

1. Report No. FHWATX78-218-3	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle TRAPS 52 User's Guide--Analytical and Experimental Assessment of Highway Impact on Air Quality		5. Report Date March 21, 1978	
		6. Performing Organization Code	
7. Author(s) J. A. Bullin, J. C. Polasek		8. Performing Organization Report No. Research Report 218-3	
9. Performing Organization Name and Address Chemical Engineering Department and Texas Transportation Institute Texas A&M University College Station, Texas 77843		10. Work Unit No.	
		11. Contract or Grant No. 2-8-75-218	
		13. Type of Report and Period Covered Research - September, 1974 February, 1978	
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation: Transportation Planning Division: P. O. Box 5051 Austin, Texas 78763		14. Sponsoring Agency Code	
		15. Supplementary Notes Work done in cooperation with FHWA, DOT	
16. Abstract Data from essentially all previous experimental programs were used to develop and verify an improved roadway dispersion model. The TRAPS 52 model presented here is based on the TRAPS II model. The latter was modified from the original TRAPS model by replacing an iterative step in that program with a fitted fourth degree polynomial in order to increase calculational speed. In addition, the virtual origin is now calculated by direct iteration rather than the secant method used in the original model. The development of the TRAPS series of models is presented along with the coding for the use of TRAPS 52 on a Texas Instruments SR 52 hand held programmable calculator. The TRAPS 52 coding requires the use of 3 magnetic cards. The variables required from the user are fully explained, along with the variables output to the user. The program limitations are also explained and two examples using the TRAPS 52 model are included.			
17. Key Words Roadway pollution dispersion modeling, programmable calculators		18. Distribution Statement No Restrictions. This document is available to the public through the National Technical Information Service Springfield, Virginia 22161	
19. Security Classif. (of this report) unclassified	20. Security Classif. (of this page) unclassified	21. No. of Pages 23	22. Price

Research Report

on

TRAPS 52 USER'S GUIDE:
ANALYTICAL AND EXPERIMENTAL ASSESSMENT OF
HIGHWAY IMPACT ON AIR QUALITY

by

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J. C. Polasek

Submitted to

File D-8 P
State Department of Highways
and Public Transportation

Research Report 218-3

Research Study No. 2-8-75-218

Sponsored by

State Department of Highways and Public Transportation
in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

CHEMICAL ENGINEERING DEPARTMENT
and
TEXAS TRANSPORTATION INSTITUTE
College Station, Texas 77843

March 21, 1978

Implementation

A study of the dispersion of pollutants from roadways is under way. Early results in the model development portion of the project indicate that existing models should be used with caution. The TRAPS pollution dispersion model was developed from the data of previous experimental programs outside Texas. An improved version of that model, called TRAPS II, is presented here. The new version is approximately twice as fast as its predecessor and is at least 10 times faster than any model prior to the original TRAPS model. Due to its speed and simplicity, this model has been adapted for use on a Texas Instruments SR 52 hand held programmable calculator. Called TRAPS 52, it can be conveniently used in the field, or where access to a computer is limited. A listing of this program is presented in this manual.

Disclaimer

This work was sponsored by the Texas State Department of Highways and Public Transportation in cooperation with the United States Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Please be advised that no warranty is made by the Texas State Department of Highways and Public Transportation, the Federal Highway Administration, or the Texas Transportation Institute as to the accuracy, completeness, reliability, usability, or suitability of the computer program and its associated data documentation. No responsibility is assumed by the above parties for incorrect results or damages resulting from the use of the program.

Summary

Data from essentially all previous experimental programs were used to develop and verify an improved roadway dispersion model. The TRAPS 52 model presented here is based on the TRAPS II model. The latter was modified from the original TRAPS model by replacing an iterative step in that program with a fitted fourth degree polynomial in order to increase calculational speed. In addition, the virtual origin is now calculated by direct iteration rather than the secant method used in the original model. The development of the TRAPS series of models is presented along with the coding for the use of TRAPS 52 on a Texas Instruments SR 52 hand held programmable calculator. The TRAPS 52 coding requires the use of 3 magnetic cards. The variables required from the user are fully explained, along with the variables output to the user. The program limitations are also explained and two examples using the TRAPS 52 model are included.

