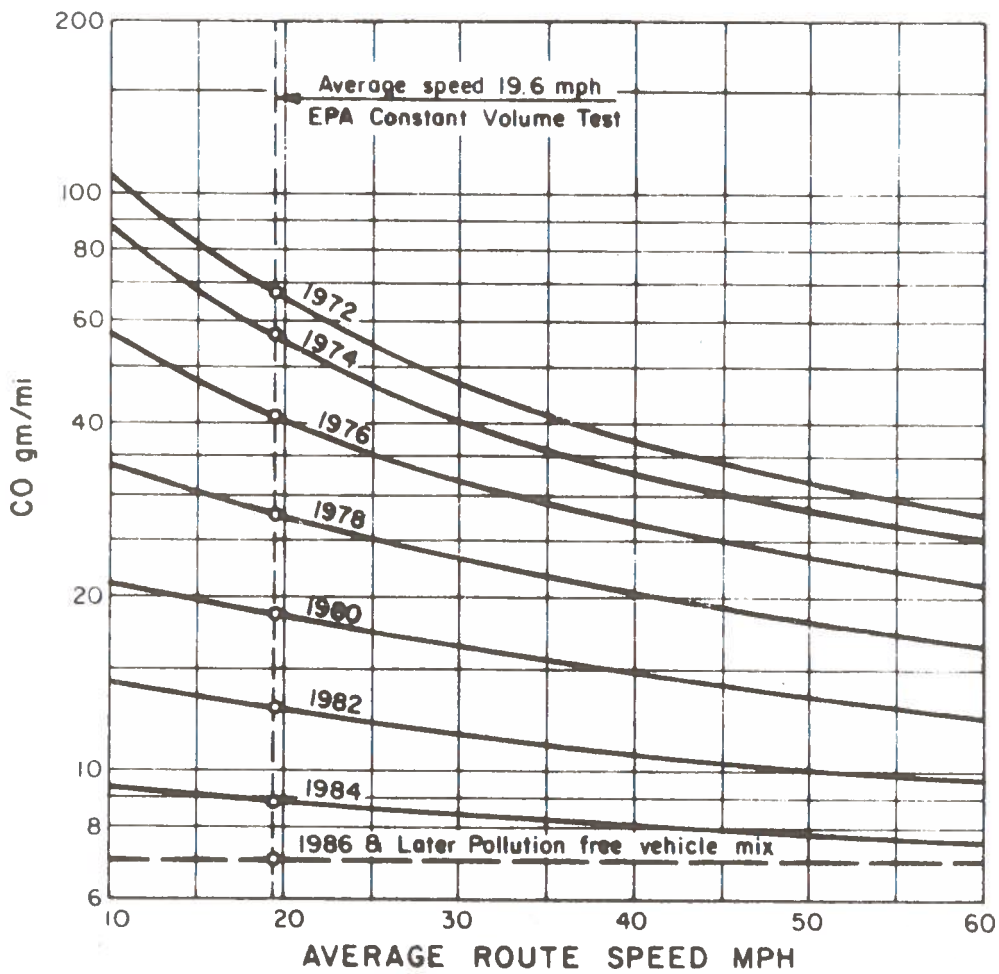
Reference: Air Quality Manual CA-HWY-MR65708S(2)-72-10,
California Division of Highways, April 1972

Figure 7. Emission Factors for City Streets

buses) is approximated as 5% at all sites, based upon Maryland
State Highway Administration estimates. All of the Baltimore
Air Quality Analyses are for 1978, and thus the 1978 curves on
the graphs are used.

For each road section, the emission factor in grams per mile
per vehicle is multiplied by the number of vehicles per hour per
lane. The result is converted to the units of grams per meter per
second per lane by dividing by 5.79×10^6. This number is used
for the emissions of the road section.

4.3 RECEPTOR LOCATION

The points at which the pollutant concentrations are calcu-
lated by the air pollution dispersion model are called the recep-
tors. In each Air Quality Analysis performed by TSC, receptors
are chosen at points where concentrations are of the most interest.
These are generally the points at which the pollutant levels are
expected to be the highest or the points at the limit of human
access. A table such as Figure 8 is filled out for each site's
receptors. The X and Y distances entered in the table are based
upon the set of coordinate axes superimposed upon the diagram
mentioned in Section 4.1. The Z value is the receptor height; for
the TSC analyses ground-based receptors (Z=0) were used.

4.4 PEAK HOUR CONCENTRATION COMPUTATION

The EPA national primary and secondary ambient air quality
standards for carbon monoxide are an annual maximum one-hour
average (not to be exceeded more than once per year) of 35 ppm,
and an annual maximum eight-hour average of 9 ppm. In view of
these standards, each TSC Air Quality Analysis considers reason-
able worst-case situations for one-hour and eight-hour periods and
calculates the carbon monoxide concentrations for each situation
at the chosen receptors.

TSC used, for its one-hour worst case, the traffic and vehicle
speeds for the peak traffic hour (i.e., the 7 a.m. to 8 a.m. rush
hour) with the following meteorological conditions:

RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)

Figure 8.   Receptor Table

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1. Wind Speed: 1 meter per second.

2. Stability: Class E, Stable.

3. Height of the Mixing Layer: 1000 feet or 2000 feet.

4. Wind Direction: Each of the eight principal directions
    (i.e., N, NE, E, etc.).

Since the worst-case conditions can occur with winds from any
direction, the concentrations are calculated for each of the eight
principal directions, rather than just for the most common wind
directions. TSC tests show that the use of either 1000 feet or
2000 feet for the mixing layer height leads to approximately the
same results in the regions near the highway that were analyzed.
Concentrations are tabulated in a table such as that shown in
Figure 9. These are labeled as the Peak Hour Concentrations.

4.5 EIGHT-HOUR AVERAGE CONCENTRATION COMPUTATION

For its worst-case eight-hour period (7 a.m. to 3 p.m.), TSC
used an eight-hour period consisting of one peak hour and seven
off-peak hours. Though the seven off-peak hours will have
different traffic counts and speeds and thus will have differing
amounts of pollutant produced, their total contribution to the
eight-hour average can be represented as seven times the contri-
bution of an average off-peak hour. Therefore, the eight-hour
average concentration is found by averaging the worst-case peak
hour concentration and seven worst-case average off-peak hour
concentrations.

TSC used, for its worst-case average off-peak case, the
average off-peak daytime-hour traffic counts and vehicle speeds,
and the following meteorological conditions:

1. Wind Speed: 2 meters per second.

2. Stability: Class E, Stable.

3. Height of the Mixing Layer: 1000 feet or 2000 feet.

4. Wind Direction: Each of the eight principal directions.

CONCENTRATIONS
(ppm)

WIND SPEED:
STABILITY:
MIXING HEIGHT:

RECEPTOR NUMBER	WIND DIRECTIONS							
	N	NE	E	SE	S	SW	W	NW

Figure 9.   One-Hour Concentration Table

Concentrations are tabulated in a table such as that shown in Figure 9, and are labeled as the Off-Peak Hour Concentrations.

Since the eight-hour average national primary and secondary ambient air quality standard is 9 ppm, only receptor/wind direction combinations that have a peak hour concentration of over 9 ppm are used for the calculation of eight-hour average concentrations. All other receptor wind direction pairs will have low enough eight-hour concentrations to be of no interest. The eight-hour average concentrations are entered in a table such as that of Figure 10.

RECEPTOR NUMBER	8-HOUR AVERAGE CONCENTRATIONS (ppm)				(For receptors with Peak Hour Concentration greater than 9 ppm)			
	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW

Figure 10.   Eight-Hour Average Concentration Table

5. THE MODIFIED EPA MODEL

Each TSC Air Quality Analysis used a TSC-modified version of the EPA Highway Line Source Model to calculate carbon monoxide concentrations. The listings for the TSC Model are in Appendix D. In this section, the original EPA Model and the TSC modifications of it are discussed.

5.1 THE ORIGINAL ZIMMERMAN MODEL

The EPA Highway Line Source Model is an air pollution dispersion model. It is of the Gaussian type, as will be discussed below. The computer program for this model was written by John Zimmerman, EPA National Environmental Research Center, Research Triangle Park, North Carolina. This program is in FORTRAN IV.

The EPA Model can calculate the pollutant concentrations at any number of receptors produced by a single horizontal straight line segment source of uniform emission. It first calculates the location of line sources to represent each lane of a given road, based on the location of the downwind edge of the road, the road width, and the width of the center strip. Then the Model calculates the concentration at each receptor due to each line source. Finally, the Model sums the contributions at each receptor due to each lane to produce the final computed concentration.

The concentration due to a single line source at a receptor is given by:

$$C(R) = \int_{0}^{L} Q_S \, P_R(\ell) d\ell$$

Where:

$C(R)$ is the concentration at receptor R

L   is the length of the line source

Q_S is the line source strength

$P_R(\ell)$ is the concentration produced at R by a unit strength point source located a distance ℓ from the end of the line source.

To compute the integral, the Model divides the line source into smaller line source segments and computes the sum of the contributions of each segment to the pollutant concentration at the receptor. The line source is divided into progressively greater numbers of smaller line source segments until successive calculated values of pollutant concentration seem to have converged. The contribution from each small line source segment is calculated by the trapezoidal rule, which approximates the contribution to the integral by a small line source segment as the average of the contributions of point sources located at each end of the segment. Thus, the above equation becomes:

$$C(R) = \frac{Q_s}{N}\left[\frac{P_R(0) + P_R\left(\frac{L}{N}\right)}{2} + \frac{P_R\left(\frac{2L}{N}\right) + P_R\left(\frac{L}{N}\right)}{2} + \cdots\right] + E_N$$

$$= \frac{Q_s}{N}\left[\frac{1}{2}P_R(0) + \sum_{i=1}^{N=1} P_R\left(\frac{iL}{N}\right) + \frac{1}{2}P_R(L)\right] + E_N$$

Where

N is the number of line source segments of length $\frac{L}{N}$ into which the line source has been divided.

E_N is the error term (which decreases as N increases).

Thus, each step in the calculation of the concentration due to the line source is reduced to the calculation of the concentrations at the receptor due to N point sources. N is continually doubled until a convergence criterion is met. This convergence criterion is discussed in Section 5.5.

To calculate the concentration at a receptor due to a point source, the EPA Model uses the following equation adapted from the Workbook of Atmospheric Dispersion Estimates, Public Health Service Publication No. 999-AP-26, by D. Bruce Turner:

$$P_R(x,y,z,H) = \frac{1}{2\pi U \sigma_y \sigma_z}$$

$$\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left[\exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right) + \sum_{N=1}^{J} A(N)\right]$$

$$A(N) \triangleq \exp\left(\frac{-(z-H-2NL)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H-2NL)^2}{2\sigma_z^2}\right)$$

$$+ \exp\left(\frac{-(z-H+2NL)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H+2NL)^2}{2\sigma_z^2}\right)$$

Where:

P_R is the concentration at receptor R which is located at point (x,y,z) due to a unit point source of pollution located at point $(0,0,H)$. [x is the downwind distance; y is the crosswind distance, z is the vertical distance].

U is the wind speed.

σ_y a function of x, is the standard deviation of concentration in the crosswind direction.

σ_z a function of x, is the standard deviation of concentration in the vertical direction.

L is the height of the mixing layer.

J is chosen such that N=J is the first value of N such that A(N) is less than a given small constant.

This equation is a form of the standard Gaussian plume model of air pollution dispersion. The first exponential accounts for crosswind dispersion. The first z exponential gives the contribution of pollution directly from the source. The second z exponential gives the contribution of pollution which was reflected from the ground. The A(N) terms account for multiple eddy reflections from both the ground and the stable layer.

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The inputs to the EPA Model are:

1. The endpoint of the downwind edge of the road.

2. The width of the road.

3. The width of the road center strip, if any.

4. The height of emissions.

5. The emission strength of each lane of the road.

6. The wind direction.

7. The wind speed.

8. The height of the mixing layer.

9. The coordinates of the receptors.

The Model produces as output the pollutant concentration at each receptor.

5.2 TSC MODIFICATION FOR MULTIPLE SEGMENTS

TSC made five modifications to the original EPA Model. The first of these is a modification to allow the Model to treat multiple road segments. The original Model was designed to calculate concentrations due to a single multilane roadway. However, the TSC Air Quality Analysis Methodology, as discussed in Chapter 4, is based upon dividing a complex road configuration into several road segments and then calculating the contribution of each segment to the pollutant concentration at each receptor. This novel approach required a modification to the original Model to allow:

1. The entering of multiple road segments by specification of their end points.

2. The iteration of the Model over all the road segments so that the concentrations at each receptor due to each road segment could be calculated.

3. The superposition of the concentrations at each receptor due to all the road segments, in order to produce the total predicted concentration at each receptor.

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With these modifications, the Model can be used to calculate
concentrations due to any set of horizontal straight roadways.
Thus, any complex configuration of at-grade roadways can be modeled.
Each linear segment of roadway can be modeled as a separate segment.
Also, each section of roadway having different emission character-
istics can be modeled as a separate segment. In addition, an over-
pass can be modeled as two ground level segments (for the
approaches) and one or more elevated horizontal sections for the
elevated portion. It may be even better to modify the Model to
allow non-horizontal segments, but this has not as yet been done.

5.3   TSC MODIFICATION FOR MULTIPLE WIND DIRECTION AND SECTOR AVERAGING

The second TSC modification of the EPA Model allows the Model
to consider multiple wind directions, rather than a single wind
direction, and to compute principal wind direction concentrations
by sector averaging. As mentioned in Section 4.4, it is possible
for the worst-case traffic and meteorological conditions to occur
for any wind direction. Since the wind direction is a variable of
primary importance in the determination of the pollutant concentra-
tion produced at a given receptor by a given road configuration,
it is desirable to consider many wind directions for each situation
considered. Therefore, the Model was modified to iterate on wind
direction so that results for several wind directions can be pro-
duced sequentially in one Model run. From these results, the
worst-case wind direction can be chosen for each receptor, and
thus the worst-case results can be used. In general the worst-case
wind direction will be different for each receptor.

In the Air Quality Analyses that TSC performed for the five
Baltimore sites, the eight principal wind directions are used. Due
to the well known variability of wind direction at the low wind
speeds being considered, it was decided to use a sector-averaged
pollutant computation of the following form:

$$C_{SA} = \frac{1}{4}\left[C(\theta_n - 22.5°) + 2C(\theta_n) + C(\theta_n + 22.5°)\right]$$

where

C_{SA} is the sector-average pollutant concentration for a principal wind direction.

$C(\theta)$ is the calculated concentration for wind direction θ

θ_n is the nominal angle for the principal wind direction.

Using the multiple wind direction capability, sixteen different Model runs are made using wind directions every 22.5°. The modified Model then automatically computes the pollutant concentration at each receptor for each principal wind direction, using sector averaging.

5.4 TSC MODIFICATION FOR ROAD ENTRY

The third TSC modification to the EPA Model changes the way road segments are entered as input to the Model. The original EPA Model requires the coordinates of the endpoints of the downwind edge of a road segment to be entered. Since the modified Model considers several wind directions, there is no defined downwind edge. Rather than defining a nominal downwind edge, the Model was modified to allow input of the coordinates of the endpoints of the centerline of each road segment.

Under pressure to produce its initial Air Quality Analysis in a very short amount of time, TSC did not realize the need for this modification, and thus entered road centerline endpoints while the Model was assuming that the endpoints of the road downwind edge were being entered. Therefore, the road positions in our initial Air Quality Analysis were displaced by half the width of the road from their correct positions. This introduced an overestimate of about 10% in the maximum calculated pollutant concentration values (and thus a conservative estimate of these maximum values) and an underestimate of certain low concentration values. When this modification was made, an amended Air Quality Analysis was produced.

5.5 TSC MODIFICATION FOR CONVERGENCE

The fourth TSC modification to the EPA Model was a minor
change to improve convergence. As mentioned in Section 5.1, the
number of point sources used to approximate the integral is con-
tinually doubled until successive calculated values of pollutant
concentration seem to converge. The convergence test is based
upon Richardson's Extrapolation:

$$R(n) = \frac{4C_n - C_{n-1}}{3}$$

where $R(n)$ is the Richardson Extrapolation and C_i is the ith calcu-
lated concentration.

A ratio is defined:

$$ratio = \left| \frac{R(n) - R(n-1)}{R(n)} \right|$$

When the ratio is less than .02, convergence is assumed. The
authors found that, for very small values of C_n, many iterations
were often required for the ratio to become small enough for con-
vergence to be assumed. However, these iterations were not con-
sidered to be useful. Therefore, the modification was made to
stop iterating when C_n was less than 10^{-6}. This modification
significantly improved the speed of Model runs.

5.6 TSC MODIFICATION FOR CORRECTION OF VIRTUAL SOURCE PLACEMENT

The final TSC modification of the EPA Model corrects an over-
prediction that TSC found in the EPA Model, involving the use of
virtual sources. TSC has found that, in some cases, the E.P.A.
Model overpredicts pollutant concentrations. This is due to the
way in which the model handles the mechanical mixing of emissions
with air, caused by the motion of the vehicles. This region of
mixing (called the mixing cell) is modeled by placing a virtual
emission source upwind of the road (rather than at the road) so
that the pollutant plume is spread out somewhat, both horizontally
and vertically, when it reaches the actual road position. Thus the

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road acts as an area source. In essence, this means that the road is shifted upwind of its actual location before the pollution due to it is calculated. This situation is shown in Figure 11.

It was found that this process of road shifting will lead to an over-prediction of pollution in those cases where some part of the road is just downwind of the receptor. To take an extreme case, Figure 12 shows a road which is near to, but downwind of, a receptor. When the road is moved to its virtual position it becomes upwind of the receptor. Therefore, though the pollution contribution to a receptor from a downwind road should be zero, the Model will actually calculate a large concentration value at the receptor, since the road is assumed to be at its virtual position.

The need for modification to account for this discrepency was recognized by Dr. Prerau in an analysis of the Model subsequent to the initial TSC Air Quality Analysis and subsequent to the testimony of Mr. Darling. It was decided that the necessary correction could be effected by shifting upwind only that part of each road which was originally upwind of the receptor. With this correction, a road such as that shown in Figure 11 would be shifted as shown in Figure 13, and a downwind road such as that of 12 would not be shifted to a virtual position at all.

The modification discussed above was made and another analysis was performed using the corrected Model. In addition, E.P.A. was notified of this error which they subsequently corrected.

The results of the analysis with a Model incorporating all five of the changes discussed above showed pollutant concentration values that were one-half to two-thirds of the previous results for the maximum values of carbon monoxide concentration and even smaller fractions of the previous results for some other values. These improved results were submitted to the Government Counsel as an amendment to the original Air Quality Analysis. They are shown in footnotes in Appendix A.

The results of the remaining four TSC Air Quality Analyses presented in Appendix E were also obtained, using the EPA Model with all of the five TSC modifications.
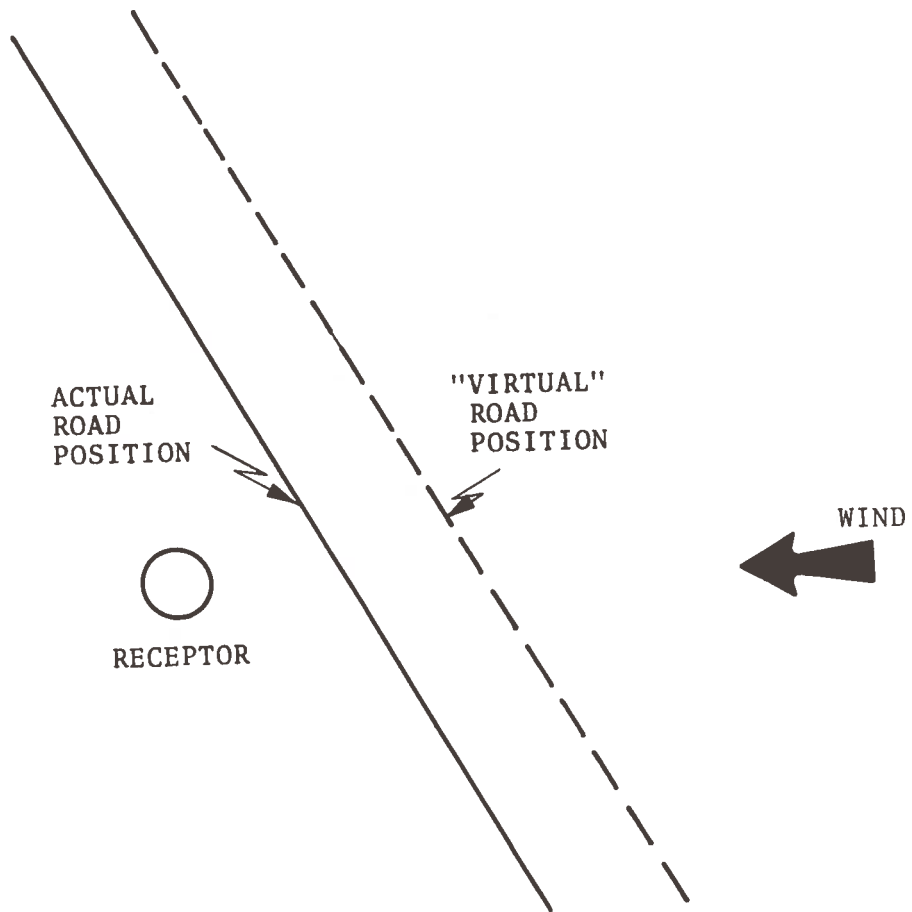
Figure 11. Location of the Virtual Source