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Introduction

TRAPS 52 is a simplified version of the TRAPS II air pollution dispersion model. This version has been designed to run on the Texas Instruments' SR52 hand held programmable calculator. The program calculates the carbon monoxide concentration at any distance downwind from a roadway, given site geometry, meteorology, and traffic parameters.

The program is quite flexible, accepting inputs in either metric units, English units, or a mixture of both. Many error conditions are caught as soon as the parameter is entered and the parameter is rejected. If an error occurs later, a code indicating the most probable cause is returned. Meteorology and traffic parameters can be updated without changing the site geometry for running multiple cases at a single site.

Terminology and Background

In the following discussion underlined variables are required from the user, and those with a broken underline are calculated and returned by the program.

Consider a straight multilane roadway passing through reasonably level terrain as represented in Figures 1 and 2. The road has a width of HWID ft. (m), including a narrow median. A windspeed of UBAR miles/hour (meter/sec) is measured or predicted at a height of REFHT ft.(m). The terrain has associated with it a parameter Z₀ ft. (m) equal to 0.15 times the average height of the obstacles on the terrain. A given number of vehicles (VPH) pass the site in any given hour. The vehicles emit an average of EFACT gms of carbon monoxide per vehicle per mile traveled. At some downwind distance X ft. (m) and at some height Z ft. (m), it is desired to determine the CO concentration.

The program uses the $\overline{U_{BAR}}$ and Z_0 to calculate a 10 meter (32.8 ft.) wind velocity ($\overline{U_{10}}$), a 1 meter (3.28 ft) wind velocity ($\overline{U_1}$), a roughness wind velocity ($\overline{U^*}$), and an eddy diffusivity (\overline{DIFFY}) in order to fill in all the meteorological parameters needed to calculate the plume concentrations using the non-Fickian Gaussian plume equation. It calculates a roadedge CO concentration ($\overline{CO_1}$) using an empirical formula developed by Maldonado¹. The program then finds the point at which the concentration in the Gaussian plume matches the empirical concentration at the roadedge. This moves the apparent or "virtual" origin of the plume $\overline{X_{PRIME}}$ ft (m) upwind. The concentration at any downwind point, $\overline{CO_{X,Z}}$, can then be calculated directly from the Gaussian plume equation.

The program was developed using limited data and should not be applied outside the limits imposed by the design data. In addition, some of the algorithms used place further restrictions on the region of accurate results. The program accordingly should be applied with care and only inside the following limits:

1. $0.1 \text{ m} (0.38 \text{ ft}) \leq Z_0 \leq 0.8 \text{ m} (2.63 \text{ ft})$. This is sufficient to account for all cases from a full grown grain crop to a thin forest of 20 ft (6m) tall trees. Most residential areas fall inside these bounds. City street canyons do not.
2. $\overline{U_{10}} \geq 0.54 \text{ m/sec} (1.2 \text{ mile/hour})$. Below this windspeed, Gaussian pluming becomes less important than buoyant pluming, which is not accounted for in this model. Few, if any, models work below this windspeed.
3. The median width must be less than 20 ft (6m). The program assumes a mixing cell extending 10 ft (3m) beyond the last active traffic lane, allowing inclusion of a 20 ft median, but including a wider median will cause serious underprediction!

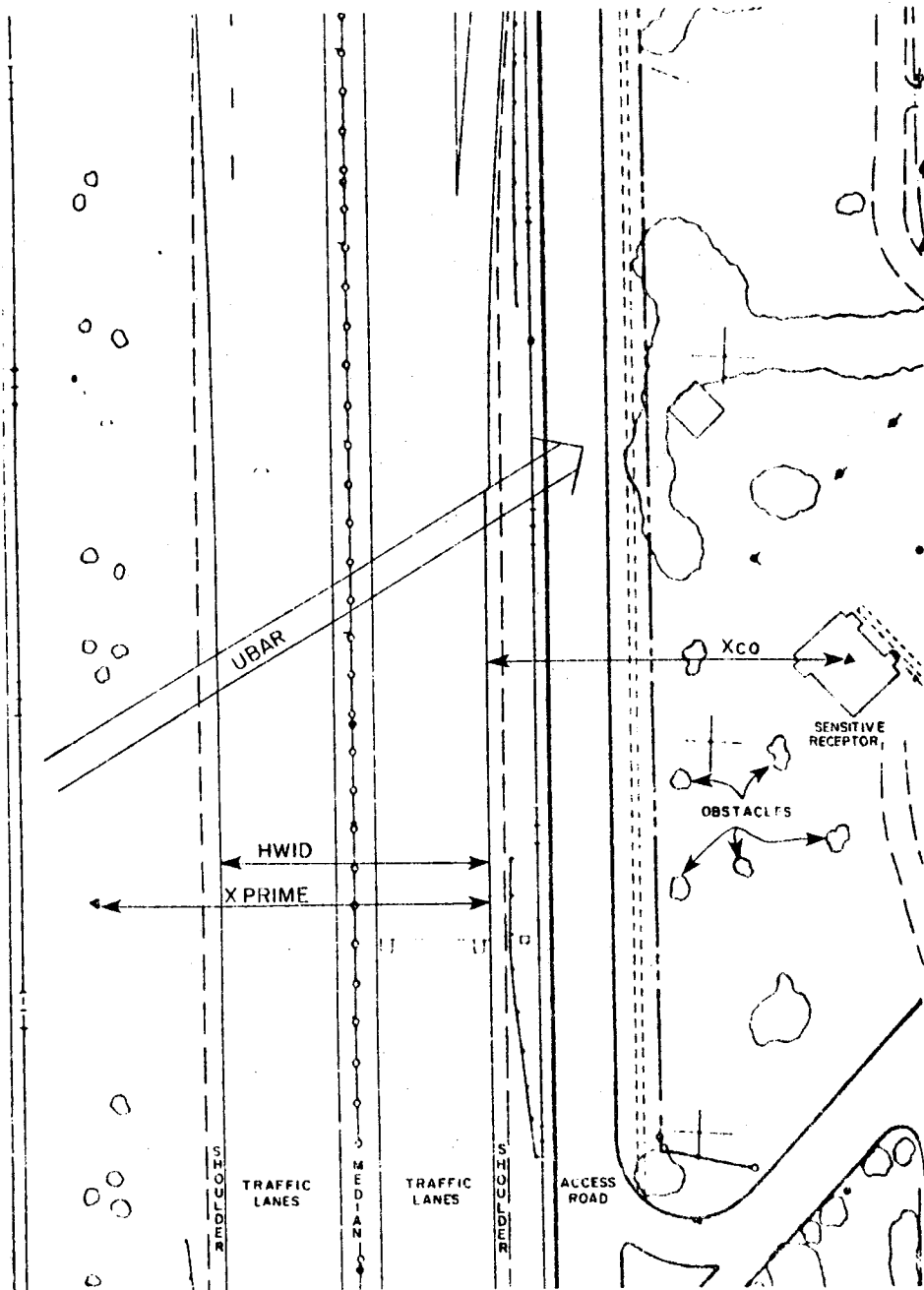


Figure 1

Aerial View of Typical Site

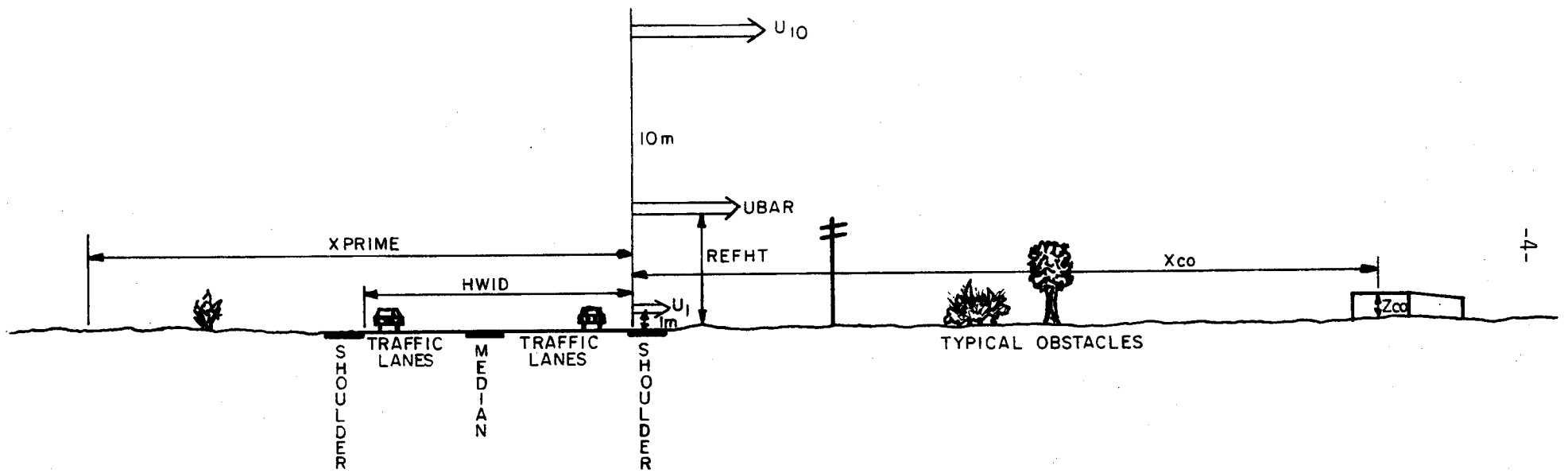


Figure 2
 Cross Section of Typical Site

Theory of Operation

The TRAPS series of models are somewhat unusual from a user point of view because they use a different version of the diffusion equation to calculate the dispersion downwind of a roadway as opposed to such models as Caline 2, Hiway, and Airpol 4. These other models all employ a Fickian solution to the anisotropic diffusion equation, imposing two highly restrictive boundary conditions on the system. First, the solution is based on a completely smooth site. Obstacles on the terrain must be ignored. Second, the wind shear due to velocity changes with altitude is assumed nonexistent.

The development of the TRAPS models is reported by Maldonado in his master's thesis (1976), and in papers by Maldonado and Bullin (1977), and Polasek and Bullin (1976). This series avoids these two major restrictions by using the non-Fickian solution to the diffusion equation proposed by Sutton (Pasquill, 1974).