ACTUAL
ROAD
POSITION

"VIRTUAL"
ROAD
POSITION

WIND

RECEPTOR
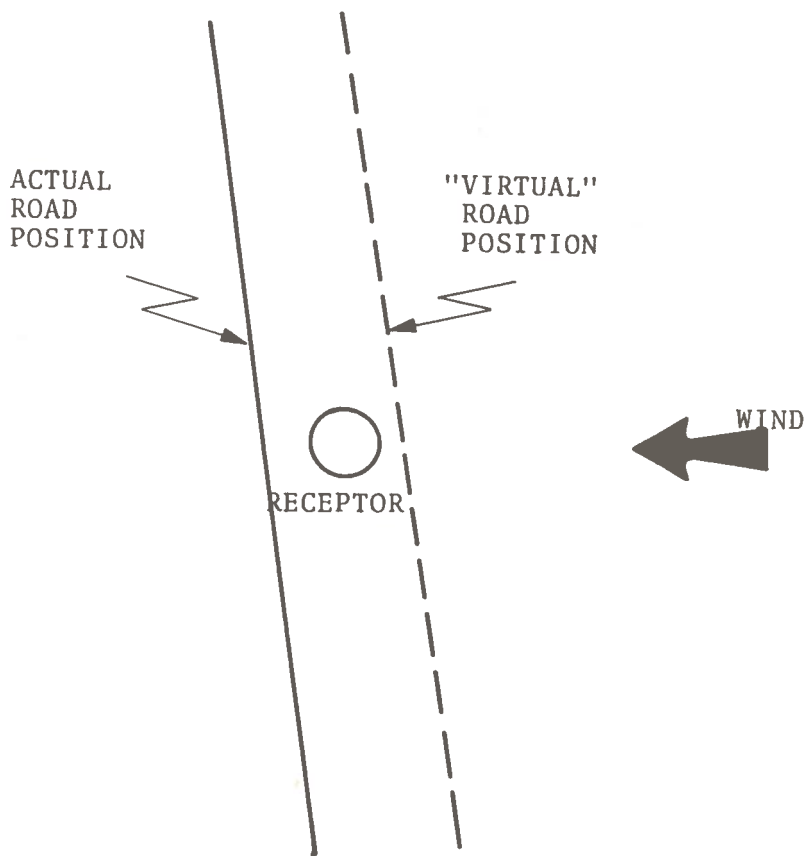
Figure 12.   Illustration of Virtual Source Placement
by the Original EPA Model

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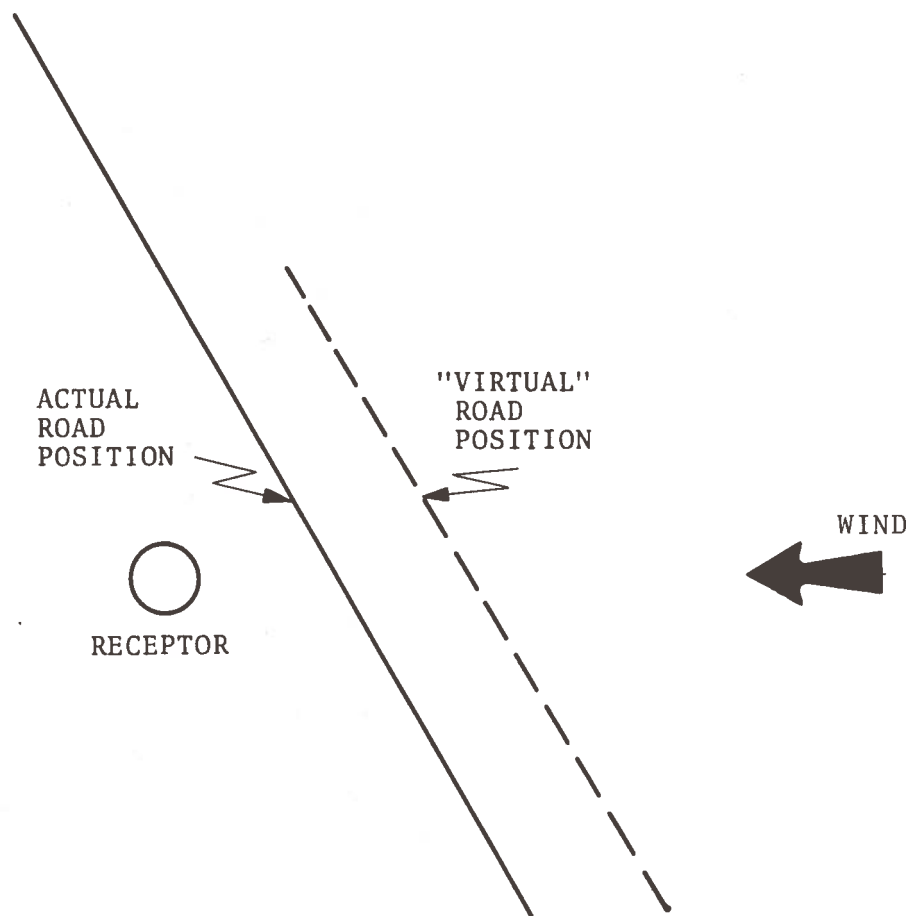
Figure 13. Correction of Virtual Source Placement

6. TSC ANALYSIS OF A PROPOSED COMPLEX INTERCHANGE: THE FRANKLIN-MULBERRY CORRIDOR AT CITY BOULEVARD

6.1 BUILD CASE

6.1.1 Road Segmentation

The Air Quality Analysis for the Franklin-Mulberry Corridor involves four roads: Franklin Street, Mulberry Street, I-170, and City Boulevard. The proposed complex interchange of roadways was divided into twenty-one segments. Figure 14 depicts the physical layout of this site. Table 1 shows how the roadways were defined as input to the model program.

6.1.2 Emission Calculations

The traffic data and emission factors used in this analysis can be found in Table 2 for the peak hour.

6.1.3 Receptor Location

Nineteen receptors were used in this Air Quality Analysis. Eight receptors were positioned on the sidewalks of both Franklin and Mulberry Street. The remaining three receptors were positioned in an area where a large office building is expected to be constructed. The location of these coordinates can be seen in Figure 14. The receptor coordinates are shown in Table 3.

6.1.4 Peak Hour Concentration

The computed concentrations for the peak hour case can be viewed in Table 4. The highest peak hour concentration of 12.95 occurs at receptor 15 with the wind from an easterly direction (i.e., along the Corridor). The maximum peak hour concentration for each receptor is shown in Figure 15. All values are less than one half of the national primary ambient air quality standard.
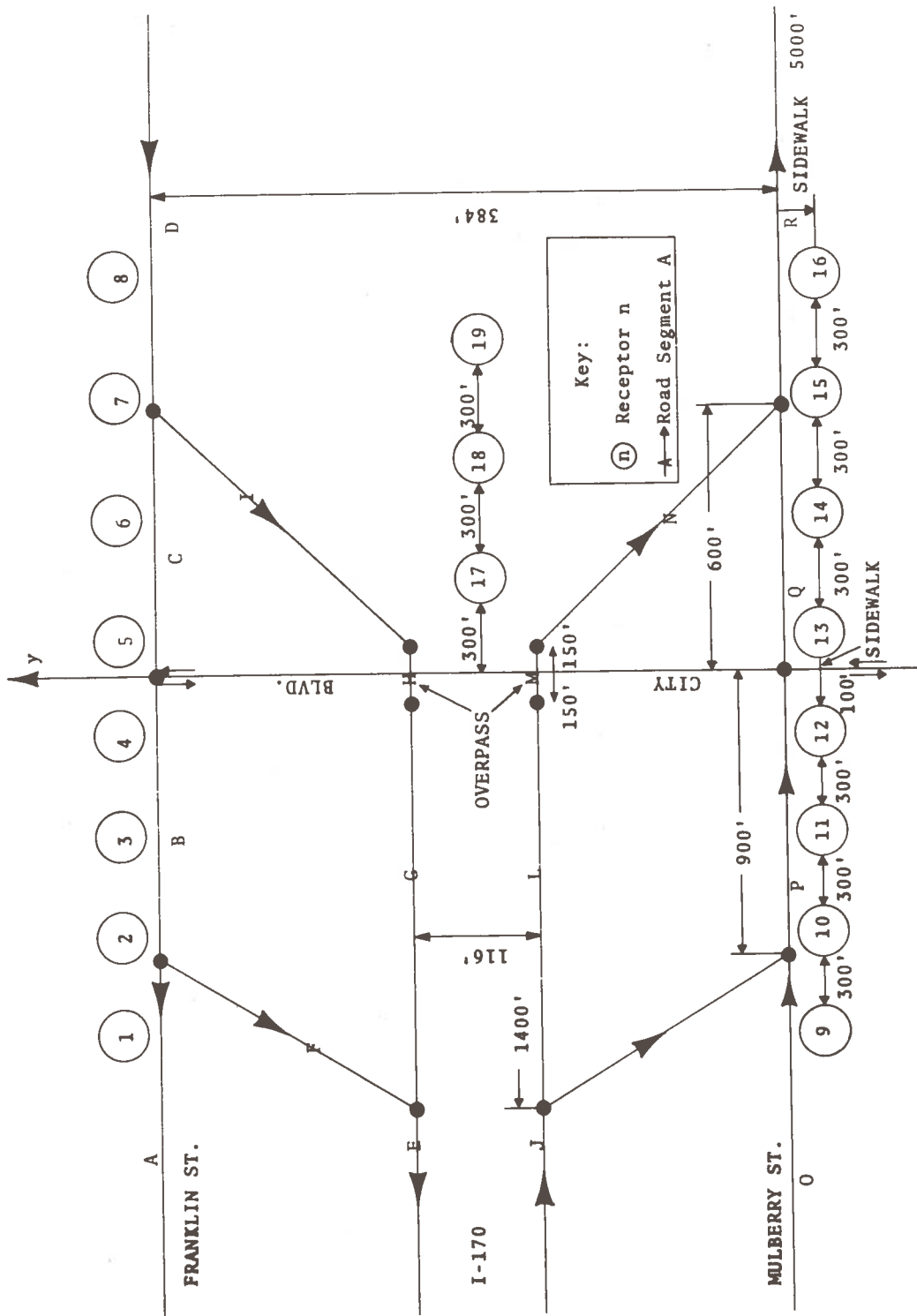
Figure 14. I-170/City Boulevard Interchange in the Franklin-Mulberry Corridor, Build Case

TABLE 1. I-170/CITY BOULEVARD INTERCHANGE, BUILD CASE,
HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
A	-5000	198	-900	198	3	24	0	2
B	-900	186	0	186	3	48	0	4
C	0	192	600	192	3	36	0	3
D	600	192	5000	192	3	36	0	3
E	-5000	58	-1400	58	3	36	0	3
F	-1400	58	-900	192	3	24	0	2
G	-1400	58	-150	58	3	24	0	2
H	-150	58	150	58	21	24	0	2
I	150	58	600	192	3	24	0	2
J	-5000	-58	-1400	-58	3	36	0	3
K	-1400	-58	-900	-192	3	24	0	2
L	-1400	-58	-150	-58	3	24	0	2
M	-150	-58	150	-58	21	24	0	2
N	150	-58	600	-192	3	24	0	2
O	-5000	-198	-900	-198	3	24	0	2
P	-900	-186	0	-186	3	48	0	4
Q	0	-192	600	-192	3	36	0	3
R	600	-192	5000	-192	3	36	0	3
S	0	189	0	5000	3	152	80	6
T	0	-189	0	189	3	152	80	6
U	0	-5000	0	-189	3	152	80	6

TABLE 2. I-170/CITY BOULEVARD INTERCHANGE, BUILD CASE,
PEAK HOUR EMISSIONS

HIGHWAY SEGMENT	10% 2 DIR ADT	COMMUTER SPLIT	VEH/HR	VEH/HR/LANE	SPEED	1978 EMMISION FACTOR FOR CO 5% HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
A	910	1/3	303	152	25	25	3800	.00065
B	3316	1/3	1105	276	25	25	6900	.00119
C	1510	1/3	503	168	25	25	4200	.00072
D	3810	1/3	1270	423	25	25	10570	.00182
E	4706	1/3	1569	523	49	13	6800	.00117
F	2406	1/3	802	401	37	22	8800	.00152
G	2300	1/3	767	384	51	13	5000	.00086
H	2300	1/3	767	384	51	13	5000	.000862
I	2300	1/3	767	384	38	21	8050	.00138
J	4706	2/3	3138	1046	43	14	14600	.00252
K	2406	2/3	1604	802	34	23	18400	.00317
L	2300	2/3	1534	767	46	14	10750	.00184
M	2300	2/3	1534	767	46	14	10750	.00184
N	2300	2/3	1534	767	36	22	16800	.00290
O	910	2/3	607	304	25	25	7600	.00131
P	3316	2/3	2211	553	25	25	13800	.00238
Q	1510	2/3	1007	336	25	25	8440	.00146
R	3810	2/3	2541	847	25	25	21175	.00365
S	2660	1	2660	443	35	22	9750	.00168
T	3170	1	3170	528	35	22	11600	.00201
U	3560	1	3560	593	35	22	13050	.00225

TABLE 3. I-170/CITY BOULEVARD INTERCHANGE, RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)
1	-1000.0	213.0	0.0
2	-700.0	213.0	0.0
3	-400.0	213.0	0.0
4	-100.0	213.0	0.0
5	82.0	213.0	0.0
6	328.0	213.0	0.0
7	682.0	213.0	0.0
8	982.0	213.0	0.0
9	-1000.0	-213.0	0.0
10	-700.0	-213.0	0.0
11	-400.0	-213.0	0.0
12	-100.0	-213.0	0.0
13	82.0	-213.0	0.0
14	382.0	-213.0	0.0
15	682.0	-213.0	0.0
16	982.0	-213.0	0.0
17	300.0	0.0	0.0
18	600.0	0.0	0.0
19	900.0	0.0	0.0

TABLE 4. I-170/CITY BOULEVARD INTERCHANGE, BUILD CASE,
PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 600m

RECEPTOR NUMBER	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW
1	0.26	0.99	6.56	5.76	4.24	5.02	3.48	0.00
2	0.32	1.09	6.86	6.39	4.56	4.93	4.67	0.13
3	0.57	1.62	7.34	6.87	4.91	4.91	5.12	0.00
4	4.70	4.21	8.42	8.70	9.41	4.82	5.43	0.00
5	7.01	0.00	4.80	3.92	10.96	7.88	8.08	4.36
6	0.60	0.08	5.63	3.75	3.95	5.49	5.73	1.67
7	0.32	0.00	6.87	4.48	3.91	5.52	6.28	1.49
8	0.26	0.00	6.83	4.49	3.94	5.33	6.90	0.86
9	4.95	5.84	6.34	1.27	0.34	0.00	5.96	6.92
10	5.51	7.21	10.99	1.26	0.43	0.26	8.23	6.73
11	5.76	7.49	10.79	1.87	0.76	0.00	9.12	6.77
12	8.44	7.42	11.20	5.42	6.29	0.00	9.73	6.64
13	10.22	3.43	7.89	0.00	9.39	5.95	12.72	8.88
14	4.42	4.57	9.89	0.16	0.81	2.23	9.13	6.67
15	5.18	6.34	12.95	0.00	0.44	2.26	10.59	7.48
16	5.18	6.36	12.87	0.00	0.35	1.15	12.02	7.13
17	2.04	1.58	2.18	3.07	3.44	5.37	6.25	3.33
18	1.37	1.28	2.11	2.53	2.53	3.37	4.66	2.05
19	1.39	1.35	2.17	2.71	2.62	3.51	4.09	2.04

Figure 15. I-170/City Boulevard Interchange, Build Case, Maximum Peak Hour Concentrations (ppm)

6.1.5 Off-Peak Hour Emissions

The traffic data and emission factors used in the off-peak hour can be seen in Table 5.

6.1.6 Eight-Hour Average Concentrations

These results are shown in Table 6. The calculations were performed only for those receptors showing greater than nine ppm for the peak hour concentrations. Maximum values for these receptors are plotted in Figure 16. All values are less than one half of the national primary ambient air quality standard.

6.2 NO BUILD CASE

6.2.1 Road Segmentation

The "No Build" case considers the roadway location as it currently exists. The roadways involved in this analysis are: Franklin Street, Mulberry Street, Fremont Avenue, Myrtle Avenue and Greene Street. These roadways were segmented into sixteen sections. These sections of roadway can be seen in Figure 17. The input, defining each section to the model program, can be found in Table 7.

6.2.2 Emission Calculation

The traffic data and emission factors used in the peak hour emission calculation are shown in Table 8.

6.2.3 Receptor Location

The receptors used in this analysis are shown in Figure 17. The receptor coordinates are the same as in the build case (Table 3).

6.2.4 Peak Hour Concentration

The "No Build" peak hour results are found in Table 9 and the maximum value for each receptor is entered in Figure 18. The highest concentration was found at receptor 12 with a west wind.

TABLE 5.   I-170/CITY BOULEVARD INTERCHANGE, BUILD CASE,
OFF-PEAK HOUR EMISSIONS

HIGHWAY SEGMENT	5% 2 DIR ADT	COMMUTER SPLIT	VEH/HR	VEH/HR/LANE	SPEED	1978 EMISSION FACTOR FOR CO 5% HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
A	405	1/2	203	102	25	25	2550	.000441
B	1658	1/2	829	207	25	25	5175	.000895
C	755	1/2	378	126	25	25	3150	.000545
D	1905	1/2	953	317	25	25	7925	.001370
E	2353	1/2	1176	392	51	13	5096	.000881
F	1203	1/2	602	301	38	21	6321	.001093
G	1150	1/2	575	288	53	13	3744	.000648
H	1150	1/2	575	288	53	13	3744	.000648
I	1150	1/2	575	288	39	21	6047	.001046
J	2353	1/2	1176	392	51	13	5096	.000881
K	1203	1/2	602	301	38	21	6321	.001093
L	1150	1/2	575	288	53	13	3744	.000648
M	1150	1/2	575	288	53	13	3744	.000648
N	1150	1/2	575	288	39	21	6047	.001046
O	405	1/2	203	102	25	25	2550	.000441
P	1658	1/2	829	207	25	25	5175	.000895
Q	755	1/2	378	126	25	25	3150	.000545
R	1905	1/2	953	317	25	25	7925	.00137
S	1330	1	1330	222	40	21	4662	.000806
T	1585	1	1585	264	40	21	5544	.000959
U	1780	1	1780	297	40	21	6237	.001078

TABLE 6.   I-170/CITY BOULEVARD INTERCHANGE, BUILD CASE, EIGHT-
HOUR AVERAGE CONCENTRATIONS (ppm), (FOR RECEPTORS
WITH PEAK HOUR CONCENTRATION GREATER THAN 9 ppm)

RECEPTOR NUMBER	WIND DIRECTIONS							
	N	NE	E	SE	S	SW	W	NW
1								
2								
3								
4								
5					3.71			
6								
7								
8								
9								
10			3.24					
11			3.23				2.66	
12			3.43				2.84	
13	3.38				3.14		3.90	
14			2.89				2.76	
15			3.78				3.15	
16			3.77				3.55	
17								
18								
19								

Figure 16. I-170/City Boulevard Interchange, Build Case, Maximum
Eight-Hour Average Concentrations (ppm)

TABLE 7. FRANKLIN-MULBERRY CORRIDOR EASTERN TERMINUS, NO BUILD
CASE, HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
A	-5000	192	-1000	192	3	36	0	3
B	-1000	192	0	192	3	36	0	3
C	0	192	1100	192	3	36	0	3
D	1100	192	5000	192	3	36	0	3
E	-5000	-192	-900	-192	3	36	0	3
F	-900	-192	0	-192	3	36	0	3
G	0	-192	1100	-192	3	36	0	3
H	1100	-192	5000	-192	3	36	0	3
I	-2250	5000	-1000	192	3	48	0	4
J	-1000	192	-900	-192	3	48	0	4
K	-900	-192	350	-5000	3	48	0	4
L(S)	-12	5000	-12	192	3	24	0	2
L(N)	12	5000	12	192	3	24	0	2
M	0	192	0	-192	3	24	0	2
N	1100	5000	1100	192	3	48	0	4
O	1100	192	1100	-192	3	48	0	4
P	1100	-192	1100	-5000	3	48	0	4

TABLE 8. FRANKLIN-MULBERRY CORRIDOR EASTERN TERMINUS, NO BUILD CASE, PEAK HOUR EMISSIONS

HIGHWAY SEGMENT	10% 2 DIR ADT	COMMUTER SPLIT	VEH/HR	VEH/HR/LANE	SPEED	1978 EMISSION FACTOR FOR CO 5% HDV $\frac{gm/mi}{veh}$	$\frac{gm/mi}{hr}$ lane	$\frac{gm/m}{sec}$ lane
A	4065	1/3	1355	451	25	25	11270	.00194
B	5356	1/3	1788	596	25	25	14900	.00257
C	2523	1/3	841	280	25	25	7000	.00120
D	1251	1/3	417	139	25	25	3475	.00060
E	4065	2/3	2710	903	25	25	22575	.00389
F	5356	2/3	3570	1190	25	25	29750	.00513
G	2523	2/3	1681	560	25	25	14000	.00241
H	1251	2/3	834	278	25	25	6950	.00120
I	87	1	87	22	25	25	550	.00009
J	888	1	888	222	25	25	5550	.00095
K	1808	1	1808	452	25	25	11300	.00195
L(N)	3329	2/3	2220	1110	20	28	31080	.00535
L(S)	3329	1/3	1109	555	20	28	15540	.00268
M	1742	1	1742	871	20	28	24338	.00420
N	281	1	281	70	25	25	1750	.00030
O	725	1	725	181	25	25	4525	.00078
P	1572	1	1572	393	25	25	9825	.00169

TABLE 9.   FRANKLIN-MULBERRY CORRIDOR EASTERN TERMINUS, NO BUILD CASE, PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 600m