$$\psi(X,Z) = \frac{Qr}{u_1 \Gamma(s)} \left[\frac{u_1}{r^2 K_1 X} \right]^s \exp \left[\frac{u_1 Z^r}{r^2 K_1 X} \right] \quad (1)$$

where X = distance downwind of source

Z = vertical distance above source

$\psi(X,Z)$ = CO concentration at X,Z

Q = source strength

u_1 = windspeed at 1 meter

K_1 = diffusion constant

r = $\alpha - \beta + 2$ r > 0

s = $(\alpha + 1)/r$

$\Gamma(s)$ = Gamma function of s

α = constant from the power law wind equation $0 < \alpha < 1$

β = stability constant $0.5 < \beta < 1.5$

Sensitivity analyses run on early versions of TRAPS prototypes showed that changes in the stability constant β had very little effect on the answers generated. This constant was then "fixed" at 1.0 to increase computational speed. This forces s and $\Gamma(s)$ to 1.0 as well, making the form used in the TRAPS models

$$\psi(X,Z) = \frac{Q}{rK_1X} \exp \left[\frac{u_1 Z^r}{r^2 K_1 X} \right] \quad (2)$$

with $r = \alpha + 1$.

In order to use this equation, three meteorological parameters, u_1 , K_1 , α , must be calculated.

Calculation of u_1 , K_1 , and α

It has been well documented that windspeed is not constant with height, (Project Prairie Grass, 1958). The shape of the windspeed profile with height is mainly dependent on the surface roughness. One of the best equations for predicting this profile is the log law equation:

$$u_Z = \frac{u_*}{K} \ln \left(\frac{Z}{Z_0} \right) \quad (3)$$

u_Z = windspeed at height $Z > Z_0$

u_* = friction velocity

K = von Karmon's Constant

Z_0 = roughness height (0.15 times average obstacle height)

Given a wind velocity at a particular height, and an estimate of Z_0 , this equation can generate the value of u_1 and u_* .

However, the nonFickian solution to the diffusion equation assumes that the wind follows a power law equation:

$$u_z = u_1 \left(\frac{z}{z_1} \right)^\alpha = u_1 z^\alpha \quad (4)$$

for $z_1 = 1.0$

Accordingly, an α must be estimated which gives a profile closely matching that of the power law equation. This is best done by minimizing the squared error over a representative interval. In the case of the TRAPS models, the interval of 1 to 10 meters was chosen as the best interval to fit. Since both functions are continuous in this range, the squared error can be integrated over this interval. The " α of best fit" can then be calculated iteratively. However, the original TRAPS model was modified by eliminating this iterative step through the use of a fitted polynomial equation. Examination of Equations (3) and (4) reveals that α is solely a function of z_0 . The α 's were then calculated for 150 different values of z_0 and the results fitted to a fourth degree polynomial. This procedure reduces required computational time by approximately 50%.

Last, K_1 is estimated from an equation given by Calder (1949) to be:

$$K_1 = 0.4 u_* \quad (5)$$

Since the total source Q of a highway is not concentrated in a single thin line, but rather is diffused from a large area, the effect is the same as that of a line source at some distance upwind of the roadway. In order to match equation (2) to the real world, this distance must be estimated. The method used consists of independently calculating the concentration at the downwind edge of the roadway and then calculating the point in the plume that matches the concentration.

An empirical equation was used to calculate the roadedge concentration at a five foot height. This equation was obtained by dimensional analysis followed by a statistical analysis. It agrees with the form presented by Pasquill (1974). The final equation is

$$\chi = 3.44 Q / (u_{10} W) \quad (6)$$

χ = CO concentration at a 5 ft. height and on the downwind edge of roadway

u_{10} = 10 meter windspeed

W = width of roadway (including median)

This equation provided a better "fit" to the data from North Carolina (Noll, et. al., 1975) than equations incorporating a wind direction parameter.

The result was then matched to the Gaussian plume by direct iteration. Maldonado (1976) originally used the secant method to determine the virtual original distance. The convergence equation used is

$$X_{n+1} = \frac{Q}{rK\chi} \exp \left[\frac{u_1 Z^r}{r^2 K_1 X_n} \right] \quad (7)$$

where

X_{n+1} = X of the $(n + 1)^{th}$ trial

X_n = X of the n^{th} trial

X_1 is set at three times the highway width. Convergence to plus or minus one meter usually occurs on the third or fourth trial.

Once this point is known, any downwind concentration can be calculated directly by equation (2).

Using The Program

Traps 52 may be coded onto 3 magnetic cards. The necessary coding is shown in detail in the Appendix. The first card is used to enter the site geometry and needs to be loaded only once per site. The second card is used to load the traffic and meteorology parameters and calculate the roadedge concentration. It must be reloaded every time these parameters are changed. The third card is used only to calculate the downwind concentrations. It must be loaded after card 2 if downwind concentrations are needed. Often, the roadedge concentration is enough to show that the road is no threat to air quality and card 3 does not have to be loaded.

To use the program, locate card 1. Load both sides. One may now enter in any order the following parameters: HWID, REFHT, and Zo. The program returns an integer code to remind the user of the last parameter entered. REFHT is parm 1., HWID is parm 2., and Zo is parm 3. As soon as the program has both Zo and REFHT, it calculates a number of meteorological parameters needed to calculate the plume characteristics, stopping with the parameter R in the display (see Maldonado¹ for an explanation of this parameter). If a parameter code is returned flashing, the program found the parameter to lie outside of the valid model range and rejected it. Reset the parameter in range and reenter it after pressing 'CE'. To enter REFHT, punch in the number and strike key A. To enter HWID, punch in the number and strike key B. To enter Zo, punch in the number and strike key C. If an entered number is positive, the program assumes the units to be feet. If the number is negative, it changes the sign and assumes the units to be meters. To display any of the parameters, strike 2nd and the entering key. The result will be in feet. To convert to meters, strike key D.