RECEPTOR NUMBER	N	NE	E	SE	S	SW	W	NW
1	0.63	1.47	9.36	7.51	6.41	5.01	7.17	0.18
2	0.55	1.79	9.02	6.28	6.24	6.35	8.73	0.34
3	0.91	2.63	8.97	6.42	5.80	6.58	8.80	0.04
4	5.09	6.28	9.82	8.10	6.27	6.44	9.02	0.03
5	5.68	0.10	4.16	3.29	4.27	7.35	11.31	6.06
6	0.94	0.13	3.91	3.31	2.76	4.39	8.00	2.55
7	0.57	0.19	3.71	3.33	2.77	3.56	7.02	1.70
8	0.71	0.62	3.46	3.28	3.68	3.32	6.40	1.34
9	6.09	6.93	7.21	3.69	1.23	0.00	13.34	6.45
10	6.75	8.74	13.83	0.36	1.98	2.21	16.92	8.92
11	7.11	9.09	11.95	0.43	1.13	0.97	16.83	8.55
12	9.66	7.76	7.88	1.51	0.87	0.70	17.16	8.49
13	7.89	3.60	7.80	0.56	0.75	1.08	14.47	7.44
14	3.91	3.72	7.66	0.71	0.53	0.50	11.86	6.01
15	3.49	3.97	7.36	1.03	0.50	0.43	10.99	5.54
16	3.62	4.02	7.20	2.65	1.84	0.39	10.55	5.25
17	2.06	1.01	1.49	2.12	1.72	3.00	3.97	3.59
18	1.36	1.02	1.40	2.57	1.95	2.31	3.22	2.73
19	1.33	1.13	1.29	2.58	2.54	2.18	3.03	2.29

Figure 17. Eastern Terminus of the Franklin-Mulberry
Corridor, No Build Case

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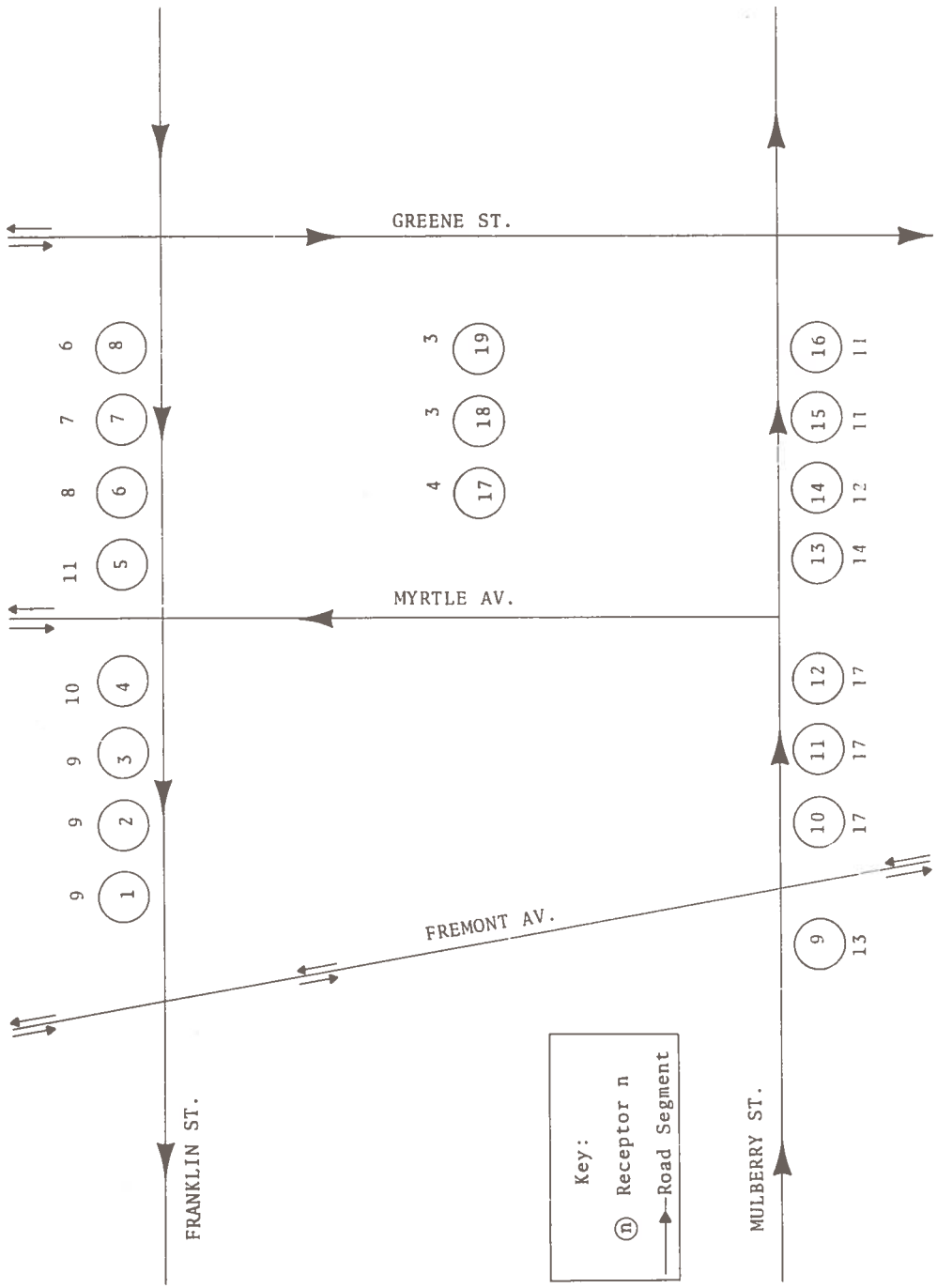
Figure 18. Franklin-Mulberry Corridor, Eastern Terminus, No-Build Case, Maximum Peak Hour Concentrations (ppm)

The value, 17.16 ppm, is about 30% higher than the maximum value
for the Build case (i.e., 12.95 at receptor 15). The "No Build"
peak hour pollution exceeds the Build values at all of the high
pollution receptors, 9-13. However, in no case did either the
"Build" or "No Build" peak hour concentrations exceed one-half of
the national primary ambient air quality standard.

6.2.5 Off-Peak Hour Emissions

The traffic data and emission factors used in the off-peak
hour analysis can be found in Table 10.

6.2.6 Eight-Hour Average Concentration

These results are shown in Table 11 and Figure 19. The
highest concentration found was 4.80 ppm as compared to 3.90 ppm
in the Build case. Again all concentrations for both the "Build"
and "No Build" cases were less than half of the national primary
ambient air quality standard.

6.3 CONCLUSIONS

As stated in Section 3.1, TSC elected to prepare a separate
air quality analysis for the I-170/City Boulevard Interchange
which is the portion of the Franklin-Mulberry Corridor where the
highest air pollution levels could be anticipated in 1978. Thus, it
is not surprising that the TSC-computed peak hour concentrations
of 6-13 ppm in the "Build" case are about twice as large as the
values calculated by the Interstate Division for Baltimore County
for the central portion of the Corridor where lower concentrations
would be expected.

The key points emerging from the TSC analysis are that the
highest pollution levels calculated were greater in the "No Build"
case than in the "Build" case, but in neither case did either the
peak hour or eight-hour average concentrations exceed one-half
of the national primary ambient air quality standards. It would
appear that the effect on air quality is not a major consideration
bearing on the decision to build, or not build, this portion of the
3-A System.

TABLE 10. FRANKLIN-MULBERRY CORRIDOR EASTERN TERMINUS, NO BUILD CASE, OFF-PEAK HOUR EMISSIONS

HIGHWAY SEGMENT	5% 2 DIR ADT	COMMUTER SPLIT	VEH/HR	VEH/HR/LANE	SPEED	1978 EMISSION FACTOR FOR CO 5% HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
A	2033	1/2	1016	339	30	23	7797	.00134
B	2678	1/2	1339	446	30	23	10258	.00177
C	1261	1/2	631	210	30	23	4830	.00083
D	416	1/2	208	69	30	23	1587	.00027
E	2033	1/2	1016	339	30	23	7797	.00134
F	2678	1/2	1339	446	30	23	10258	.00177
G	1261	1/2	631	210	30	23	4830	.00083
H	416	1/2	208	69	30	23	1587	.00027
I	44	1	44	11	25	25	275	.0000474
J	444	1	444	111	25	25	2775	.00048
K	904	1	904	226	25	25	5650	.00097
L(N)	1665	1/2	830	415	25	25	10375	.00178
L(S)	1665	1/2	830	415	25	25	10375	.00178
M	871	1	871	436	25	25	10900	.00187
N	141	1	141	35	25	25	875	.00015
O	363	1	363	91	25	25	2275	.00039
P	768	1	786	197	25	25	4925	.00085

TABLE 11. FRANKLIN-MULBERRY CORRIDOR EASTERN TERMINUS, NO BUILD
CASE, EIGHT-HOUR AVERAGE CONCENTRATIONS (ppm), (FOR
RECEPTORS WITH PEAK HOUR CONCENTRATION GREATER THAN
9 ppm)

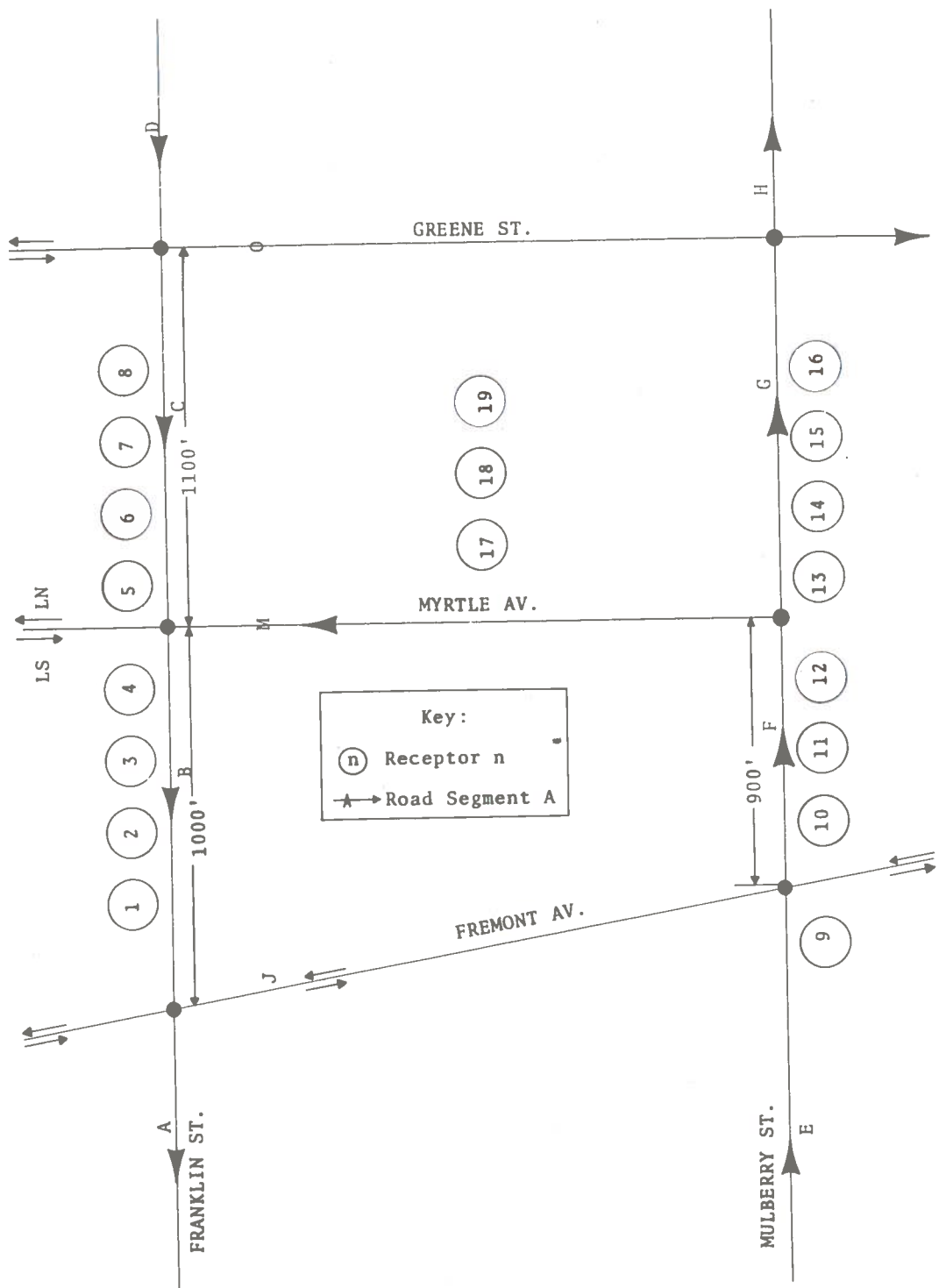| RECEPTOR NUMBER	WIND DIRECTIONS							
	N	NE	E	SE	S	SW	W	NW
1			3.76					
2			3.61					
3								
4			3.65				3.74	
5							4.33	
6								
7								
8								
9							3.71	
10			3.82				4.79	
11		2.62	3.29				4.72	
12	2.90						4.80	
13							4.07	
14							3.34	
15							3.10	
16							2.97	
17								
18								
19								

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Figure 19. Franklin-Mulberry Corridor, Eastern Terminus, No-Build Case, Maximum Eight-Hour Average Concentrations (ppm)

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7. SUMMARY AND CONCLUSIONS

In this report, a case study on the computer analysis of air pollution produced by highways, streets, and complex interchanges has been presented. The case study in question concerns a series of air quality analyses performed by the Transportation Systems Center for sections of the proposed 3-A System of highways in Baltimore.

The Transportation Systems Center became involved in the 3-A System analysis when Mr. Darling was asked by the FHWA and the Justice Department to appear as an air quality expert for the Government in the trial of a citizen suit which attempted to block construction of the 3-A System. Mr. Darling testified as to the adequacy of the air quality portion of the environmental impact statement which had been prepared by the Maryland Department of Transportation for a section of the 3-A System - the Franklin-Mulberry Corridor. He stated that the General Electric Model, which had been used in preparing the environmental impact statement, was a state-of-the-art technique at the time the analysis was done, but that it had many inadequacies. He discussed an air quality analysis which had been performed by the Transportation Systems Center for the portion of the Corridor where the potential for high air pollution would be the greatest. This analysis showed that the national primary standards for air pollutant concentrations would not be exceeded whether this 3-A System section were built or not built, but that estimates of pollutant levels were slightly higher for the latter case. Subsequently, the Transportation Systems Center performed air quality analyses for four additional sites related to the 3-A System.

The air quality analyses for the five 3-A System-related sites are treated in this report as a case study, exemplifying the Transportation Systems Center air quality analysis methodology. This methodology consists of five steps: (1) Road Segmentation - dividing the road configuration into a set of homogeneous straight segments; (2) Emissions Calculation - using traffic volume and

speed estimates to calculate the pollutant emissions of each
segment; (3) Receptor Location - positioning the points at which
concentrations will be calculated at strategic locations; (4) Peak
Hour Concentration Calculation - calculating pollutant concentra-
tions for a peak hour traffic situation; (5) Eight-Hour Average
Concentration Computation - calculating pollutant concentrations
for an eight-hour period consisting of one peak hour and seven off-
peak hours. The procedure for each step is described in this
Report. A set of standard tables are used for data entry in
carrying out the five-step process.

The above methodology was used to calculate pollutant concen-
trations for each of the five 3-A System-related sites. The sites
include highways, streets, and a complex interchange. The com-
pleted standard tables for each air quality analysis are shown in
the Report and the results for each site are given.

The Transportation Systems Center methodology is based upon
the use of the TSC-modified version of the EPA Highway Line Source
Model. The original EPA Model is a Gaussian plume air pollution
dispersion model, specifically tailored for calculating air pollu-
tion dispersion from a single highway line source. This model
was modified for use in the five-step procedure. The modifications
allow for: (1) the use of multiple highway line source segments;
(2) the calculation, in the same run, of the pollutant concentra-
tions produced by winds from each of several directions; (3) the
computation of principal wind direction pollutant concentrations
by sector averaging; (4) the entry of road segments by the coor-
dinates of the endpoints of the center line of the road. A modi-
fication to speed convergence of the model was also included. In
addition, a significant error in the EPA Model involving the place-
ment of virtual sources was found and corrected.

The Transportation Systems Center's five-step approach to the
computer analysis of vehicle-source air pollution (as shown in this
case study) is an easy-to-use, straightforward procedure which can
be followed in the performance of future air quality analyses.
Within the limitations of the model and the traffic estimates used,

it can produce reasonable estimates of worst-case pollutant concentrations for comparison with the EPA national ambient air quality standards or other one-hour and eight-hour standards. Use of an improved or expanded model would allow for a greater variety of applications and for improved accuracy of results.

APPENDIX A

VERBATIM TESTIMONY OF
EUGENE MERRILL DARLING, JR.

ON MAY 1, 1973 AS A WITNESS
FOR THE DEFENSE IN
CIVIL ACTION FILE NO. 72-1041M

UNITED STATES DISTRICT COURT
FOR THE
DISTRICT OF MARYLAND

ATTORNEYS PRESENT DURING MR. DARLING'S TESTIMONY

APPEARANCES FOR PLAINTIFFS:

On behalf of the Movement Against Destruction
John C. Armor, Esq.

On behalf of the Sierra Club:
Roger K. Garfink, Esq.
Alfred H. Kreckman, Jr., Esq.

On behalf of Frank P. and Eleanor Marie Lukowski:
Geoffrey S. Mitchell, Esq.

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APPEARANCES FOR DEFENDANTS:

On behalf of Joseph Axelrod:
Lloyd J. Hammond, Esq.

On behalf of the Mayor and City Council of Baltimore:
Lawrence F. Rodowsky, Esq.

On behalf of Claude Brinegar:
Mrs. Jean G. Rogers, Attorney

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EUGENE MERRILL DARLING, JR., was called as a witness for and on behalf of the Defendants, and, having been first duly sworn, testified as follows:

The CLERK. State your full name for the record.

Mr DARLING. Eugene Merrill, M-E-R-R-I-L-L, Darling, Jr.

The CLERK. Your first name is Eugene?

Mr. DARLING. Eugene.

The CLERK. You may take the stand. Please speak loudly and clearly, sir.

DIRECT EXAMINATION

Mr. RODOWSKY. Mr. Darling, I am showing you a two page statement of qualifications which has been previously furnished to the plaintiffs.

I ask you if you have reviewed that and if that is succinctly accurate except for the spelling of software?

Mr. DARLING. I have.

Mr. RODOWSKY. You can file that as 231, I believe,

Judge MILLER. No. 243. Is there any objections?

Mr. ARMOR. No objection

Judge MILLER. It will be received as Defendants' Exhibit 243.

(Thereupon, the statement of qualifications was marked for identification as Defendant' Exhibit 243 and was received in evidence.)

Judge THOMSEN. Do you want to cross examine on qualifications?

Mr. GARFINK. No, Your Honor.

Mr. RODOWSKY. Mr. Darling, that statement of qualifications refers to a project on which you are working known as TEA.

Can you explain a little more fully what the TEA project is?

Mr. DARLING. Yes. This is our acronym for Technology for Environmental Assessment. It is a program at the Transportation Systems Center which I lead, which is sponsored by the Office of the Secretary, U.S. Department of Transportation which is concerned with analyzing the tools which are currently available for highway planners, airport planners, and other transportation systems planners to study and evaluate and assess the effect of the systems on air quality.

Our approach has been, and we have been at this for about a year and a half now, to acquire existing dispersion models, mathematical dispersion models, which is the main thrust of our program which have been developed by us, by not-for-profit research firms and by companies, and also to acquire air quality data from transportation sites and to use these data to validate the models.

By validation I mean to compare the predicted concentrations which a model produces, with actual measured concentrations at the same points and to report our findings to the Office of the Secretary of Transportation, to the Environmental Protection Agency, and to state, municipal and local agencies who are involved in environmental impact analysis; the purpose being to have a quantitative basis for appraising which tools perform best in doing this type of analysis.

Mr. RODOWSKY. How old is this field of modeling pollution dispersion relative to mobile transportation as opposed to stationary sources?

Mr. DARLING. Well, the basic techniques applicable to this field have been around for a long time. They are based on work that was done many decades ago. However, the actual beginning of applications of these techniques to real world problems came about as a result of the National Environmental Policies Act of 1969, the Clean Air Act of 1970, the Federal Air Highway Act of 1970, all of which now require agencies to file environmental impact statements, so the actual application of models to this problem dates back four, five years, approximately.

Mr. RODOWSKY. In connection with your work at the Transportation Systems Center, have you supervised a survey of mathematical models relating to carbon monoxide dispersion by motor vehicles and other forms of transportation?

Mr. DARLING. Yes. This was the first task under our program; to do a very exhaustive state-of-the-art survey. Our emphasis is on computer modeling of transportation system air pollution because I am in the Information Sciences Division. I have published a report on this subject dated June, 1972, which I believe is the most comprehensive and up-to-date survey available of this field at the present time.

Mr. RODOWSKY. And approximately how many models did your survey uncover as being proposed by anybody?

Mr. DARLING. Well, we have detailed technical specifications of some 34 models. Now, let me

hasten to say that this is not a comprehensive list. We put an advertisement in the Commerce Business Daily and invited anyone in this field with qualifications to submit them to the Transportation System Center. We had inquiries from some 70 firms, but we received detailed information, on a questionnaire which was provided by the Center to those who wished to respond, from 34 firms.

Mr. RODOWSKY. What does the expression "validation of a model" mean?

Mr. DARLING. Well, as I mentioned before, it is a matter of trying to see how well the model's predictions agree with the real world. The model will predict the concentration of carbon monoxide, say, for instance, at a particular point of interest. In order to validate it, you would have to set up a carbon monoxide measuring device at the same point of interest, test the carbon monoxide, measure it, and compare your measured value with what the model predicts.

This is by no means a simple process. In order to model air pollution emissions, one needs a tremendous amount of data. Basically, one needs to know all the characteristics of the traffic, the mix of vehicles, the age of the vehicles, the speeds of the vehicles, the volumes that are being accommodated on the highway, plus other traffic data, particularly emission factors which are multiplied in to give you the actual number of grams of pollution emanating from a segment of the highway, for instance. But that's not all.

In addition to that, one needs meteorological data. One needs to know about the wind conditions, about the stability of the atmosphere, about the mixing

level (which is the layer in which pollution is trapped) and that's not all either. You need to know all about the geography, topography, terrain, types of buildings, types of land that you are dealing with. So it is a very, very complex process and there is very little adequare data available at the present stage which can be used for this type of validation.

Mr. RODOWSKY. Of the approximately 34 models which have come to your attention, have any of these been validated in the sense which you have described?

Mr. DARLING. Not to my satisfaction, and I don't believe to the satisfaction of those who have developed them and used them, and for the reason that I mentioned: the data is not available.