After these three parameters have been successfully entered, locate card 2. Load both sides. One may now enter in any order: UBAR (parm 4.), VPH (parm 5.), and EFACT (parm 6.). The parameter number is echoed as each parameter is entered. A flashing 4. indicates that the calculated U_{10} is less than 0.54 meter/second (1.2 mile/hour). Reenter a higher windspeed after pressing CE. To enter UBAR, punch in the desired value and strike key A. If the number entered is positive, the program assumes the units to be miles/hour. If the number is negative, the program changes the sign and assumes the units to be meters/second. To enter VPH, punch in the desired value and strike key B. The only permitted units are vehicles per hour. A negative input here will result in a negative CO output. To enter EFACT, punch in the desired value and strike key C. The only units permitted are grams per vehicle mile. Entering a negative here will also result in a negative CO concentration. To review any of these parameters, simply strike 2nd and the entering key. Key E will convert the displayed value of UBAR miles per hour to meters per second. When satisfied with these parameters, strike key D. The program will halt with the roadedge CO concentration in the display. If this is low enough, nothing more need be done and another UBAR, VPH, and EFACT can be keyed in without loading any other cards.

If, however, this value exceeds the ambient air standards, or if a numerical value must be known for a downwind receptor for some other reason, the third card must be loaded. Locate it and load both sides. Strike key A. The value returned is the virtual origin distance in ft. The program is now ready to calculate downwind concentrations at the 5 ft. (1.524 m) height. Simply key in a distance and strike key C. The returned value is the concentration in PPM. For other heights, key in the desired height and strike key B. This permanently changes the

height until it is changed again by the B key or until a new virtual origin is calculated. The displayed value is the height in meters. If either X or Z is positive, the program assumes the units to be ft. If the value is negative, the program reverses the sign and assumes meters. All internal carried values are metric in the program. See the register usage table for exact placement and units.

To change a parameter, one must reload the card by which the parameter was originally entered, reenter the parameter and continue from that point, skipping any other parameter loading steps unless changes are desired. To go to a new site, reload card 1 and strike RESET. This makes the program forget the existing parameters.

Examples

Here are 2 examples of the utility of Traps 52 for the traffic designer. They each have no specific real world counterpart, but, in searching, many similar situations can be found.

Example 1

Rural Bypass Interstate highway passing 500 ft from a school play ground. 4 ft brush upwind and downwind. 4-15 ft wide traffic lanes with 10 ft median. Average vehicle speed 63 miles per hour; most vehicles warm. 1200 VPH during rush hour. Do worst case analysis ($1.2 = U_{10}$).

1. Load Card 1.
2. Enter 10 +/- A 1. (REFHT)
3. Enter 4 x 15 + 10 = 70. B 2. (HWID)
4. Enter 4 x .15 = 0.6 C 1.378... (Zo)
5. Load Card 2.
6. Enter .54 +/- A 4. (Minimum Windspeed) (UBAR)
7. Enter 1200 B 5. (VPH)
8. Enter 23 C 6. (Emission Factor for Warm Cars) (EFACT)
9. Key D 3.876... (Roadedge CO concentration)

This roadway offers no threat to environmental quality even at the edge of the roadway. At 500 ft the rise in CO due to the roadway is probably undetectable. No further calculations need be done.

Example 2

A proposed freeway is 150 ft wide with an 8 ft median (158 ft total). There are parking lots on both sides of the expressway for use by spectators of sporting events in a large arena 1000 ft upwind of the expressway. The

lowest recorded windspeed for this area is 0.8 mile per hour measured at 8 ft. There are 8 metered ramps in the area that may be used by spectators leaving the parking lots, each ramp permitting 1000 VPH onto the roadway. The expressway normally carries 3000 VPH thru traffic. Calculate the exposure of those people sitting in the cars 150 ft downwind of the freeway, ignoring the cars idling in the parking lot immediately after a large event lets out.