Mr. RODOWSKY. Mr. Darling, have you reviewed the air quality calculations set forth in Exhibit 5 in these proceedings, and I am referring specifically to the supplement to the Franklin-Mulberry environmental impact statement?

Mr. ARMOR. Your Honor, we would object and ask if we could approach the bench for a conference on the record because from here on in we have several major objections to this entire line of questioning.

Mr. RODOWSKY. Well, I don't think that question was objectionable and the next one I think is not going to be -- raise any problems and I am not going much further than that, really.

Mr. ARMOR. Your Honor, our objection is on what this witness has done. He has the background facts and his competence to express an opinion.

Judge MILLER. He is not asking for an opinion. All he is asking is if he looked at it.

Mr. ARMOR. All right, we will withdraw the objection right now.

Mr. RODOWSKY. The question, Mr. Darling, is whether you have reviewed the air quality calculations in the supplement to the environmental impact statement Document 5 in these proceedings?

Mr. DARLING. Yes, I have.

Mr. RODOWSKY. Can you identify the source of the mathematical model used for those calculations?

Mr. DARLING. Yes. It is the model developed by GE and reported in a report dated September, 1971.

Mr. RODOWSKY. Have you reviewed two letters from EPA to the Interstate Division which are marked in evidence in these proceedings as exhibits 232 and 234? I am showing you 232 and 234.

Mr. DARLING. Yes, I have reviewed these.

Mr. RODOWSKY. Can you identify the source of the mathematical model used by EPA in exhibit 232 and 234?

Mr. DARLING. This is the same GE model.

Mr. RODOWSKY. And by the same, do you mean the same as used in the environmental impact statement on Franklin-Mulberry?

Mr. DARLING. Correct.

Mr. RODOWSKY. Now, was the formula used in the environmental impact statement on Franklin-Mulberry and in the EPA letters to which I have just referred, the state-of-the-art as of the time those formula or that formula was used?

Mr. DARLING. In my opinion, this was a state-of-the-art analysis. The GE report was and still is,

I might say, the most comprehensive report on air pollution in the vicinity of a wide variety of highway configurations.

Mr. RODOWSKY. Mr. Darling, have you undertaken to compute carbon monoxide diffusion for the proposed or the area of proposed I-170N and the proposed City Boulevard in Baltimore City on the basis of any of the models other than this GE formula which are now being tested by your Center?

Mr. DARLING. I have.

Mr. RODOWSKY. And who is the author of the model which you have used in that undertaking?

Mr. DARLING. The model is of the type which is most commonly used presently for air quality analysis. It is called the Gaussian Plume.

This particular computer program realization of this model was developed by John Zimmerman at the Environmental Protection Agency, Division of Meteorology, Modeling Branch, at Research Triangle Park, North Carolina.

Mr. RODOWSKY. And what does Mr. Zimmerman's model seek to simulate? And I ask you if you have a diagram here which would assist you in explaining what the model undertakes to simulate?

Mr. DARLING. Yes, I do. Could I address myself --

Mr. GARFINK. Objection.

Judge MILLER. Just a minute. Is there an objection?

Judge THOMSEN. What is the objection? He asked him what this model is intended to do. What is the objection to the question?

Mr. GARFINK. At some point we have to make an objection concerning relevancy, and I think it might be proper for us to approach the bench to make it.

Mr. RODOWSKY. Relevancy?

Mr. GARFINK. Yes, sir.

Judge THOMSEN. Why do you want to come to the bench? You want the witness not to hear it?

Mr. GARFINK. I think it would be helpful if the witness did not hear it.

Judge THOMSEN. Do you object to the witness leaving the room?

Mr. RODOWSKY. Not at all, sir.

Judge THOMSEN. All right, let the witness leave the room. It is inconvenient to have a reporter up here if we don't have to.

(The witness left the room, and the following proceedings took place in the absence of the witness:)

    - - -

Mr. GARFINK. May it please the Court, this whole subject is a very difficult one for the Court and for the lawyers to understand. But as I understand, the basis of what this witness will testify about will be the calculation of a carbon monoxide concentration using so-called Gaussian Plume Model, and our information is that --

Well, on the status of the case at the present time, there has been envidence concerning the use of a model called the G.E. study model which is a model designed to determine, mathematically, carbon monoxide calculations in the proximity of the edge of the road.

As we understand the model that the witness is about to testify about, it is not valid for sources less than 300 feet away -- or maybe just the opposite. It is not sensitive with respect to receptors, which are closer than 300 feet to the source of the pollution, which would then put us in the position, Your Honor, of trying to compare apples with oranges.

Judge THOMSEN. He has testified this is the one most frequently used for this purpose; that is the one he is going to use. Isn't that what he just said?

Mr. RODOWSKY. I think what he meant is the Gaussian plume underlying theory is the one most frequently used.

Judge THOMSEN. This theory?

Mr. HAMMOND. That's right. The theory for the model is based on Gaussian plume.

Judge THOMSEN. I am not quite sure I understand the difference between a theory upon which the model is based and the model.

Mr. ARMOR. Your Honor, we have other objections as to the basis for which his calculations came, in that the transportation figures testified to by the previous witness did not concern Franklin-Mulberry as an independent facility.

Second, that there isn't an explanation of what the wind roses are which were used in his calculations and, depending on the basis, if there is no occurrence in 24 hours, it may still leave major sections of inversion in hours during the day. So it is not properly --

Judge THOMSEN. Isn't that a matter of cross-examination?

Mr. ARMOR. And, Your Honor, there is some other point we wish to raise, and that is the defendants are offering evidence as to state-of-the-art in 1973 concerning air pollution. And if they are conceding that state-of-the-art in all areas to be used at 1973 in analyzing the environmental impact statement, that is fine. But if not, we would object to their using the standard.

Mr. RODOWSKY. That is not what the evidence was from the witness.

Judge MILLER. That was as of the date the things were prepared, as I understand.

Mr. ARMOR. As of his report in 1972, which he testified to.

Judge MILLER. The last witness just testified as to the state-of-the-art as of the date the particular things in question were prepared; that is, the letters and 5-B.

Mr. ARMOR. Yes. But he also has stated that his work and the formula he is using, especially the validation, post-dates the G.E. report. So if he wants to talk about the G.E. formulas, fine.

But it we are going beyond that, then we have an objection.

Judge THOMSEN. The objection is overruled. You may cross-examine on it.

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Mr. RODOWSKY. Mr. Darling, the pending question was whether you would explain to the Court what the Zimmerman model is designed to simulate. And I would ask you, to assist in the explanation of that simulation, would a diagram be helpful to you?

Mr. DARLING. Yes.

Mr. RODOWSKY. And I think you indicated that it would.

Mr. RODOWSKY. And if the Court please, I would like to have the witness permitted to put up on the board what you might call a configuration diagram, so he can explain what this model, which was used, is designed to represent.

Judge MILLER. You want to mark this for identification?

Mr. RODOWSKY. Yes.

Judge MILLER. Defendants Exhibit No. 244.

(Thereupon, a configuration diagram was marked for identification as Defendants Exhibit No. 244.)

Mr. DARLING. May I proceed to the easel?

Judge MILLER. You must wait for the question.

Mr RODOWSKY. By use of the diagram (Figure 14), would you explain what the model is designed to simulate?

Mr. DARLING. The model breaks up any network of streets into line segments. We have analyzed two cases: The build case which is the full 3-A System, with I-170 and City Boulevard interchange with the proposed Franklin and Mulberry configuration; and the "no build" case, without City Boulevard and I-170.

What the model does is to compute the pollution emanating from each road segment in this complex. To give you an example, this is a segment here, from here out to a distance of about 5,000 feet.

Here's another one, yet another one, and this one, so Franklin is four separate segments. Similarly: Mulberry has four, here, here, and here. Each one of the entrance and exit ramps is a separate segment.

I-170 is broken up into three segments - here and here. In the exhibit, there is a natural labeling of each one of these segments - I don't know what page that is.

Similar situation on the "no build" case (Figure 17). This would be one segment, and so forth. So what one does is to compute the contribution of each segment of road to the pollution at each one of a number of receptors -- which in this diagram are labeled 1, 2, 3, and so forth, up to a total of nineteen -- and this, one sums up -- this is a standard technique called super-position -- the contribution from each one of the segments with respect to each receptor point.

Is that sufficient?

Mr. RODOWSKY. Yes, thank you.

Mr. RODOWSKY. If the Court please, to follow the next phase of Mr. Darling's testimony, I would like to have this report marked for identification.

Judge MILLER. Marked as Defendants Exhibit 245 for identification.

(Thereupon, a report of model was marked for identification as Defendants Exhibit No. 245.)

Mr. RODOWSKY. Referring to the report which you have prepared, Mr. Darling --

Judge MILLER. Do you have another copy, by any chance? Do you have an extra one?

Mr. RODOWSKY. Sure.

Judge MILLER. All right.

Mr. RODOWSKY. The first three pages of that report are an explanation of the model, perhaps in somewhat more technical terms than the description which you gave, working from the diagram?

Mr. DARLING. Yes. This is the writeup of the model that was prepared by Mr. Zimmerman, and it came to us with a deck of cards that he furnished with it.

Mr. RODOWSKY. These are computer cards, I take it?

Mr. DARLING. Computer cards, yes. Excuse me.

Mr RODOWSKY. Now, page 4 of your

proposed report, you have listed there the various inputs into the model; is that correct?

Mr. DARLING. That's correct.

Mr. RODOWSKY. And with respect to highway segment end points for the "build" (Table 1) and "no build" (Table 7) situation, what was the source of the information used in the model for those particular inputs?

Mr. DARLING. This was provided by the Interstate Division.

Mr. RODOWSKY. And referring to the input for height of the emissions, what is the source of that information? From the standpoint of the build alternative (Table 1).

Mr. DARLING. This also comes from the Interstate Division, as far as the height of the overpass of I-170 over City Boulevard. The "3-foot" value is the height of the tailpipe of an automobile. It is the standard height that is used in these models.

Mr. RODOWSKY. Now, you have a wind speed input. And as I read that, you are using one meter per second for peak hour?

Mr. DARLING. That's correct.

Mr. RODOWSKY. And what is your reason for the use of that wind speed?

Mr. DARLING. This is the "worst case" situation. Less than or equal to one meter per second is a "calm" by meteorological definition.

Mr. RODOWSKY. And you used certain wind directions. Would you explain the reason for the use of those directions?

Mr. DARLING. These are the most frequent wind directions in the Baltimore area, as taken from the wind rose that was previously mentioned.

Mr. RODOWSKY. What does "stability class" mean in this model?

Mr. DARLING. "Stability class" is a parameter of the Gaussian plume formulation. It is really a measurement of the degree to which anything emitted into the atmosphere is mixed up and dispersed.

If the stability is high, things tend to remain in the atmosphere and not become mixed with fresh air. If stability is high -- excuse me.

If the stability is low, then one has a good deal of turbulent mixing, and any pollutants injected into the atmosphere, so "worst case" would use a stable atmosphere.

What we have done is a "worst case" type of analysis.

Mr. RODOWSKY. And what is the mixing layer input?

Mr. DARLING. The mixing layer is the height at which a temperature inversion occurs. Which means that, at that point, the temperature is increasing with height, and any materials that are emitted into the atmosphere are trapped below that height and cannot escape to a higher level.

Mr. RODOWSKY. And what was the basis for the use of 600 meters as the height of the mixing layer, for the purpose of the calculation which you have made?

Mr. DARLING. Based on the study by George Holsworth, of EPA, Raleigh-Durham, this is the average summer morning mixing height in the Baltimore area.

Again, summer is the worst pollution season.

Mr. RODOWSKY. Now, with respect to your next input, the coordinates of receptors, would any other pages in your report assist you in explaining what that is?

Mr. DARLING. For the build case, the next figure on page 5 of the exhibit shows the location of these. Each receptor is located 300 feet from the adjoining one, the only exceptions being four and five at the top on Franklin Street flanking City Boulevard (Table 1).

Four is only one hundred feet from City Boulevard and five is actually right on the curb, three feet each way from the City Boulevard and Franklin and similarly 12 and 13 on Mulberry at City Boulevard are also -- 13 is on the sidewalk and 12 is one hundred feet west of City Boulevard.

All of the other receptors are separated by three hundred feet.

Mr. RODOWSKY. That is one from another?

Mr. DARLING. One from another, correct.

Mr. RODOWSKY. But in relation, sir, to the theoretical receptors on Mulberry Street, where are those receptors in relation to the curb line of Mulberry Street?

Mr. DARLING. They are on the sidewalk three or four feet away from the street.

Mr. RODOWSKY. Is that true likewise with respect to Franklin Street?

Mr. DARLING. Yes. They are completely symmetrical.

Mr. RODOWSKY. What are receptors 17, 18 and 19 in the diagram appearing on page 5 designed to represent?

What area?

Mr. DARLING. I was informed that is was proposed that a building might be located in this area and therefore this might be a region of interest for air quality.

Mr. RODOWSKY. Do you know what building that you were referred to?

Mr. DARLING. I think it is the Social Security Building, I believe.

Mr. RODOWSKY. Now, would you explain the factors set forth on page 6 of your report and ask if that is the table to which on page 4 there is a reference under the heading "Emission Rate"?

Mr. DARLING. That is true. For the build case, these are the peak hour emissions (Table 2).

Mr. RODOWSKY. And page 7 represents what?

Mr. DARLING. This is the off-peak hour (Table 5). Our definition of peak hour is ten percent of average daily traffic, two directional traffic, which again is a very conservative figure. Eight percent is the one normally used. Off-peak is five percent of the two directional average daily traffic.

Mr. RODOWSKY. When you say our definition --

Mr. ARMOR. Excuse me. The report we have has no page numbers. If the same is true of the Court when you say page 6, we would like to refer to it.

Judge THOMSEN. Ours are numbered. Do you want to come up and key them?

Mr. RODOWSKY. If the Court please, I apologize. I was so anxious to get a copy of this to them early they got one that was not numbered.

Judge THOMSEN. Well, they are consecutive pages, aren't they?

Mr. RODOWSKY. Yes.

Judge THOMSEN. Page 1 -- there is a cover sheet and then page 1. Other than that, they seem to go along.

Mr. ARMOR. All right, that is

squared away. Thank you, Your Honor.

Mr. RODOWSKY. With respect to calculations relating to the assumed build situation that you have described, Mr. Darling, are there any inputs into the Zimmerman model other than those which you have already described?

Mr. DARLING. I'm not sure that I understand the question.

Mr. RODOWSKY. Well, have we covered all the assumptions which were made for purposes of calculation?

Mr. DARLING. Yes. The inputs listed on page 4 and these are the emission values that were used for 1978 for the peak hour emissions (Table 2) and for the off-peak (Table 5) on the next page.

Mr. RODOWSKY. I ask you what are the results of the application of the model with the inputs described with respect to the build situation for the area of I-170 and City Boulevard as you have described it schematically?

Mr. DARLING. Okay, Let me first state that the data shown there are only a selection of all the computations that we made, namely those cases where either the one hour peak or the eight-hour average were equal to or greater than half the national prime ambient air quality standard.

Now, in the case of the one hour peak, this is 35 parts per million, so anything 17 and above appears up there in the green letterings, and in the case of the eight hour average, it is nine parts per million, so anything above five or above eight percent under the eight-hour average.

We computed the concentrations at all the nineteen receptor points, and for all of the wind directions indicated. These are the values for the worst wind direction, and which fulfill the criteria shown.

One can see that for the one-hour peak case, both for the year 1978, of course, the one-hour peak case, the largest concentrations occurred at receptors 15 and 16, 24* and 25* parts per million, respectively, both below the standards (Note: Figure 15 shows corrected maximum peak hour concentrations for the build case).

In the case of the 8-hour average, the value of 7* occurred at the same points, which is 2 parts per million below the ambient air quality standards (Note: Figure 16 shows corrected maximum eight hour average concentrations for the build case).

In the "no-build" case -- excuse. I have to get my own diagram.

Judge MILLER. What you have been referring to are those which are on Defendants Exhibit 244 for identification, the graph, and not the ones that are in your report:

Mr. DARLING. They are identical, Your Honor.

Judge MILLER. I understand that. You have included in your report all of the calculations.

Mr. DARLING. Correct.

Judge MILLER. For all nineteen.

Mr. DARLING. That's correct.

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* Revised one-hour peak computations showed 13 ppm for receptors 15 and 16. Revised eight-hour average values were 4 ppm at receptors 15 and 16. See Chapter 5 for a discussion of the program revisions.

Judge MILLER. Whereas, you have only shown the worst ones there.

Mr. DARLING. That's right, the ones that are of interest. The exhibit here is also repeated in my handout on the "no build" cases, page 14, and here by the same criterion, we see that it says that the highest level of pollution occur at receptors 10, 11 and 12; 29* and 30* parts per million there, which is higher by about 20 per cent than the "build" case (Note: Figure 18 shows corrected maximum peak hour concentrations for the no build case).

The 8-hour averages occur at the same three receptors and are 8* parts per million, which is one part per million under the standard (Note: Figure 19 shows corrected maximum eight-hour average concentrations for the no build case).

Mr. RODOWSKY. It might be more meaningful, Mr. Darling, if we went back to page 8 in your report. And as I understand it, page 8 (Figures 15 and 16 combined) of your report corresponds with what has been reflected on the larger Exhibit 244, at the top portion, under the heading "build"?

Mr. DARLING. That's correct.

Mr. RODOWSKY. Now, page 9 of your report reflects what?

Mr. DARLING. Page 9 has the complete analysis for the "build" case for the five different wind directions indicated,

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*The following revised values were computed: one-hour peak 17 ppm at receptors 10-12; eight-hour average 5 ppm at receptors 10-12. See Chapter 5 for a discussion of the program revisions.

and for the nineteen receptors (Figure 18 is the corrected version).

Mr. RODOWSKY. And page 10 of the report reflects what?

Mr. DARLING. This is the eight-hour average concentrations for those cases where the one-hour peak was greater than or equal to 9 parts per million - which is the 8-hour standard (Table 6 is the corrected version).

These are the only cases in which you could possibly have an eight-hour average above 9 and, as you can see, none of them reach this value.

Mr. RODOWSKY. Now, page 11 (Figure 17) of your report reflects what?

Mr. DARLING. This is the bottom part of the posted exhibit. The "no build" case.

Mr. RODOWSKY. And in the "no build" case, do the numerals encircled there place the theoretical receptors in the formula?

Mr. DARLING. Yes. They are the identical receptors as shown in the "build" case, same locations.

Mr. RODOWSKY. And in the "build" case, are the roadways referred to there, Franklin Street, Mulberry Street, Fremont, Myrtle and Greene, placed on the basis of the distance information furnished to you by Interstate?

Mr. DARLING. That is the "no build" case. You mean the "no build."

Mr. RODOWSKY. The "no build" case.

Mr. DARLING. Yes, that's correct.

Mr. RODOWSKY. And with respect to the use of the formula in the "no build" instance, are all of the inputs set forth on page 4 the same, with the exception of

the emission grade?

Mr. DARLING. No. The "no build" cases are entirely different.

Mr. RODOWSKY. Oh, excuse me.

Mr. DARLING. This is the input data as set forth on page 12 (Table 8).

Mr. RODOWSKY. From the standpoint of the highway segments, which is reflected on 11 (Figure 17), have you used the same wind speed, and wind directions, stability class, mixing layer, for purposes of the "no build" alternative?

Mr. DARLING. Yes. The meteoroligical variables are the same.

Mr. RODOWSKY. With respect to your peak and off-peak hour emissions, as used in the "no build" alternative, are they set forth on page 12 (Table 8) and 13 (Table 10) of your report?

Mr. DARLING. Correct.

Mr. RODOWSKY. And with respect to the assumptions on peak and split, what are the basis of the assumptions in the "no build" alternative?

Mr. DARLING. All of these data come from the Interstate Division.

Mr. RODOWSKY. Do you know the purpose of making the assumption of 10 per cent peak and two-thirds/one-third, commuter split?

Mr. DARLING. These are all very conservative assumptions.

Mr. RODOWSKY. And now would you explain, Mr. Darling, what the results of your calculations were with respect to the "no build" alternative, from the standpoint of the diffusion of carbon monoxide, as predicted by this model?

Mr. DARLING. Yes. We can refer to page 14 (Figures 18 and 19, combined) in the exhibit, and see that the highest level of carbon monoxide occurred at receptors 10, 11 and 12, which are south of Mulberry Street, between Fremont and Myrtle. This is a very heavily traveled area.

The traffic volumes are something in excess of 50,000 per hour.

Mr. RODOWSKY. Per hour?

Mr. DARLING. Per day -- excuse me.

The values that are recorded here are 29* to 30* parts per million for the one-hour peak, and the associated 8-hour average is 8* parts per million.

Mr RODOWSKY. How do your findings for the "no build" alternative compare to the projected diffusions for the "build" alternatives?

Mr. DARLING. These findings show that for some receptors the "no build" case has considerably higher pollution.

Mr RODOWSKY. If the Court please, I would ask that Mr. Darling's report 245 be admitted into evidence, as well as the large diagram 244.

Judge MILLER. Any objections?

Mr. GARFINK. No objections.

Judge MILLER. It will be received as Defendants' Exhibit 244 and 245 respectively.

(THEREUPON, Defendants' Exhibit Nos. 244 and 245 were received in evidence)

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*Revised computations show one-hour peak concentrations of 17 ppm instead of 29 to 30 ppm and eight-hour average concentrations of 5 ppm instead of 8 ppm at receptors 10-12. See Chapter 5 for a discussion of the program revisions.

Mr. RODOWSKY. No other questions of Mr. Darling.

Judge THOMSEN. We will take our recess now.

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AFTERNOON SESSION

Cross-Examination   2:36 pm.

Mr. GARFINK. Mr. Darling, can you tell me what transportation system was assumed in the project traffic figures that you used?

Mr. DARLING. Which case are you referring to?

Mr. GARFINK. Well, the "build" case.

Mr. DARLING. All of the figures that I used for the "build" case came from the Interstate Division.

Mr. GARFINK. Did you know whether they included traffic figures for the Outer Harbor or Crossing?

Mr. DARLING. I simply accepted the figures that were given to me. I am not an expert on traffic analysis.

Mr. GARFINK. In your model, did you make any assumptions with respect to traffic on existing streets?

Mr. DARLING. I made no assumptions. I used the data that were provided to me.

Mr. GARFINK. Do you know whether the data provided you assumed any traffic figures for local streets?

Mr. DARLING. I am not competent to testify to that point.

Mr. GARFINK. If the traffic figures employed did not include any traffic figures for local streets, would your results for carbon monoxide pollution levels increase or decrease?

Mr. RODOWSKY. Objection on the assumption. There is an exhibit in evidence, which is 239, which shows existing Franklin and Mulberry schematically. Maybe it is the phrase "local streets" --

Judge MILLER. I'm not sure what he means by "local streets," myself.

Mr. GARFINK. Mr. Darling, do the emission factors that you used in making your calculations take into account the one-year delay granted by the Environmental Protection Agency for the retro-fitting catalytic converter devices?

Mr. DARLING. No.

Mr. GARFINK. They do not.

If you had assumed a factor for the one-year delay, would that increase or decrease the calculation of carbon monoxide pollution levels?

Mr. DARLING. I presume it would have increased them somewhat. However, I might point out that the relationship is such that for freeways the difference between two contiguous years, at that period of time, would be quite small. I can't say precisely what. But it would not be a major effect.

Mr. GARFINK. Do your emission factors for automobiles take into account the particular vehicle mix by years?

Mr. DARLING. Yes. they do.

Mr. GARFINK. That are present in Baltimore?

Mr. DARLING. For the year 1978.

Mr. GARFINK. The year 1978.

Have you included in your model the carbon monoxide impact of

stop-and-go traffic?

Mr. DARLING. This is, I understand, built into the speed and traffic flow data which was provided me by the Interstate Division.

Mr. GARFINK. But you don't know?

Mr. DARLING. I have discussed this point with Mr. Wagner, and he tells me that this is a correct representation of the traffic flow, which would include this effect.

Mr. GARFINK. Have you measured the actual levels of carbon monoxide in the Franklin-Mulberry corridor today?

Judge THOMSEN. You mean the witness himself?

Mr. DARLING. During my lunch period, you mean?

Mr. GARFINK. I just want to establish for the record you have not actually measured it.

Mr. DARLING. No, sir.

Mr. GARFINK. Could you describe for the Court whether you included or incorporated in your model the irregular topography of the Franklin-Mulberry corridor, including the part of the road that is depressed, the rising ramps, and the surrounding buildings?

Mr. DARLING. The analysis that I did is for the interchanges that are shown on the exhibit. For these portions of road, Franklin-Mulberry and City Boulevard are all at grade highways and I-170 overpasses, City Boulevard at the height of 18 feet as mentioned in my previous testimony. I did not analyze the cut section of I-170.

Mr. GARFINK. Let me ask you, Mr. Darling, do you think your results are accurate?

Mr. DARLING. What do you mean by "accurate"?

Mr. GARFINK. Well, you used the workbook of atmospheric estimates prepared by the U.S. Environmental Protection Agency, prepared by D. Bruce Turner?

Mr. DARLING. I used it, you say?

Mr. GARFINK. Did you use this?

Mr. DARLING. I did not use it.

Mr. GARFINK. In making your model?

Mr. DARLING. It is not my model, sir.

Mr. GARFINK. Is this the workbook, Mr. Darling, the workbook that is referred to in the second page of your report?

Mr. DARLING. Yes, sir.

Mr GARFINK. I offer this as Plaintiffs' Exhibit 246 for identification.

Judge MILLER. You want it marked for identification?

Mr. GARFINK. Marked for identification.

Judge MILLER. All right, it will be marked for identification as Plaintiffs' Exhibit 246.

(THEREUPON, workbook of atmospheric estimates (EPA), was marked for identification as Plaintiffs' Exhibit No. 246.)

Mr. GARFINK. Mr. Darling, I show you the figure 3-2, on page 8. Would you explain to me what that means?

Mr. DARLING. This figure does not bear any relationship to my analysis.

Mr. GARFINK. Would you explain that? You refer to it in your exhibit.

Mr. DARLING. What is referred to is the equation upon which the Zimmerman computer program is based. The analysis that I did

could not be done using this document.

Judge MILLER. When you refer to "this document," you are referring to the workbook?

Mr. DARLING. Yes, sir.

Judge MILLER. Mr. Darling, can you tell me whether the model that you employed to make your calculations is accurate within 300 feet downwind of the source for measuring carbon monoxide?

Mr. DARLING. You say downwind?

Mrs. ROGERS. Objection, Your Honor. I believe the witness indicated some concern as to the definition of "accurate" as used by Mr. Garfink in his prior question. I think it should be clarified in this question.

Mr. GARFINK. All right.

Do you believe your calculations are accurate to the factor of 3?

Mr. DARLING. I don't think I can answer the question as phrased in that way.

Do you mean anywhere, everywhere, for all time, for all places?

Mr. GARFINK. No, for the calculations that you made in the "build" and "no build" alternatives, Mr. Darling.

Mr. DARLING. Yes.

Mr. GARFINK. Do you think that your computation, your calculation of carbon monoxide pollution levels in the Franklin-Mulberry corridor are as accurate as the factor of 3?

Mr. DARLING. Oh, yes, certainly.

Mr. GARFINK. More accurate?

Mr. DARLING. More accurate.

Mr. GARFINK. How accurate?

Mr. DARLING. This again is a question that is hard to answer, as I testified earlies. Those models have not been adequately validated.

However, I have looked into some figures on the validation of similar kinds of models, and the typical errors run 60 to 80 per cent. However, I should also add that those errors are generally for low pollution cases; that is, where the average concentration of carbon monoxide is, say, of the order of 5 or 6 parts per million.

So we are only talking about errors of 2 to 3 parts per million as being typical.

Now, I would also hasten to add that the samples are small and this model, like all other models available for analysis, has not been adequately validated.

Mr. GARFINK. Isn't it possible that the carbon monoxide levels measured for the build alternative for the highest peak hour, which was somewhere around 30 parts per million, that they could be low by as much as one-third?

Mr. DARLING. Well, I think you have to understand that when you are dealing with a crude tool, as all of these dispersion models now available are, you attempt to make the most conservative estimate by taking a "worst case" analysis.

That is, considering metheorological conditions which are very unfavorable by considering particular wind conditions and height of the temperature inversion.

This is the way one attempts to arrive at a "worse case" estimate.

Mr. GARFINK. You didn't answer my question.

Could you be erroneous by two-thirds?

Mr. DARLING. This is conceivable.

Mr. GARFINK. It is conceivable?

Mr. DARLING. Yes.

Mr. GARFINK. Okay.

Now, is the model which you have used in making your calculations applicable to sources downwind closer than three hundred feet?

Mr. DARLING. Yes, sir.

Mr. GARFINK. How closely?

Mr. DARLING. Well, essentially as close as you want. It is true that the Turner workbook only goes down I believe to, what is, I believe one hundred meters, the extension of the dispersion curves.

However, the studies that have been done by S.R.I. in St. Louis and in San Jose, California, have empirically extended these curves down to distances close to the highway.

The model as developed by EPA has no restriction on closeness to the highway.

Mr. GARFINK. Do you feel that the model that you have used here is comparable to the GE study model?

Mr. DARLING. In what sense?

Mr. GARFINK. In the ability to measure edge of the road carbon monoxide calculations.

Mr. DARLING. I think that it is in the same class from that point of view. It is a state-of-the-art model. None of them are very good.

Mr. GARFINK. Excuse me a minute.

Mr. Darling, in your direct testimony you said you had seen the figures in the supplement to the final environmental impact statement on Franklin-Mulberry and that the formula used there was drawn from the GE model; did the formula used by the Inter-

state Division, to your knowledge, leave out any factors or variables found in the GE model?

Mr. DARLING. Well, as you know, Mr. Armor, there were two formulations that were developed by GE. One which we might call the complete formulation that was used by Dr. Marcus in his analysis.

Another one is based upon a simple regression relationship which was used by EPA in their reply to the Interstate Division, and which was used by the Interstate Division in the preparation of the environmental impact statement.

So if you are referring to the second one, the answer is no.

Mr. GARFINK. Would you state with reference to the first, the factors which affect air pollution which were not used in the supplement to the final environmental impact statement?

Judge THOMPSEN. With respect to the first. He said there are two and that they used the second one.

Now, do you want him to compare the first and second?

Mr. ARMOR. Yes, Your Honor, I asked him what factors had been left out.

Judge THOMPSEN. You asked him what was left out. I didn't understand him saying that anything was left out from the second one, but that they used the second one.

Do you want to know how the first one differs from what they did? Is that it? What factors were left out?

Mr. ARMOR. I'll pursue it in more detail, Your Honor.

Mr. ARMOR. Mr. Darling, recognizing that all these tools are, as you call them, crude, is it

not a more accurate though crude approximation to use all of the factors shown in the General Electric formula than to use solely the speed of the vehicles and the assumptions of the effectiveness of these emission controls?

Mr. DARLING. Well, there is not a yes or no answer to that question. The GE people themselves derived the regression equation in order to come up with a simplified tool which could be used by highway planners, and they found in fact quite a good linear relationship between this complex factor and traffic flow.

Therefore, I feel that it probably is a perfectly reasonable relationship to use.

Mr. ARMOR. Wasn't the correlation .81?

Mr. DARLING. I don't recall the exact number.

Mr. ARMOR. But in any case, it was not a perfect correlation?

Mr. DARLING. Oh, my heavens! We don't find those in the real world.

Mr. ARMOR. Well, are you saying then that there is no need to consider factors such as wind speed, highway geometry, diffusion factors, as a function of distance, et cetera, in analyzing air pollution?

Are these irrelevant factors?

Mr. DARLING. Certainly not.

Mr. ARMOR. So an evaluation which does not use these factors is to that extent abbreviated or inaccurate; would that be correct?

Mr. DARLING. No. I'll stick by my previous answer.

Mr. ARMOR. Now, Mr. Darling, were there any factors which were named in the General Electric study affecting air pollution impacts, which were not used in your analysis?

Mr. DARLING. This is not my analysis. I used someone else's model.

The Gaussian Plume model is solely concerned with the dispersion of the pollutants by the atmosphere. This is lacking in the GE mode.

What I have done is a state-of-the-art approach using a different point of view, an alternate point of view.

Mr. ARMOR. Mr. Darling, referring to the state-of-the-art, to your knowledge, especially from the Stanford Research Studies, does the state-of-the-art include a factor for dispersion of pollutants as a function of the speed of the automobiles involved?

Mr. DARLING. This certainly is a factor, I will agree.

Mr. ARMOR. And was that factor used in Dr. Zimmerman's program which you employed to get your results?

Mr. DARLING. No.

Mr. ARMOR. Now, you have talked about a "worst case" situation. On your direct testimony you said that among the factors which can affect the results is topography and buildings in the area.

Do you know if the wind roses given to you as part of your basic data were taken at Friendship Airport or somewhere else in the Baltimore metropolitan area?

Mr. DARLING. I believe they were Friendship.

Mr. ARMOR. And would not the ground wind speeds be lower in the City of Baltimore as a function to the buildings and their heights than they would be at Friendship Airport?

Mr. DARLING. I am not sure I would want to make that as a blanket statement. There are areas where they might be higher, others where they might be lower. It is not a simple relationship.

Mr. ARMOR. From your background in meteorology, Mr. Darling, would it not be true that whatever wind speed exists at an airport outside of the city, that the wind speeds at ground levels inside that city would tend to be lower than the airport wind speeds; if you know?

Mr. DARLING. Well, again, if you are talking about an average over different types of configurations of building, that probably would be true.

Mr. ARMOR. So what looks like a rare "worst case" by analyzing wind speed patterns at the airport would be a less rate "worst case" analyzing the actual wind speeds in the city?

Mr. DARLING. I did not use the wind rose in my analysis, Mr. Armor. I took the most common wind direction from the rose which presumably would not be greatly different, and I used a "worst case" wind speed which is one meter per second, which is basically a calm wind, meteorologically. I did not make use of the wind rose other than to pick the directions.

Mr. ARMOR. But if the wind speed factors, ground level, inside the city are less than those shown on the airport, the roses would give a less frequent indication of the occurrences of inversion; is that correct?

Mr. DARLING. It is not a pertinent point. As I explained to you, I only used the wind roses to get the directions. I took a "worst case" speed, a speed that

is probably certainly, for any length of time in downtown Baltimore, rather infrequent.

Mr. ARMOR. Now, in your calculations you used a speed of 25 miles per hour on Mulberry Street, did you not, for the build alternative?

Mr. DARLING. I took the figures given to me by the Interstate Division.

Mr. ARMOR. Was the figure, Mr. Darling, which the Interstate Division gave you and that you used, 25 miles per hour on Mulberry Street?

Mr. DARLING. Well, we are talking about which, the build or no build?

Mr. ARMOR. The build alternative in 1978.

Mr. DARLING. May I refer to my--

Mr. ARMOR. Yes, you may.

Mr. DARLING. That is correct.

Mr. ARMOR. Now, Mr. Darling, you said you reviewed the figures shown in the supplement to the final environmental impact statement on Franklin-Mulberry.

What speed for Mulberry Street was assumed in that statement? Was it not 15 miles an hour?

Mr. DARLING. I don't recall.

Mr. ARMOR. You may review the figures in order to find out.

Mr. DARLING. I am not a traffic expert.

Mr. ARMOR. I refer you, Mr. Darling, to Section 4 of Exhibit 5-B, the supplement to the final environmental impact statement on Franklin-Mulberry, the figures on air quality which you said you reviewed, and I ask you, would you please state whether the speed for Mulberry Street used in those calculations is 15 miles per hour?

Mr. DARLING. I have no association with these computations.

Mr. ARMOR. On direct examination, did you not testify, Mr. Darling, that you reviewed those calculations?

Mr. DARLING. I did review them.

Mr. ARMOR. Well, then, would you please tell me that figure for input?

Mr. DARLING. On page 14 of the supplement the speed on Franklin-Mulberry is 25 miles per hour as indicated.

Mr. ARMOR. Mr. Darling, are you familiar with the term "volume capacity ratio"?

Mr. DARLING. Yes.

Mr. ARMOR. And you said you are not a traffic expert, so I will just ask you, generally, does a high volume capacity ratio mean that any highway is approaching the level of unstable operation?

Mr. DARLING. As I understand it, that would be the case.

Mr. ARMOR. Now, if the operating -- I ask you to assume, for the moment, if the operating speeds on Mulberry Street, in your "build" alternative, are 20 -- excuse me -- are 15 miles an hour rather than 25 miles an hour, will that have an effect on the air pollution results which you obtained?

Mr. DARLING. I repeat, I am not qualified to speak about what speeds and volumes should be used on the streets. I simply accepted them and used them.

Mr. ARMOR. Mr. Darling, the question was not about what would be the appropriate speeds. The question was based on your expertise in using the model which you have testified to.

If the input is 15 miles per hour on Mulberry Street for the "build" alternative, rather than the 25 miles an hour which you used, would that affect the air pollution results that you get?

Mr. DARLING. Yes. However, that is an academic question.

Mr. ARMOR. Would it increase or decrease?

Mr. DARLING. It would increase the air pollution.

Mr. ARMOR. And without doing the calculations, are you able to quantify in any way the amount that it would increase the figures shown?

Mr. DARLING. This is, again, not a simple computation. Remember, in our model we used 21 segments, and each one contributes by superposition to each one of those receptors shown.

But for that particular segment, it would increase the pollution by 60 per cent, but only for the segment where the change in speed occurred.

Mr. ARMOR. All right. Now, Mr. Darling, you have said many times that you used these figures that were supplied to you by the Interstate Division.

Are you familiar with the term "Gigo - g-i-g-o?

Mr. DARLING. No.

Mr. ARMOR. Are you familiar with the phrase "garbage in - garbage out"?

Mr. DARLING. Being an old computer hack, I have heard that expression, yes.

Mr. ARMOR. So, whatever the validity of your formula, is it correct to say that if you were given the wrong assumptions to use in it, that the results are unreliable because of that?

Mr. DARLING. The model is not a deus ex machina. Obviously, it

is only as good as the input.

Mr. ARMOR. Mr. Darling, I refer your attention again to Section 4 of Exhibit 5-B, the supplemental to the final statement, and I refer your attention to page 12, the last line of calculations.

Does that not show that a 15-mile-per-hour speed was used for Mulberry Street in that calculation? This is for a 1972 situation.

But that was the situation that was assumed to exist at that time?

Mr. DARLING. Right. But I am dealing with 1978.

Mr. ARMOR. And you were also, Mr. Darling, dealing with the assumptions supplied to you be the Interstate Division?

Mr. DARLING. Correct.

Mr. ARMOR. Now, Mr. Darling, I show you a document which is entitled "Modeling Air Pollution Concentrations Near Highways," by Ralph Sklarew and Bruce Turner and John R. Zimmerman.

Are you familiar with that article?

Mr. DARLING. I have not read this article.

Mr. ARMOR. Let me just ask you a question, then.

Judge THOMSEN. He said he is not familiar with it.

Mr. ARMOR. Therefore, I will not attempt to introduce the article, but I will ask him a question.

Judge THOMSEN. You can't get it in the back door that way. I mean, what you read him - you are reading him from the article. You can't - it does not make what is in the article evidence. You may ask

him a question.

Mr. ARMOR. Mr. Darling, does the Gaussian diffusion model have problems in its applicability to roadway structures where the geometry is not at grade; with it elevated or be it depressed?

Mr. DARLING. The model will not handle fill-type highways. That is where the highway is sitting up on solid ground. It will, however, handle elevated sections, such as I-170 crossing City Boulevard. There is no natural way of handling depressed sections or cut sections of highway.

If it has any validity, it is essentially for "at-grade" and elevated sections, which are the two types I analyzed here.

Mr. ARMOR. So, for a depressed configuration, such as Franklin-Mulberry, for its length, the Gaussian model would not be the recommended one to use?

Mr. DARLING. There isn't any recommended model for that situation.

Mr. RODOWSKY. No redirect.

Judge THOMSEN. Mr. Mitchell, do you have anything?

Mr. MITCHELL. No, Your Honor

Mr. HAMMOND. Your Honor, can Mr. Darling be excused to go back to Boston?

Mr. ARMOR. Your Honor, on the point we were raising before, the availability of the program, we will put on our own witness to put on the program and not use cross-examination. So we would have no objection.

Judge MILLER. Thank you, Mr. Darling.

(There was a short recess)

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APPENDIX B

LETTER FROM THE OFFICE OF THE CHIEF COUNSEL, FHWA

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WASHINGTON, D.C. 20591

JUL 6 1973

IN REPLY REFER TO:

HCC-40

Mr. Eugene M. Darling, Jr.
TCD - Transportation Systems Center
Department of Transportation
Cambridge, Massachusetts 02142

Dear Gene:

Enclosed is a copy of the Court's decision in the M.A.D.
Case, issued June 22, 1973. Note the discussion on
page 58 of the developmental state of the art of CO
prediction modeling. The Court held that the air quality
calculations contained in the EIS for I-70 were reasonably
sufficient considering the state of the art. Your excel-
lent testimony seems to have carried the day on this
issue.

Sincerely yours,

Martin Lefkowitz
Attorney Advisor

Enclosure

APPENDIX C

EXCERPT FROM THE DECISION DATED JUNE 22, 1973 OF JUDGES ROSZEL
Z. THOMSEN AND JAMES R. MILLER, JR. IN CIVIL ACTION FILE NO.
72-1041M, UNITED STATES DISTRICT COURT FOR THE DISTRICT OF
MARYLAND

"... The state-of-the-art in the prediction of concentrations
of carbon monoxide (CO) is now at the theoretical stage. There
seems to be general acceptance of the "Gaussian plume" theory and
the theoretical formula developed by the General Electric Study of
September, 1971. There are, however, many variations of the formula
and no satisfactory evidence was presented to the court that any
of them have been empirically validated. The court finds that the
air quality calculations contained in the supplemented final EIS
were a reasonably sufficient attempt to deal with the problem,
considering the present state-of-the-art.

Whatever the actual concentrations of carbon monoxide now
generated by the automobiles using the Franklin-Mulberry corridor
are at this time, and whatever will be the actual concentrations
of CO generated in 1978 by automobiles which will use I-170 in the
F-M corridor, the evidence convinced the court that the one-hour
and eight-hour concentrations of CO produced in the F-M corridor
will be less after the construction of I-170 in that corridor than
they presently are. The basic reason for this conclusion is that
the production of CO decreases as the average speed of a motor
vehicle increases. If the City Boulevard, which is a part of the
3-A system and of the City's Master Plan of Highways, is built (and
at this time there is no reason to think the City will not do so),
the CO emission concentrations will be still lower because of the
greater ease of dispersal of the automobile traffic throughout the
CBD that this will allow without traffic backups..."