1. Load Card 1.
2. Enter 8 A 1. (REFHT)
3. Enter 158 B 2. (HWID)
4. Enter $5 \times .15 = \underline{0.75}$ C 1.418... (Assume average car height 5 ft) (Zo)
5. Load Card 2.
6. Enter .8 A 4. (UBAR)
7. Enter $3000 + 8 \times 1000 = \underline{11000.}$ B 5. (VPH)
8. Enter 29 C 6. (Emission Factor for mostly cold cars) (EFACT)
9. Key D 21.4... (Roadedge CO concentration)
10. Load Card 3.
11. Key A 176.6... (Virtual Origin. Calculation will take about 2 minutes)
12. Enter 150 C 13.0... CO concentration 150 ft downwind at 5 ft height)

This is inside Ambient Air standards. However, methods should be considered to limit the number of people reaching their cars at one time.

APPENDIX

Register Usage Table

<u>Register #</u>	<u>Variable Name</u>	<u>Definition</u>	<u>Parameter #</u>
00	X	Downwind distance of receptor (meters)	
01	REFHT/Zo	Altitude ratio for log law windspeed	
02	X + X PRIME	Virtual downwind distance of receptor (meters)	
03	Z	Height of receptor (meters)	
04	X PRIME	Virtual origin distance (meters)	
05	VAR2	Intermediate variable 2	
06	VAR1	Intermediate variable 1	
07	CO1	Roadedge CO concentration (gm/m ³)	
08	EFACT	Average vehicle emission factor (gm/veh-mi)	6
09	VPH	Vehicles per hour	5
10	R	ALPHA + 1	
11	ALPHA	Power Law Windspeed constant	
12	Zo	0.15 times the average obstacle height (meters)	3
13	REFHT	Height of Windspeed measurements (meters)	1
14	HWID	Highway width (meters)	2
15	DIFFY	Eddy Diffusivity (meter ² /sec)	
16	U*	Friction wind velocity (meter/sec)	
17	U1	One meter windspeed (meter/sec)	
18	U10	Ten meter windspeed (meter/sec)	
19	UBAR	Windspeed at REFHT (meter/sec)	4

Program Installation

The method of installing the program is simple and straightforward. The basic method used for installing programs will be found in the SR52 users manual on pages 76 and 77. The program listing can be found in the Appendix of this report.

The listing is in 3 sections since 3 cards are required. Each section must be "keyed in" and then recorded before the next section is "keyed in". As many copies as desired can be recorded before the next section is "keyed in".

In the listing, the '*' designates the use of the '2nd' key, as per Texas Instruments convention.

SR-52 Coding Form



LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112	46	*LBL			04	4			78	*5		A REFHT
	11	A			50	*st flg			50	*st flg		B HIWID
	94	+/-		040 152	01	1			02	2		C Zo
	80	*if pos			25	CLR			60	*if flg		D
	87	*1			02	2		080 192	00	0		E
005 117	51	SBR			81	HLT			67	*7		A'
	22	INV			46	*LBL			25	CLR		B'
	46	*LBL		045 157	13	C			03	3		C'
	87	*1			94	+/-			81	HLT		D'
	42	STO			80	*if pos		085 197	46	*LBL		E'
010 122	01	1			89	*3			67	*7		REGISTERS
	03	3			51	SBR			25	CLR		00
	50	*st flg		050 162	22	INV			43	RCL		01 <i>Ln</i> <u>REFHT</u> Zo
	00	0			46	*LBL			01	1		02
	60	*if flg			89	*3		090 202	03	3		03
015 127	02	2			42	STO			55	÷		04
	67	*7			01	1			43	RCL		05
	25	CLR		055 167	02	2			01	1		06
	01	1			75	-			02	2		07
	81	HLT			93	.		095 207	54	)		08
020 132	46	*LBL			01	1			23	<i>Ln</i> ×		09
	12	B			54	)			42	STO		10
	94	+/-		060 172	80	*if pos			00	0		11
	80	*if pos			77	*4			01	1		12 Zo
	88	*2			46	*LBL		100 212	90	*if zro		13 REFHT
025 137	51	SBR			78	*5			68	*2		14 HWID
	22	INV			25	CLR			80	*if pos		15
	46	*LBL		065 177	03	3			79	*6		16
	88	*2			85	+			46	*LBL		17
	85	+			95	=		105 217	68	*2		18
030 142	06	6			81	HLT			25	CLR		19
	93	.			46	*LBL			04	4		FLAGS
	00	0		070 182	77	*4			85	+		0
	09	9			75	-			95	=		1
	06	6			93	.		110 222	81	HLT		2
035 147	95	=			07	7			46	*LBL		3
	42	STO			54	)		TEXAS INSTRUMENTS INCORPORATED				4
	01	1		075 187	80	*if pos						