APPENDIX D

THE TSC-MODIFIED EPA HIGHWAY LINE SOURCE MODEL PROGRAM

```
C          THIS PROGRAM CALCULATES THE CONCENTRATION FROM A LINE SOURCE
C           AT EACH OF A NUMBER OF RECEPTORS. SUBROUTINE RELCO
C           IS CALLED WHICH IN TURN CALLS SUBROUTINE SIGMA.
C      EMIS----LANE EMISSIONS PER ROAD
C      XVZ,XVY----DISTANCES FOR Z AND Y VIRTUAL SOURCES.
C      HIG----MIXING HEIGHTS
C      ANGL----ANGLES
C      POLL----CONCENTRATIONS PER RECEPTOR AND ANGLE
C      XPRR----RECEPTOR
C      SCLS----CONCENTRATIONS
C      REPX1,REPY1,REPX2,REPY2----ROAD COORDINATES
C      HIN----ROAD HEIGHT
C      WIDD----ROAD WIDTH
C      CCCNT----CENTER STRIP
C      XLANE----NUMBER OF LANES
       DIMENSION EMIS(40)
       DIMENSION XVZ(6),XVY(6),QLS(24),HEAD(20)
       DIMENSION HIG(2)
       DIMENSION ANGL(30)
       DIMENSION POLL(30,25)
       DIMENSION XPRR(30),YPRR(30),ZPRR(30)
       DIMENSION SCLS(30)
       DIMENSION REPX1(40),REPX2(40),SEPX1(40),SEPX2(40)
       DIMENSION HIN(40),WIDD(40),CCCNT(40),XLANE(40)
       COMMON /A/ GY(6),GZ(6,6)
       DATA XVZ/0.012,0.012,0.017,0.027,0.035,0.058/
       DATA XVY/.009,.013,.020,.032,.044,.044/
       IRD=5
       IWRI = 6
       WRITE(6,6051)(GY(I),I=1,6)
```

```
       WRITE(6,6052)((GZ(I,J),I=1,6),J=1,5)
  6051 FORMAT(5X,6E20.6)
  6052 FORMAT(1X,5E20.6)
       WRITE(6,1049)
C      XMET----CONVERSION FACTOR (FEET TO METERS)
C      XKST----STABILITY
C      HIG----HEIGHT OF LIMITING LID (FEET)
       XMET=.3048
       XKST=5.0
       U=1.0
       NANG=17
       ANGL(1)=22.5
       ANGL(2)=45.0
       ANGL(3)=67.5
       ANGL(4)=90.0
       ANGL(5)=112.5
       ANGL(6)=135.0
       ANGL(7)=157.5
       ANGL(8)=180.0
       ANGL(9)=202.5
       ANGL(10)=225.0
       ANGL(11)=247.5
       ANGL(12)=270.0
       ANGL(13)=292.5
       ANGL(14)=315.0
       ANGL(15)=337.5
       ANGL(16)=360.0
       ANGL(17)=22.5
     9 FORMAT(8F10.4)
    11 FORMAT(I2)
```

```
   12 FORMAT(8F10.3)
   13 FORMAT(8F10.3)
   14 FORMAT(20A4)
   15 FORMAT(1H0, 20A4)
   16 FORMAT(1X, 28HWIDTH OF AT-GRADE HIGHWAY IS ,F10.3,3H  M, /,
     1 1X,24HWIDTH OF CENTER STRIP IS , F10.3  )
   17 FORMAT(1X, 37HEMISSION RATE (GRAMS/SECOND*METER) OF ,I4,
     1  8H LANE(S) )
   18 FORMAT(1H ,36HTHE SCALE OF THE COORDINATE AXES IS ,F10.4,4H KM. )
   19 FORMAT(1H0,51HCOORDINATES OF THE ENDPOINTS OF THE LINE SOURCE ARE
     1F10.3,1H,,F10.3,7H   AND  ,F10.3,1H,,F10.3)
   20 FORMAT(1H0,17HWIND DIRECTION IS,F7.0,25H  DEGREES   WIND SPEED IS,
     1F7.1,11H METERS/SEC,/,19H STABILITY CLASS IS,I2,3X,
     2 26HHEIGHT OF LIMITING LID IS,F8.1,6HMETERS   )
   23 FORMAT(1X, 18HEMISSION HEIGHT IS , F8.3, 7H METERS   )
   28 FORMAT(1H0,52H  RECEPTOR LOCATION          RECEPTOR      CONCENTRATION
     1,/,6X,2HRR,10X,29HSR          HEIGHT(M)      PPM        )
   30 FORMAT(1H ,3(F10.4,2X),E15.5)
   31 FORMAT(1H1)
C        READ HEADER CARD
   35 READ(IRD,14)HEAD
C     READ NUMBER OF CASES
C     READ  NUMBER OF RECEPTORS FOR THIS CASE
      READ (IRD,11) NRECP
      DO 2050 LK=1,NRECP
      READ(IRD,12) XPRR(LK),YPRR(LK),ZPRR(LK)
 2050 CONTINUE
      READ(IRD,11) NCASE
      DO 2051 LL=1,NCASE
      READ(IRD,12)REPX1(LL),SEPX1(LL),REPX2(LL),SEPX2(LL),HIN(LL),
```

```
      1    WIDD(LL),CCCNT(LL),XLANE(LL)
       NBL=XLANE(LL)
 2051 CONTINUE
C     MIXING HEIGHT LOOP
       DO 4000 LBL=1,1
       HL=HIG(LBL)*XMET
C     ANGLE LOOP
       DO 3050  LY=1,NANG
       DO 8 J=1,NRECP
       SCLS(J)=0.0
    3 CONTINUE
C     ROAD LOOP
       DO 1000  IDOW = 1,NCASE
       WRITE(IWRI,31)
       WRITE(IWRI,15)HEAD
       REP1=REPX1(IDOW)
       SEP1=SEPX1(IDOW)
       REP2=REPX2(IDOW)
       SEP2=SEPX2(IDOW)
       H=HIN(IDOW)
       WIDTH=WIDD(IDOW)
       CNTR=CCCNT(IDOW)
       XNL=XLANE(IDOW)
       REP1=REP1*XMET
       REP2=REP2*XMET
       SEP1=SEP1*XMET
       SEP2=SEP2* XMET
       H=H*XMET
       WIDTH=WIDTH*XMET
       CNTR=CNTR*XMET
```

```
C          REP1,SEP1 ARE THE COORDINATES OF AN END POINT OF THE LINE
C           SOURCE IN SOURCE COORDINATES.
C          REP2,SEP2 ARE THE COORDINATES OF THE OTHER END POINT OF THE
C           LINE SOURCE IN SOURCE COORDINATES.
C          H IS THE EFFECTIVE EMISSION HEIGHT OF THE SOURCE IN METERS.
C        CNTR IS THE WIDTH OF THE CENTER STRIP (M)
C          WIDTH IS THE HIGHWAY WIDTH  (M) FOR AT GRADE
C          XNL IS THE NUMBER OF LANES FOR THE AT-GRADE HIGHWAY.
       NL=XNL
       IF(XNL.GT.1.) XNL=XNL-1.
       DELW=(WIDTH-CNTR)/XNL
       WRITE(IWRI,19)REP1,SEP1,REP2,SEP2
       WRITE(IWRI,23)H
       WRITE(IWRI,17)NL
       DO 2052 LPD=1,NL
       QLS(LPD)=EMIS(IDOW)
 2052 CONTINUE
 1921 FORMAT(8F11.5)
C          QLS IS THE LINE SURCE STRENGTH (GRAMS/SECOND*METER)
       WRITE (IWRI,2)(QLS(I),I=1,NL)
    2 FORMAT(8F12.6)
       CUT=0.0
C        XNDL IS THE NUMBER OF LINE SOURCES REPRESENTING THE TOP OF THE
C          CUT SECTION.
C        WIDTC IS THE WIDTH OF THE TOP OF THE CUT(M)
       IF(CUT.EQ.0.)GOTO101
C          DQLS IS THE CUT SECTION SOURCE STRENGTH
       DQLS=0.
       DO 40 I=1,NL
   40 DQLS=DQLS+QLS(I)
```

```
      NL=XNDL
      IF(XNDL.GT.1.) XNDL=XNDL-1.
      DOWNL=NL
      DQLS = DQLS/DOWNL
      DELW=WIDTC/XNDL
      WRITE(IWRI,29)WIDTC
   29 FORMAT(32H WIDTH OF TOP OF CUT SECTION IS ,F10.3,3H M  )
      DO100I=1,NL
  100 QLS(I)=DQLS
      GOTO102
  101 WRITE(IWRI,16)WIDTH,CNTR
  102 CONTINUE
      THETA=ANGL(LY)
      KST=XKST
C         THETA IS THE WIND DIRECTION IN DEGREES.
C          THE METEOROLOGICAL DIRECTION (N=0 DEG, E=90 DEG) IS USED
C         U IS THE WIND SPEED IN METERS PER SECOND.
C         KST IS THE STABILITY CLASS
C         HL IS THE HEIGHT OF THE LIMITING LID
      WRITE (IWRI,20) THETA,U,KST,HL
      GS=.001
C         GS IS THE SCALE OF COORDINATE AXES (KM).
      WRITE(IWRI,18) GS
      WRITE(IWRI,28)
C         CONVERT COORDINATE SYSTEM SO THAT HIGHWAY
C          IS ORIENTATED ALONG ZERO DEGREES (MATH SYSTEM)
      X1=REP1
      Y1=SEP1
      X2=REP2
      Y2=SEP2
```

```
         DX=X2-X1
         DY=Y2-Y1
C        HIGHWAY SLOPE IS DY/DX
         CALL ATH(DX,DY,ANGH,DANG)
C        ROTATE AXES SO ROAD IS HORIZANTAL AND X1 LEFT OF X2.
         REP1=Y1*SIN(ANGH)+X1*COS(ANGH)
         SEP1=Y1*COS(ANGH)-X1*SIN(ANGH)
         REP2=Y2*SIN(ANGH)+X2*COS(ANGH)
         SEP2=Y2*COS(ANGH)-X2*SIN(ANGH)
C           CONVERT WIND DIRECTION WRT HIGHWAY
         THETA=THETA+DANG
         IF(THETA.LT.0.)THETA=THETA+360.
         IF(THETA.GE.360.)THETA=THETA-360.
         T =THETA/57.2958
C           T IS THE WIN DIRECTION IN RADIANS
         SINT=SIN(T)
         COST=COS(T)
C           SINT AND COST ARE THE SINE AND COSINE OF THE WIND DIRECTION
C           P IS THE LENGTH OF THE LINE SOURCE
         P=(((REP2-REP1)*(REP2-REP1)+(SEP2-SEP1)*(SEP2-SEP1))**0.5)*GS
C        RECEPTOR LOOP
         DO  975  JDOW = 1,NRECP
         XXRR=XPRR(JDOW)* XMET
         XXSR=YPRR(JDOW)*XMET
         Z=ZPRR(JDOW) *  XMET
C           XXRR,XXSR ARE THE COORDINATES OF THE RECEPTOR
C           Z IS THE RECEPTOR HEIGHT IN METERS
         IF(XXRR.EQ.9999.)GOTO35
         CNTS=0.
         CLS=0.
```

```
C              CONVERT RECEPTOR COORDINATES WRT HIGHWAY
       XRR=XXSR*SIN(ANGH)+XXRR*COS(ANGH)
       XSR=XXSR*COS(ANGH)-XXRR*SIN(ANGH)
       RR=XRR
 5051 FORMAT(1X,I4,2X,4E20.7)
C      LANE LOOP
       DO600IL=1,NL
       DOWIL= IL-1
       IF(CUT.NE.0.)GOTO76
       IF( IL.GT.NL/2.AND.IL.NE.1)CNTS=CNTR
    76 IF(THETA.GT.90.0 .AND. THETA.LE.270.0 ) GO TO 77
       SR =  XSR - DELW * DOWIL -CNTS + WIDTH/2.0
       GOTO78
    77 SR =  XSR + DELW * DOWIL +CNTS - WIDTH/2.0
    78 ESTD=0.
C          CALCULATE DOWNWIND AND CROSSWIND DISTANCES OF RECEPTOR IR,IS
C            FOR THE ENDPOINTS OF THE LINE SOURCE
       R1=(REP1-RR)*GS
       S1=(SEP1-SR)*GS
       R2=(REP2-RR)*GS
       S2=(SEP2-SR)*GS
C      ROTATE SUCH THAT WIND IS ALONG X DIRECTION
       X1=R1*SINT+S1*COST
       Y1=S1*SINT-R1*COST
       X2=R2*SINT+S2*COST
       Y2=S2*SINT-R2*COST
 5052 FORMAT(1X,8E15.5)
 5054 FORMAT(1X,3E18.7)
C      CONSIDER THE WIND TO BE FROM THE +X DIRECTION AND THE RECEPTOR
C      TO BE AT (0,0). IN THIS CASE, X1,Y1 ARE THE UPWIND AND CROSSWIND
```

```
C        COORDINATES (KM) OF ENDPOINT REP1,SEP1 OF THE LINE SOURCE.
C        X2,Y2 ARE THE UPWIND AND CROSSWIND COORDINATES OF ENDPOINT
C        REP2,SEP2 OF THE LINE SOURCE.
C        TEST FOR AT LEAST ONE ENDPOINT UPWIND OF RECEPTOR-OTHERWISE
C        CONCENTRATION=0.
C        CHECK FOR RECEPTOR DOWNWIND OF SOURCE. IF NOT, SET CONC.=0.
C
C
C
C
C
C        CUTS OFF THAT PART OF THE ROAD WHICH IS DOWNWIND OF THE RECEPTOR
C        THIS AIDS IN CONVERGENCE AND ELIMINATES VIRTUAL SOURCE ERROR.
         IF (X1)   4402,105,4403
  4403 IF (X2) 4404,110,110
  4404 CONTINUE
         Y2=Y2-((Y2-Y1)/(X2-X1)) * X2
         X2=0.0
         P=((X2-X1)**2 + (Y2-Y1)**2)**.5
         GO TO 110
  4402 IF (X2) 500,500,4405
  4405 CONTINUE
         Y1= Y1-((Y2-Y1)/(X2-X1))* X1
         X1 = 0.0
         P=((X2-X1)**2 + (Y2-Y1)**2)**.5
         GO TO 110
C
C
C
C
```

105

```
C
  105 IF(X2) 500,110,110
C          CHECK FOR RECEPTOR BETWEEN CENTERLINE OF PLUMES FROM ENDPOINTS.
C           IF IT IS DIVIDE SOURCE INTO TWO SEGMENTS (INDX=2), GO TO 150.
  110 IF(Y1) 112,120,112
  112 IF(Y2) 115,120,115
  115 Y3=SIGN(Y1,Y2)
      IF(Y3-Y1) 150,120,150
  120 XA=X1
      XB=X2
      YA=Y1
      YB=Y2
      PP=P
      INDX=1
      GO TO 210
  150 XA=X1
      YA=Y1
      XP=X1+(X2-X1)*ABS(Y1)/(ABS(Y1)+ABS(Y2))
      XB=XP
      YB=0.
      PP=P*ABS(Y1)/(ABS(Y1)+ABS(Y2))
      INDX=2
  210 M=0
      DX=XB-XA
      DY=YB-YA
C     VIRTUAL SOURCES
      XZA=XA+XVZ(KST)
      XZB=XB+XVZ(KST)
      XYA=XA+XVY(KST)
      XYB=XB+XVY(KST)
```

```
      ESTP=0.0
      CALL RELCO(U,Z,H,HL,XZA,XYA,YA,KST,AN,RC1,XVZ,XVY)
      CALL RELCO(U,Z,H,HL,XZB,XYB,YB,KST,AN,RC2,XVZ,XVY)
      CURR=(RC1+RC2)*PP/2.
      IF(CURR) 215,215,220
  215 ESTC=0.0
      GO TO 300
C     TRY MORE POINT SOURCES LOOP
  220 PREV=CURR
      SUBT=0.0
      M=2*M+1
      DX=DX/2.
      DY=DY/2.
C     POINT SOURCE LOOP (ONLY FOR POINT SOURCES NOT ALREADY INCLUDED).
      DO 250 K=1,M,2
      DOWK = K
      X =   XA + DOWK * DX
      Y =   YA + DOWK * DY
      XZ=X+XVZ(KST)
      XY=X+XVY(KST)
      CALL RELCO(U,Z,H,HL,XZ,XY,Y,KST,AN,RC,XVZ,XVY)
  250 SUBT=SUBT+RC
      DOWM   = M+1
      CURR   =   PREV/2.0 + SUBT * PP/DOWM
      ESTC=(4.*CURR-PREV)/3.
      IF(ESTC) 215,215,255
C        ESTC AND ESTP ARE CURRENT AND PREVIOUS RICHARDSON'S
C          EXTRAPOLATIONS.
  255 RAT=ABS((ESTC-ESTP)/ESTC)
C        RAT IS A COMPARISON BETWEEN THE CURRENT AND PREVIOUS VALUES.
```

```fortran
C               WHEN RAT BECOMES LESS THAN 0.02 THE CURRENT VALUE IS ACCEPTED
C               FOR THE VALUE OF THE INTEGRAL.
C         IF ESTC IS LESS THAN 1.0E-6,ASSUME CONVERGENCE
          IF (ABS(ESTC) .LT.          .000001 ) GO TO 300
          IF(RAT-0.005) 300,260,260
  260 ESTP=ESTC
      GO TO 220
  300 ESTD=ESTC+ESTD
      IF( INDX-1) 500,500,310
  310 XA=XP
      YA=0.
      XB=X2
      YB=Y2
      PP=P*ABS(Y2)/(ABS(Y1)+ABS(Y2))
      INDX=1
      GO TO 210
  500 CLSS=ESTD*QLS(IL)*1000.
  600 CLS=CLSS+CLS
C     CONVERT TO PPM
      CLS=  CLS * 870.0
      WRITE(IWRI,30) XXRR,XXSR,Z,CLS
C     TEMPORARY STORAGE FOR POLLUTION AT EACH RECEPTOR
      SCLS(JDOW)=SCLS(JDOW) +CLS
  975 CONTINUE
 1000 CONTINUE
      WRITE(IWRI,1049)
 1049 FORMAT(1H1   )
      DO 1055 I=1,NRECP
C     ARRAY TO STORE TOTAL POLLUTION AT EACH RECEPTOR FOR EACH ANGLE
      POLL(I,LY)=SCLS(I)
```

```
       WRITE(IWRI,1050) I,SCLS(I)
  1050 FORMAT(1X,  I3,2X,E16.5   )
  1055 CONTINUE
  3050 CONTINUE
       DO 3300 I=2,NANG,2
       WRITE(IWRI,1049)
        WRITE(IWRI,3101) ANGL(I)
  3101 FORMAT(1X,F7.1)
C      SECTOR AVERAGE LOOP
       DO 3100   J=1,NRECP
       SUM =POLL(J,I-1) + 2.0*POLL(J,I)+POLL(J,I+1)
       SUM=SUM/4.0
       WRITE(IWRI,1050)J,SUM
       ICW=10.0*SUM
  3051 FORMAT(I3)
  3100 CONTINUE
  3300 CONTINUE
       WRITE(IWRI,1049)
  4000 CONTINUE
       RETURN
       END
       SUBROUTINE RELCO (U,Z,H,HL,X,XY,Y,KST,AN,RC,XVZ,XVY)
       DIMENSION XVZ(6),XVY(6)
       COMMON /A/ GY(6),GZ(6,6)
C         SUBROUTINE RELCO CALCULATES CHI/Q CONCENTRATION VALUES, RELCO
C          CALLS UPON SUBROUTINE SIGMA TO OBTAIN STANDARD DEVIATIONS.
C         THE INPUT VARIABLES ARE....
C         U    WIND SPEED (M/SEC)
C         Z    RECEPTOR HEIGHT (M)
C         H    EFFECTIVE STACK HEIGHT (M)
```

```
C              HL=L HEIGHT OF LIMITING LID (M)
C              X      DOWNWIND DISTANCE FOR CALCULATING SIGMAZ (KM)
C              XY     DOWNWIND DISTANCE FOR CALCULATING SIGMAY (KM)
C              Y      DISTANCE RECEPTOR IS CROSSWIND FROM SOURCE (KM)
C              KST    STABILITY CLASS
C           THE OUTPUT VARIABLES ARE....
C              AN     THE NUMBER OF TIMES THE SUMMATION TERM IS EVALUATED
C                     AND ADDED IN.
C              RC     RELATIVE CONCENTRATION (SEC/M**3)
C           THE FOLLOWING EQUATION IS SOLVED --
C              RC = (1/(2*PI*U*SIGMA Y*SIGMA Z))* (EXP(-0.5*(Y/SIGMA Y)**2)
C               (EXP(-0.5*((Z-H)/SIGMA Z)**2) + EXP(-0.5*((Z+H)/SIGMA Z)**2
C                  PLUS THE SUM OF THE FOLLOWING 4 TERMS K TIMES (N=1,K) --
C                  TERM 1- EXP(-0.5*((Z-H-2NL)/SIGMA Z)**2)
C                  TERM 2- EXP(-0.5*((Z+H-2NL)/SIGMA Z)**2)
C                  TERM 3- EXP(-0.5*((Z-H+2NL)/SIGMA Z)**2)
C                  TERM 4- EXP(-0.5*((Z+H+2NL)/SIGMA Z)**2)
C           THE ABOVE EQUATION IS SIMILAR TO EQUATION (5.8) P 36 IN
C           WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES WITH THE ADDITIO
C           OF THE EXPONENTIAL INVOLVING Y.
C           IWRI IS CONTROL CODE FOR OUTPUT
      IWRI = 5
C           IF X IS LESS THAN ZERO,      SET RC=0. AND RETURN.    THIS AVOIDS
C           PROBLEMS OF INCORRECT VALUES NEAR THE SOURCE.
      IF (X-XVZ(KST))30,30,5
    5 IF (XY-XVY(KST))30,300,300
C           CALL SIGMA TO OBTAIN VALUES FOR SY AND SZ
  300 CALL SIGMA (X,XY,KST,SY,SZ)
C           SY = SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C           Y-DIRECTION (M)
```

110

```
C           SZ = SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C           Z-DIRECTION (M)
C           INITIAL VALUE OF AN SET = ).
      AN=0.
C           IF THE RECEPTOR IS ABOVE THE LID, WRITE THAT OUT, SET RC = 0.
C           AND RETURN.
      IF(Z-HL)10,10,20
   20 WRITE(IWRI,1)
    1 FORMAT(1X, 24HRECEPTOR HIGHER THAN LID  )
   30 RC=0.
      RETURN
C           IF THE SOURCE IS ABOVE THE LID, SET RC = 0., AND RETURN.
   10 IF(H-HL)40,40,30
C           YD IS CROSSWIND DISTANCE IN METERS.
C           STATEMENTS 40 TO 250 CALCULATE RC, THE RELATIVE CONCENTRATION,
C           USING THE EQUATION DISCUSSED ABOVE.  SEVERAL INTERMEDIATE
C           VARIABLES ARE USED TO AVOID REPEATING CALCULATIONS.
C           CHECKS ARE MADE TO BE SURE THAT THE ARGUMENT OF THE
C           EXPONENTIAL FUNCTION IS NEVER GREATER THAN 50 (OR LESS THAN
C           -50).  IF 'AN' BECOMES GREATER THAN 45, A LINE OF OUTPUT IS
C           PRINTED INFORMING OF THIS.
   40 YD = 1000.*Y
      C1 = 0.5*(YD/SY)*(YD/SY)
      IF(C1-50.)50,30,30
   50 A1=1./(6.28318*U*SY*SZ*EXP(C1))
      C2=2.*SZ*SZ
      CA = Z-H
      CB = Z+H
      C3 = CA*CA/C2
      C4 = CB*CB/C2
```

```
      IF(C3-50.)60,70,70
 60  A2=1./EXP(C3)
     GO TO 80
 70  A2=0.
 80  IF(C4-50.)90,100,100
 90  A3=1./EXP(C4)
     GO TO 110
100  A3=0.
110  SUM=0.
     THL = 2.* HL
120  AN=AN+1.
     C5 = AN*THL
     CC = CA-C5
     CD = CB-C5
     CE = CA+C5
     CF = CB+C5
     C6 = CC*CC/C2
     C7 = CD*CD/C2
     C8 = CE*CE/C2
     C9 = CF*CF/C2
     IF(C6-50.)130,140,140
130  A4=1./EXP(C6)
     GO TO 150
140  A4=0.
150  IF(C7-50.)160,170,170
160  A5=1./EXP(C7)
     GO TO 180
170  A5=0.
180  IF(C8-50.)190,200,200
190  A6=1./EXP(C8)
```

```
        GO TO 210
  200 A6=0.
  210 IF(C9-50.)220,230,230
  220 A7=1./EXP(C9)
        GO TO 240
  230 A7=0.
  240 T=A4+A5+A6+A7
        SUM=SUM+T
        IF(T-0.01)250,260,260
  260 IF(AN-45.)120,270,270
  270 WRITE(IWRI,2)X,Y,H,T,SUM
    2 FORMAT(1X,17HN GREATER THAN 45,/,6X,4HX = ,F7.0,5X,4HY = ,F7.0,5X
    14HH = ,F5.1,5X,4HT = ,F7.3,5X,6HSUM = ,F7.3 )
  250 RC=A1*(A2+A3+SUM)
        RETURN
        END
$IBFTC DEC2
        SUBROUTINE SIGMA(X,XY,KST,SY,SZ)
        COMMON /A/ GY(6),GZ(6,6)
        AZ=X*1000.
        AY=XY*1000.
        IF(AZ-5000.)641,643,640
  640 IZ=1
        GOTO644
  641 IF(AZ.GE.500.) GOTO643
        IZ=3
        GOTO644
  643 IZ=2
  644 SZ=GZ(IZ,KST)*AZ**GZ(IZ+3,KST)
        SY=GY(KST)*AY**0.903
```

```
      RETURN
      END
      SUBROUTINE ATH(DX,DY,ANGH,DANG)
      RAD=57.2958
      IF(DX)5,6,7
    5 IF(DY.EQ.).)GOTO9
      ANGH=ATAN(DY/DX)*RAD+180.
      GOTO16
    9 ANGH=180.
      GOTO16
    6 IF(DY)10,11,12
   10 ANGH=270.
      GOTO16
   11 ANGH=0.
      GOTO16
   12 ANGH=90.
      GOTO16
    7 IF(DY)13,14,15
   13 ANGH=ATAN(DY/DX)*RAD+360.
      GOTO16
   14 ANGH=360.
      GOTO16
   15 ANGH=ATAN(DY/DX)*RAD
   16 DANG=ANGH
      ANGH=ANGH/RAD
      RETURN
      END
      BLOCK DATA
      DATA GY/0.4,0.295,0.2,0.13,0.098,.066/
      DATA GZ/2*0.0002539,0.0383,2*2.0886,1.2812,2*0.04936,0.1393,

     A2*1.1137,0.9467,0.1154,0.1014,0.112,0.9109,0.926,0.91,0.7368
     B0.2591,0.0856,0.5642,0.6869,0.865,1.2969,0.2527,0.0818,
     C0.4421,0.6341,0.8155,1.5763,.2017,.0545,.3606,.6020,.8124/
       END
```

APPENDIX E

AIR QUALITY ANALYSES FOR FOUR HIGHWAY
SEGMENTS RELATED TO THE 3-A SYSTEM

This appendix contains 1978 air quality analyses performed by the Transportation Systems Center for four different highway configurations (see Figure 3) which are either part of or linked to the 3-A System. The highway segments treated are as follows:

E1   TRANSPORTATION SYSTEMS CENTER ANALYSIS OF THE PROPOSED CITY
      BOULEVARD BETWEEN DRUID HILL AVENUE AND MCCULLOH STREET

E1.1   BUILD CASE

E1.1.1   ROAD SEGMENTATION

The proposed City Boulevard between Druid Hill Avenue and
McCulloh Street would consist of a divided roadway, each side having
three lanes. Druid Hill Avenue and McCulloh Street would not be
altered. Figure 20 shows the physical layout of this location.
As can be seen from the layout, the roadways have been sectioned
into ten segments. The contribution of each segment will be
used to determine the total concentration. Table 12 shows how
the segments were defined as input to the model program.

E1.1.2   EMISSION CALCULATION

The traffic data and the emission factors used in this
analysis can be found in Table 13. Note that an emission factor
is computed for each road segment.

E1.1.3   RECEPTOR LOCATION

Fourteen receptors were used in the air quality analysis at
this location. The placement of these receptors can be viewed in
Figure 20. The receptor coordinates are shown in Table 14.

E1.1.4   PEAK HOUR CONCENTRATION

The computed concentrations, shown in Table 15, are all less
than 11 ppm. However, since seven concentration values exceeded
nine parts per million, it was decided to run the program for
off-peak hours.

E1.1.5   OFF-PEAK HOUR EMISSION CALCULATION

The traffic data and emission factors used to compute off-
peak emissions can be seen in Table 16.

E1.1.6   OFF-PEAK HOUR CONCENTRATIONS

The off-peak hour concentrations can be found in Table 17.
As can be seen from the table, all resulting concentrations were
low.
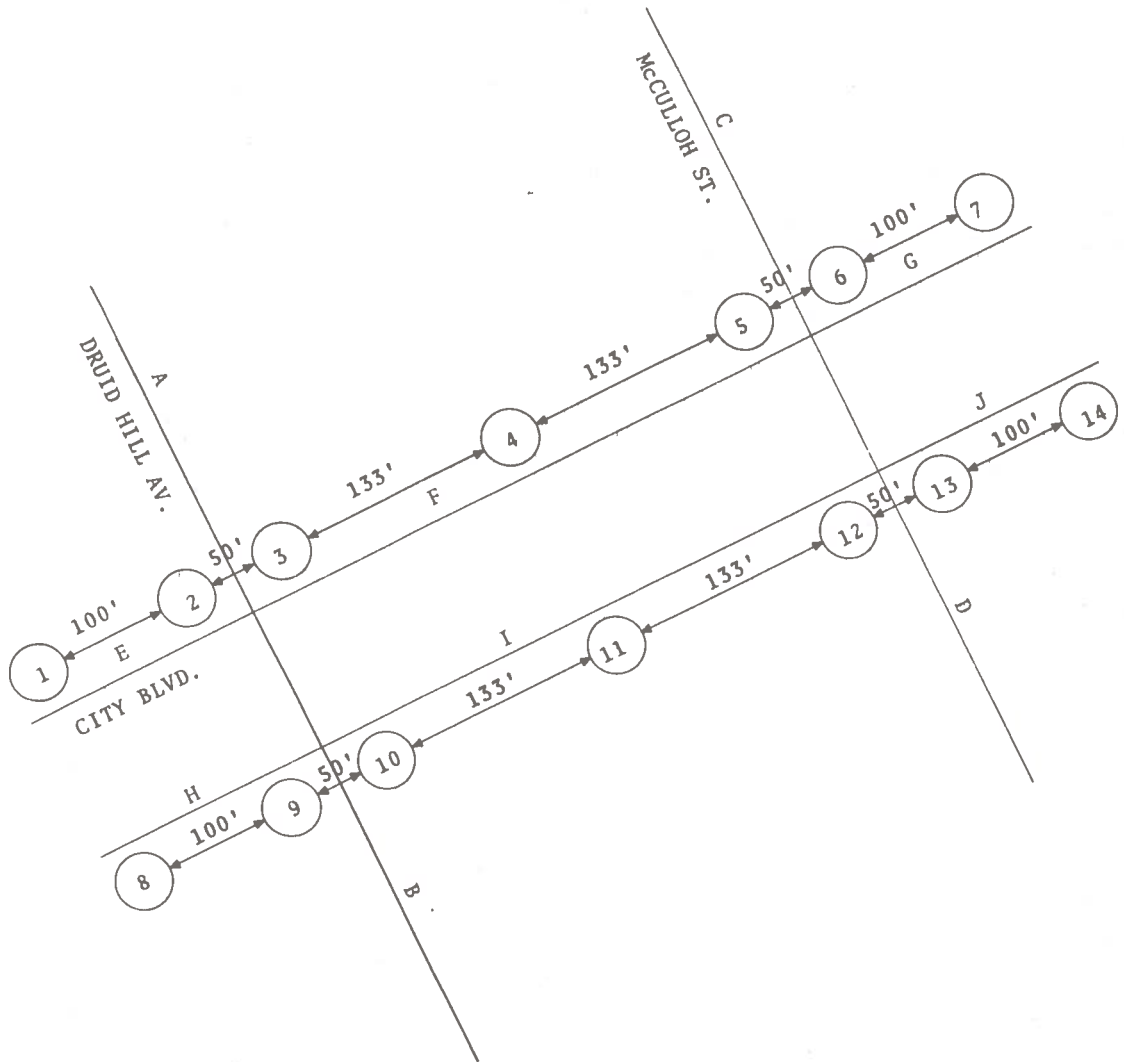
Figure 20. City Boulevard, Druid Hill Avenue,
McCulloh Street, Build Case

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TABLE 12.   CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET, BUILD CASE, HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
A	-160	5000	-160	0	3	30	0	3
B	-160	0	-160	-5000	3	30	0	3
C	160	5000	160	0	3	30	0	3
D	160	0	160	-5000	3	30	0	3
E	-5000	26	-160	26	3	36	0	3
F	-160	26	160	26	3	36	0	3
G	160	26	5000	26	3	36	0	3
H	-5000	-26	-160	-26	3	36	0	3
I	-160	-26	160	-26	3	36	0	3
J	160	-26	5000	-26	3	36	0	3

TABLE 13.   CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET, BUILD CASE, PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	$\frac{veh/hr}{lane}$	SPEED	1978 EMISSION FACTOR for CO 5% HDV $\frac{gm/mi}{veh}$	$\frac{gm/mi}{\frac{hr}{lane}}$	$\frac{gm/m}{\frac{sec}{lane}}$
A	1048	349	30	23	8027	.00138
B	1029	343	30	23	7889	.00136
C	1573	524	25	25	13100	.00226
D	1542	514	25	25	12850	.00222
E	1099	366	30	23	8418	.00145
F	1124	375	30	23	8625	.00149
G	1093	364	30	23	8372	.00144
H	1648	549	25	25	13725	.00237
I	1689	563	25	25	14075	.00243
J	1639	546	25	25	13650	.00235

TABLE 14. CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET, BUILD CASE, RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)
1	-287	56	5
2	-187	56	5
3	-133	56	5
4	0	56	5
5	133	56	5
6	187	56	5
7	287	56	5
8	-287	-56	5
9	-187	-56	5
10	-133	-56	5
11	0	-56	5
12	133	-56	5
13	187	-56	5
14	287	-56	5

TABLE 15. CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET, BUILD CASE, PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	WIND DIRECTIONS							
	N	NE	E	SE	S	SW	W	NW
1	2.17	8.18	6.17	4.13	4.05	6.28	0.00	1.27
2	2.83	8.54	6.89	7.09	4.09	6.31	0.00	4.21
3	1.26	7.45	5.40	7.26	5.71	7.46	1.69	4.32
4	1.76	7.70	5.83	4.88	5.17	7.19	1.08	1.93
5	2.75	8.16	6.74	9.38	4.69	7.05	0.77	6.51
6	0.00	6.26	4.09	9.28	7.24	8.78	3.44	6.44
7	0.00	6.23	4.02	4.58	6.47	8.34	2.53	1.74
8	5.59	7.41	2.05	1.25	0.00	7.71	4.23	4.20
9	4.34	6.82	2.79	4.15	0.00	7.73	4.27	6.98
10	4.24	8.72	1.22	4.26	1.70	8.87	5.89	6.70
11	5.99	8.93	1.72	1.90	1.09	8.60	5.38	4.96
12	6.79	9.34	2.73	6.39	0.75	8.48	4.93	9.45
13	4.21	7.67	0.00	6.32	3.41	10.12	7.46	9.35
14	4.19	7.64	0.00	1.72	2.50	9.70	6.68	4.67

TABLE 16. CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET,
BUILD CASE, OFF-PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	veh/hr lane	SPEED	1978 EMISSION FACTOR for CO 5 % HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
A	524	175	30	23	4025	.00069
B	515	172	30	23	3956	.00068
C	787	262	30	23	6026	.00104
D	771	257	30	23	5911	.00102
E	550	183	35	22	4026	.00069
F	562	187	35	22	4114	.00071
G	546	182	35	22	4004	.00069
H	824	275	35	22	6050	.00104
I	844	281	35	22	6182	.00106
J	820	273	35	22	6006	.00103

TABLE 17. CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET, BUILD CASE, OFF-PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 2mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	WIND DIRECTIONS							
	N	NE	E	SE	S	SW	W	NW
1	0.52	1.91	1.43	0.96	0.92	1.45	0.00	0.31
2	0.68	1.99	1.60	1.70	0.93	1.45	0.00	1.04
3	0.29	1.72	1.23	1.73	1.33	1.74	0.42	1.07
4	0.40	1.78	1.33	1.12	1.20	1.67	0.27	0.46
5	0.63	1.88	1.54	2.15	1.08	1.64	0.19	1.50
6	0.00	1.45	0.93	2.13	1.67	2.03	0.80	1.49
7	0.00	1.44	0.91	1.05	1.49	1.93	0.59	0.41
8	1.29	1.68	0.49	0.31	0.00	1.72	0.95	0.97
9	1.02	1.56	0.67	1.03	0.00	1.72	0.96	1.67
10	0.95	1.95	0.28	1.05	0.42	2.01	1.37	1.60
11	1.35	2.00	0.39	0.45	0.27	1.94	1.23	1.14
12	1.54	2.09	0.63	1.47	0.19	1.90	1.13	2.17
13	0.95	1.71	0.00	1.46	0.79	2.28	1.71	2.14
14	0.95	1.71	0.00	0.40	0.59	2.19	1.53	1.07

E1.1.7   EIGHT-HOUR AVERAGE CONCENTRATIONS

The eight-hour averages were computed only for receptors having over nine parts per million during the peak hour. This condition resulted in only seven of these computations. The results can be found in Table 18.

E1.2   NO BUILD CASE

E1.2.1   ROAD SEGMENTATION

The no-build case represents the highway as it presently exists. Biddle Street is a divided roadway with two lanes in each direction. Druid Hill Avenue and McCulloh Street are unchanged from the build case. Figure 21 shows the physical layout of this location. The roadways have been segmented into ten sections. Table 19 shows how the segments were defined as input to the model program.

E1.2.2   EMISSION CALCULATION

The traffic data and emission factors used in this analysis can be found in Table 20.

E1.2.3   RECEPTOR LOCATION

Fourteen receptors were used in the air quality analysis at this location. The placement of these receptors can be seen in Figure 21. The receptor coordinates are shown in Table 21.

E1.2.4   PEAK HOUR CONCENTRATIONS

The computed concentrations for this case can be found in Table 22. As can be seen from glancing at the table, many concentrations exceeded nine parts per million, thus necessitating the running of the program for off-peak hours.

E1.2.5   OFF-PEAK HOUR EMISSION CALCULATION

The traffic data and emission factors used to compute off-peak emissions can be seen in Table 23.

E1.2.6   OFF-PEAK HOUR CONCENTRATIONS

The computed concentrations for off-peak hours can be found in Table 24. All concentrations are less than 4 ppm.

TABLE 18. CITY BOULEVARD, DRUID HILL AVENUE, MCCULLOH STREET, BUILD CASE, EIGHT-HOUR AVERAGE CONCENTRATIONS (ppm), (FOR RECEPTORS WITH PEAK HOUR CONCENTRATION GREATER THAN 9 ppm)

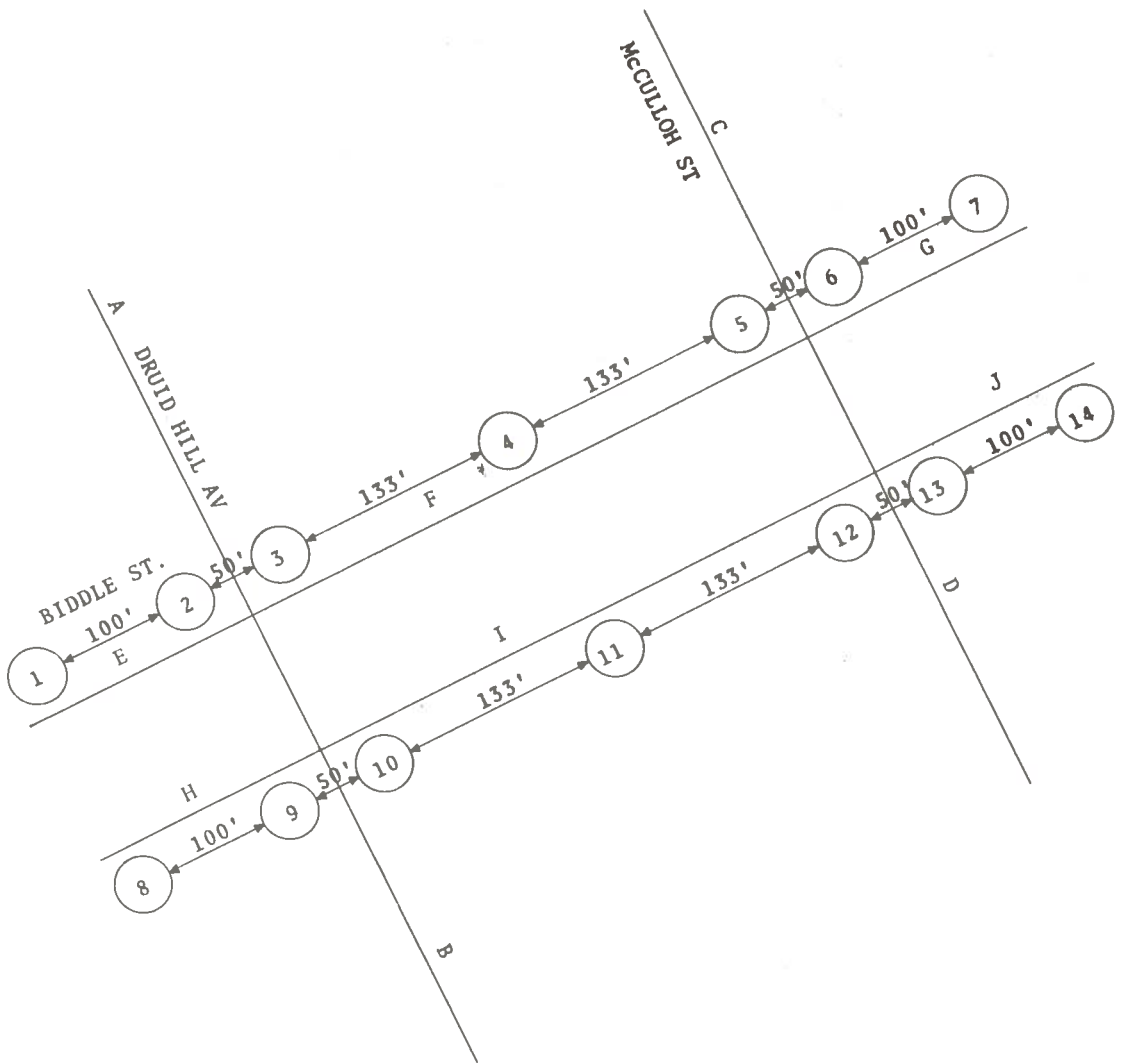| RECEPTOR NUMBER	WIND DIRECTIONS							
	N	NE	E	SE	S	SW	W	NW
1								
2								
3								
4								
5				3.05				
6				3.02				
7								
8								
9								
10								
11								
12		2.99						3.08
13						3.26		3.04
14						3.12		

Figure 21.   Biddle Street, Druid Hill Avenue,
McCulloh Street, No Build Case

TABLE 19.   BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET,
NO BUILD CASE, HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
A	-160	5000	-160	0	3	30	0	3
B	-160	0	-160	-5000	3	30	0	3
C	160	5000	160	0	3	30	0	3
D	160	0	160	-5000	3	30	0	3
E	-5000	11	-160	11	3	22	0	2
F	-160	11	160	11	3	22	0	2
G	160	11	5000	11	3	22	0	2
H	-5000	-11	-160	-11	3	22	0	2
I	-160	-11	160	-11	3	22	0	2
J	160	-11	5000	-11	3	22	0	2

TABLE 20.   BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET,
NO BUILD CASE, PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	$\frac{veh/hr}{lane}$	SPEED	1978 EMISSION FACTOR for CO 5 % HDV $\frac{gm/mi}{veh}$	$\frac{gm/mi}{\frac{hr}{lane}}$	$\frac{gm/m}{\frac{sec}{lane}}$
A	1190	397	30	23	9131	.00157
B	1123	374	30	23	8602	.00148
C	1785	595	25	25	14875	.00256
D	1835	612	25	25	15300	.00264
E	1050	525	20	27.5	14438	.00249
F	1107	554	20	27.5	15235	.00263
G	1090	545	20	27.5	14988	.00258
H	1575	788	20	27.5	21670	.00374
I	1660	830	20	27.5	22825	.00393
J	1635	818	20	27.5	22495	.00388

TABLE 21.   BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET,
            NO BUILD CASE, RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)
1	-287	27	5
2	-187	27	5
3	-133	27	5
4	0	27	5
5	133	27	5
6	187	27	5
7	287	27	5
8	-287	-27	5
9	-187	-27	5
10	-133	-27	5
11	0	-27	5
12	133	-27	5
13	187	-27	5
14	287	-27	5

TABLE 22. BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET, NO BUILD CASE, PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	W I N D D I R E C T I O N S
	N	NE	E	SE	S	SW	W	NW
1	2.58	13.43	7.18	4.72	4.77	10.80	0.00	1.45
2	3.47	13.95	8.07	7.91	4.82	10.87	0.00	4.81
3	1.59	12.75	6.49	8.24	6.69	12.28	2.18	4.94
4	2.12	13.07	7.04	5.71	6.15	12.13	1.36	2.20
5	3.37	13.53	8.10	11.06	5.83	11.99	1.03	7.40
6	0.00	11.27	5.03	10.95	8.78	13.76	4.14	7.32
7	0.00	11.20	4.94	5.48	7.81	13.36	2.99	1.99
8	6.78	11.22	2.48	1.38	0.00	11.91	4.73	4.76
9	5.35	9.73	3.39	4.59	0.00	11.96	4.78	7.98
10	6.05	13.78	1.68	4.72	2.22	13.41	6.67	8.08
11	6.89	14.07	2.22	2.19	1.36	13.32	6.18	5.72
12	7.94	14.49	3.59	7.60	1.06	13.20	5.55	10.88
13	4.99	12.41	0.00	7.53	4.34	14.96	8.56	10.75
14	4.90	12.35	0.00	2.03	3.09	14.56	7.74	5.44

TABLE 23.   BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET,
NO BUILD CASE, OFF-PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	veh/hr lane	SPEED	1978 EMISSION FACTOR for CO 5 % HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
A	595	198	30	23	4554	.00078
B	562	187	30	23	4301	.00074
C	893	298	30	23	6854	.00118
D	918	306	30	23	7038	.00121
E	656	328	25	25	8200	.00141
F	692	346	25	25	8650	.00149
G	682	341	25	25	8525	.00147
H	656	328	25	25	8200	.00141
I	692	346	25	25	8650	.00149
J	682	341	25	25	8525	.00147

TABLE 24.   BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET,
NO BUILD CASE, OFF-PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 2 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW
1	0.62	3.21	1.65	1.09	1.07	2.57	0.00	0.35
2	0.85	3.34	1.87	1.89	1.09	2.58	0.00	1.19
3	0.37	3.04	1.47	1.97	1.55	2.94	0.55	1.22
4	0.50	3.12	1.60	1.32	1.42	2.91	0.34	0.52
5	0.79	3.22	1.84	2.54	1.34	2.87	0.26	1.71
6	0.00	2.69	1.14	2.51	2.02	3.27	0.98	1.69
7	0.00	2.68	1.12	1.25	1.79	3.18	0.71	0.46
8	1.56	2.47	0.58	0.34	0.00	2.57	1.07	1.10
9	1.23	2.18	0.79	1.13	0.00	2.58	1.08	1.90
10	1.36	2.99	0.38	1.16	0.53	2.93	1.55	1.91
11	1.57	3.06	0.50	0.52	0.33	2.90	1.43	1.32
12	1.82	3.16	0.80	1.75	0.25	2.87	1.26	2.50
13	1.14	2.69	0.00	1.73	0.99	3.28	1.96	2.47
14	1.12	2.68	0.00	0.47	0.71	3.19	1.79	1.25

E1.2.7 EIGHT-HOUR AVERAGES

The eight-hour averages for this case can be seen in Table 25.
No result exceeded 4.74 ppm - much less than the EPA standard of
9 ppm for an eight-hour average.

TABLE 25. BIDDLE STREET, DRUID HILL AVENUE, MCCULLOH STREET,
           NO BUILD CASE, EIGHT-HOUR AVERAGE CONCENTRATIONS (ppm),
           (FOR RECEPTORS WITH PEAK HOUR CONCENTRATION GREATER THAN
           9 ppm)

| RECEPTOR NUMBER | W I N D   D I R E C T I O N S | | | | | | | |
	N	NE	E	SE	S	SW	W	NW
1		4.48				3.58		
2		4.57				3.61		
3		4.25				4.19		
4		4.36				4.06		
5		4.50		3.60		4.01		
6		3.76		3.56		4.58		
7		3.74				4.45		
8		3.56				3.73		
9		3.12				3.75		
10		4.33				4.24		
11		4.43				4.20		
12		4.57				4.16		3.54
13		3.90				4.74		3.50
14		3.88				4.61		

E2. TRANSPORTATION SYSTEMS CENTER ANALYSIS OF CITY BOULEVARD
BETWEEN LEXINGTON STREET AND SARATOGA STREET

E2.1 BUILD CASE

E2.1.1 ROAD SEGMENTATION

City Boulevard between Lexington Street and Saratoga Street,
running in a north-south direction, is a divided roadway with three
lanes in each direction. Figure 22 shows the physical layout of
this location. Table 26 shows how the roadways were defined as
input to the model program.

E2.1.2 EMISSION CALCULATION

The traffic data and emission factors used in this analysis
can be found in Table 27. The higher emission factor in the south
bound roadway results from the greater number of vehicles per hour
using this roadway.

E2.1.3 RECEPTOR LOCATION

Two receptors were placed at this location. One receptor was
placed twelve feet from the edge of the road and the second recep-
tor was placed forty-two feet from the edge of the road. Their
location with respect to the road can be seen in Figure 22. The
receptor coordinates are shown in Table 28.

E2.1.4 PEAK HOUR CONCENTRATIONS

The computed concentrations can be found in Table 29. The
highest concentration (9.82 ppm) occurred with winds from the
north and south at Receptor 1. No off-peak or eight-hour average
concentrations were computed for this case because it was judged
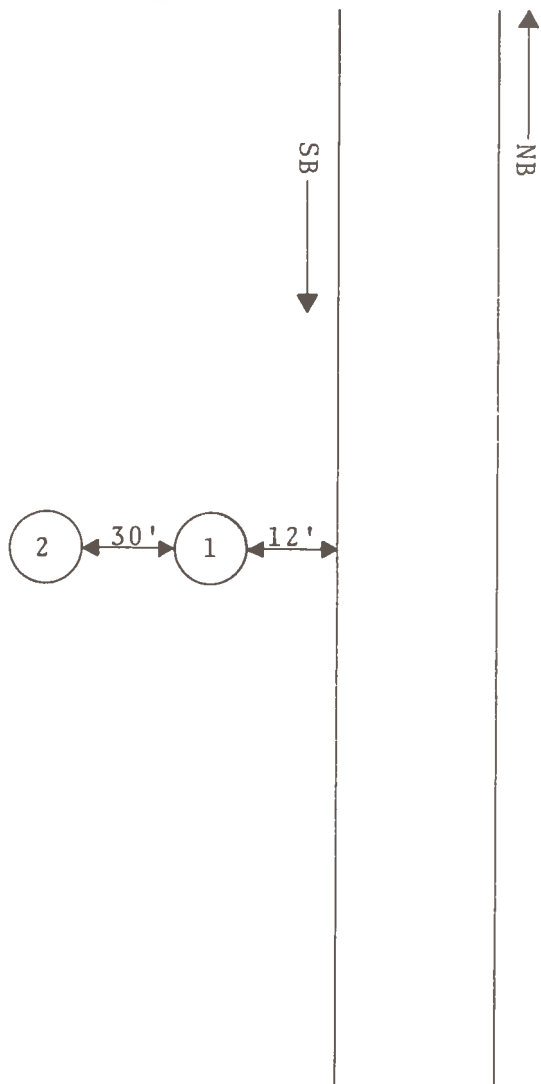that the eight-hour standard would not be exceeded.

Figure 22. City Boulevard, Lexington Street, Saratoga Street,
Build Case

TABLE 26.   CITY BOULEVARD, LEXINGTON STREET, SARATOGA STREET,
            BUILD CASE, HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
NB	35	5000	35	-5000	3	36	0	3
SB	-35	5000	-35	-5000	3	36	0	3

TABLE 27.   CITY BOULEVARD, LEXINGTON STREET, SARATOGA STREET,
            BUILD CASE, PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	veh/hr lane	SPEED	1978 EMISSION FACTOR for CO 5 % HDV $\frac{gm/mi}{veh}$	$\frac{gm/mi}{\frac{hr}{lane}}$	$\frac{gm/m}{\frac{sec}{lane}}$
NB	1562	521	35	22	11462	.00198
.SB	2329	776	30	23	17848	.00308

TABLE 28. CITY BOULEVARD, LEXINGTON STREET, SARATOGA STREET, BUILD CASE, RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)
1	-65	0	5
2	-95	0	5

TABLE 29. CITY BOULEVARD, LEXINGTON STREET, SARATOGA STREET, BUILD CASE, PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW
1	9.82	5.47	3.85	5.47	9.82	0.00	0.00	0.00
2	5.76	4.93	3.60	4.93	5.76	0.00	0.00	0.00

E3.   TRANSPORTATION SYSTEMS CENTER ANALYSIS OF EDMONDSON AVENUE

E3.1   BUILD CASE

E3.1.1   ROAD SEGMENTATION

Edmondson Avenue is a divided roadway with three lanes in each direction. An analysis was performed to ascertain what effect the 3-A system would have on this section of roadway. Figure 23 shows the physical layout of this location. Table 30 shows how each roadway was defined as input to the model program.

E3.1.2   EMISSION CALCULATION

The traffic data and emission factors used in this analysis can be found in Table 31. The traffic count reflects the peak morning rush hour inbound, resulting in a much greater emission factor in the westbound roadway.

E3.1.3   RECEPTOR LOCATION

Four receptors were placed at this site. Two receptors were located at five to twelve feet from the edge of the road in the northward direction. The other two locations, in the southward direction, were at five and twenty feet. Their locations, with respect to the road can be seen in Figure 23. The receptor coordinates are shown in Table 32.

E3.1.4   PEAK HOUR CONCENTRATIONS

The results for peak hour concentrations for each receptor and each wind direction can be found in Table 33. The highest concentration shown (7.69 ppm) is for receptor 4 with east and west winds.

Since the concentrations calculated for the peak hour were so small, no off-peak concentrations were computed.

E3.2   NO BUILD CASE

E3.2.1   ROAD SEGMENTATION

Edmondson Avenue would be the same physical layout for the No-Build case as the Build case. The change in traffic count due to the building of the 3-A system was the key factor in this
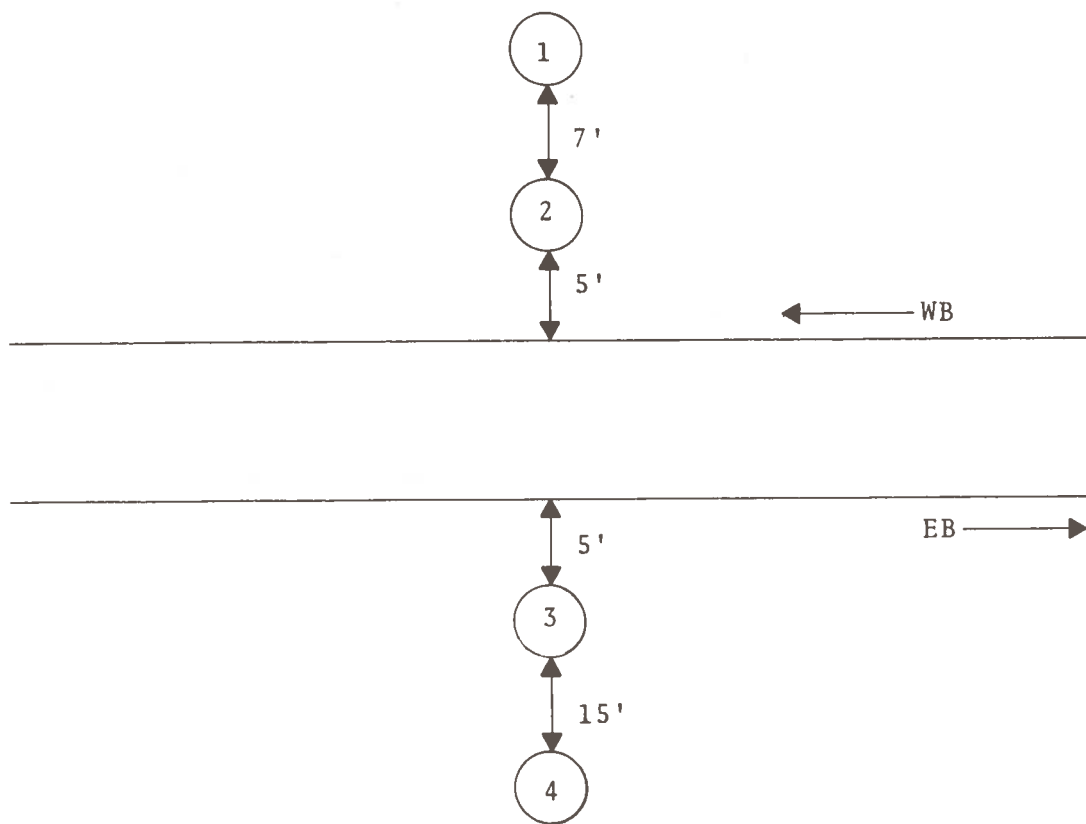
Figure 23.   Edmondson Avenue, Build Case

TABLE 30.   EDMONDSON AVENUE, BUILD CASE, HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
EB	-5000	-21.0	5000	-21.0	3.0	36.0	0.0	3.0
WB	-5000	21.0	5000	21.0	3.0	36.0	0.0	3.0

TABLE 31.   EDMONDSON AVENUE, BUILD CASE, PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	$\frac{veh/hr}{lane}$	SPEED	1978 EMISSION FACTOR for CO 5 % HDV $\frac{gm/mi}{veh}$	$\frac{gm/mi}{\frac{hr}{lane}}$	$\frac{gm/m}{\frac{sec}{lane}}$
EB	855	285	30	23	6555	.00113
WB	1433	478	25	25	11950	.00206

TABLE 32.   EDMONDSON AVENUE, BUILD CASE, RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)
1	0	51	5
2	0	44	5
3	0	-44	5
4	0	-59	5

TABLE 33.   EDMONDSON AVENUE, BUILD CASE, PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW
1	0.00	0.00	6.76	3.59	2.48	3.59	6.76	0.00
2	0.00	0.00	7.69	3.54	2.50	3.54	7.69	0.00
3	2.45	3.45	6.14	0.00	0.00	0.00	6.14	3.45
4	2.38	3.36	4.73	0.00	0.00	0.00	4.73	3.36

analysis. Figure 23 shows the physical layout of this location and Table 30 shows how each roadway was defined as input to the model program.

E3.2.2 RECEPTOR LOCATION

The receptor for the No-Build case remained in the same position as described in Table 32.

E3.2.3 TRAFFIC AND EMISSION

The traffic data and emission factors used in the No-Build case can be seen in Table 34. When compared with the Build case, the number of vehicles per hour is much greater for No-Build.

E3.2.4 PEAK HOUR CONCENTRATIONS

The results for No-Build peak hour concentrations can be found in Table 35. Upon inspection it can be seen that the No-Build case has a maximum concentration of 17.21 ppm versus 7.96 ppm for the Build case. The eight-hour average concentrations were not computed for this case.

TABLE 34. EDMONDSON AVENUE, NO BUILD CASE, PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	veh/hr lane	SPEED	1978 EMISSION FACTOR for CO 5 % HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
EB	1906	635	25	25	15875	.00274
WB	2859	953	20	27.5	26208	.00452

TABLE 35. EDMONDSON AVENUE, NO BUILD CASE, PEAK HOUR
           CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW
1	0.00	0.00	15.14	8.14	5.64	8.14	15.14	0.00
2	0.00	0.00	17.21	8.03	5.69	8.03	17.21	0.00
3	5.58	7.87	14.25	0.00	0.00	0.00	14.25	7.87
4	5.43	7.67	10.94	0.00	0.00	0.00	10.94	7.67

E4.   TRANSPORTATION SYSTEMS CENTER ANALYSIS OF I-70N THROUGH
       LEAKIN-GWYNNS FALLS PARK

E4.1   BUILD CASE

E4.1.1   ROAD SEGMENTATION

Leakin-Gwynns Falls Park is a recreational park area.   The
proposed roadway would be a divided highway with four lanes in
each direction.   An air quality analysis was performed to deter-
mine what effect the construction of this roadway would have on
the ambient air quality.   Figure 24 shows the physical layout of
this location.   Table 36 shows how the roadways were defined as
input to the model program.

E4.1.2   EMISSION CALCULATION

Traffic data and emission factors used in this analysis can
be found in Table 37.   The traffic counts, and the resulting
emission factors show the eastbound roadway, inbound, with
approximately twice as many vehicles and almost double the emis-
sions during the morning rush hour.

E4.1.3   RECEPTOR LOCATION

Only one receptor was deemed necessary at this site.   This
receptor location was chosen since it is the closest usable park
area to the proposed route of the roadway through the park.
Figure 24 shows this receptor location at 170 feet from the edge
of the roadway.   The receptor coordinates can be viewed in Table
38.

E4.1.4   PEAK HOUR CONCENTRATIONS

The results for the peak hour concentrations for each wind direc-
tion can be seen in Table 39. The largest concentration recorded
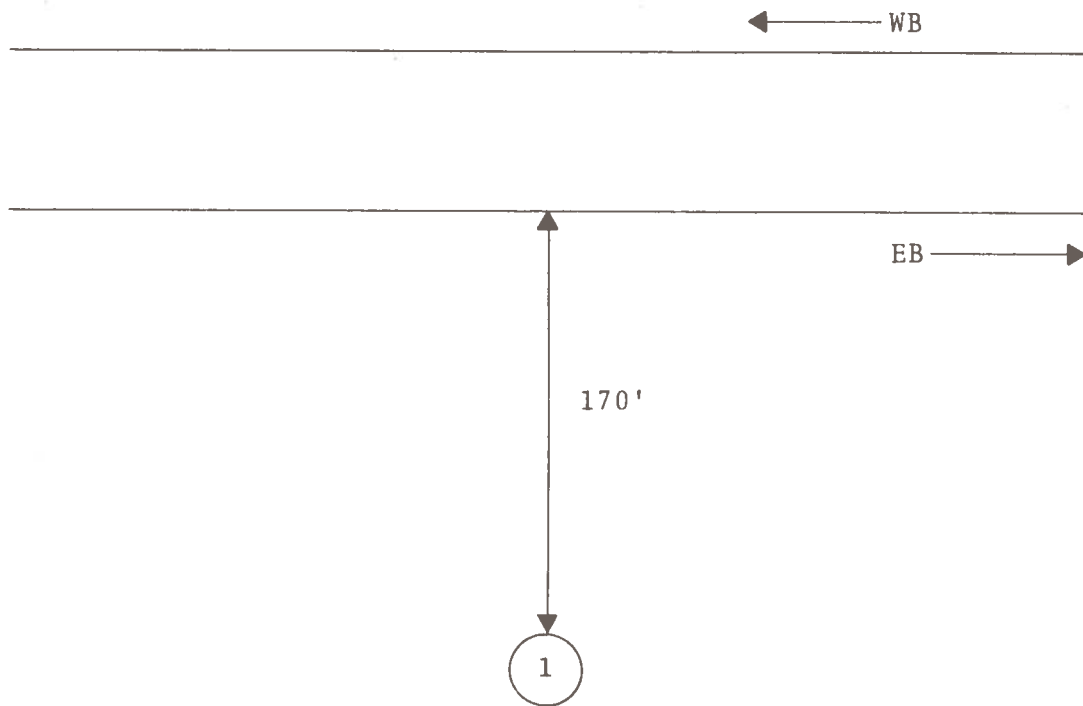was 3.06 ppm.

Figure 24. I-70N Leakin-Gwynns Falls Park, Build Case

TABLE 36. I-70N, LEAKIN-GWYNNS FALLS PARK, BUILD CASE,
HIGHWAY SECTIONS

HIGHWAY SECTION	X1 (ft)	Y1 (ft)	X2 (ft)	Y2 (ft)	SOURCE HEIGHT (ft)	HIGHWAY WIDTH (ft)	CNTR STRIP WIDTH (ft)	NO. LANES
EB	-5000	-61	5000	-61	3	48	0	4
WB	-5000	61	5000	61	3	48	0	4

TABLE 37. I-70N, LEAKIN-GWYNNS FALLS PARK, BUILD CASE,
PEAK HOUR EMISSIONS

HIGHWAY SECTION	veh/hr	veh/hr lane	SPEED	1978 EMISSION FACTOR for CO 5 % HDV gm/mi veh	gm/mi hr lane	gm/m sec lane
EB	4222	1056	48	13	13728	.00237
WB	2315	579	54	12	6948	.00120

TABLE 38. I-70N, LEAKIN-GWYNNS FALLS PARK, BUILD CASE, RECEPTORS

RECEPTOR NUMBER	X (ft)	Y (ft)	Z (ft)
1	0	-255	5

TABLE 39. I-70N, LEAKIN-GWYNNS FALLS PARK, BUILD CASE, PEAK HOUR CONCENTRATIONS (ppm)

WIND SPEED: 1 mps
STABILITY: E
MIXING HEIGHT: 1000 ft

RECEPTOR NUMBER	W I N D D I R E C T I O N S							
	N	NE	E	SE	S	SW	W	NW
1	2.49	3.06	1.71	0.00	0.00	0.00	1.71	3.06

E5.   CONCLUSIONS REGARDING THE FOREGOING FOUR AIR QUALITY ANALYSES

For all four build cases the 1978 peak hour concentrations were found to be less than one-third of the national primary ambient air quality standard. The maximum peak hour concentration for the no-build case occurred near Edmondson Avenue where a value of 17.21 ppm (still less than one-half of the standard) was cal- culated. The eight-hour average concentrations (which were com- puted) were all less than 5 ppm.

Thus again, as in the case of the Franklin-Mulberry Corridor, it appears that none of these four highway segments will produce an unacceptable level of air pollution in 1978.