SR-52 Coding Form



LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112	79	*6			42	STO			81	HLT		A
	25	CLR			01	1			46	*LBL		B
	03	3		040 152	00	0			22	INV		C
	93	.			56	*RTN			94	+/-		D
	04	4			46	*LBL		080 192	46	*LBL		E
005 117	02	2			16	*A'			14	D		A REFHT
	07	7			43	RCL			65	X		B HWID
	51	SBR		045 157	01	1			46	*LBL		C Zo
	65	X			03	3			26	*INV		D
	75	-			55	÷		085 197	93	.		E
010 122	03	3			51	SBR			03	3		REGISTERS
	93	.			27	*INV			00	0		00
	08	8		050 162	95	=			04	4		01 REFHT ln Zo
	02	2			81	HLT			08	8		02
	09	9			46	*LBL		090 202	54	)		03
015 127	51	SBR			17	*B'			56	*RTN		04
	65	X			43	RCL			46	*LBL		05
	85	+		055 167	01	1			65	X		06
	02	2			04	4			54	)		07
	93	.			55	÷		095 207	65	X		08
020 132	00	0			51	SBR			43	RCL		09
	03	3			27	*INV			01	1		10 R
	03	3		060 172	75	-			02	2		11 α
	09	9			02	2			56	*RTN		12 Zo
	51	SBR			00	0		100 212				13 REFHT
025 137	65	X			95	=						14 HWID
	85	+			81	HLT						15
	93	.		065 177	46	*LBL						16
	01	1			18	*C'						17
	01	1			43	RCL		105 217				18
030 142	03	3			01	1						19
	95	=			02	2						FLAGS
	42	STO		070 182	55	÷						0
	01	1			51	SBR						1
	01	1			27	*INV		110 222				2
035 147	85	+			95	=						3
	01	1			81	HLT						4
	95	=		075 187	81	HLT						

SR-52 Coding Form



LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112	46	*LBL			01	1			81	HLT		A
	11	A			00	0			46	*LBL		B
	94	+/-		040 152	51	SBR			14	D		C
	8-	*if pos			23	ln x			25	CLR		D
	87	*1			42	STO		080 192	93	.		E
005 117	51	SBR			01	1			01	1		A
	22	INV			08	8			09	9		B
	46	*LBL		045 157	75	-			08	8		C
	87	*1			93	.			01	1		D
	42	STO			05	5		085 197	45	y ^x		E
010 122	01	1			03	3			08	8		REGISTERS
	09	9			06	6			65	X		00
	65	X		050 162	95	=			43	RCL		01
	93	.			80	*if pos			00	0		02
	04	4			89	*3		090 202	09	9		03
015 127	55	+			04	4			65	X		04
	43	RCL			85	+			43	RCL		05
	00	0		055 167	95	=			00	0		06
	01	1			81	HLT			08	8		07
	90	*if zro			46	*LBL		095 207	54	)		08
020 132	88	*2			89	*3			90	*if zro		09
	95	=			50	*st flg			77	*4		10
	42	STO		060 172	03	3			55	+		11
	01	1			04	4			43	RCL		12
	06	6			81	HLT		100 212	01	1		13
025 137	65	X			46	*LBL			04	4		14
	93	.			12	B			90	*if zro		15
	04	4		065 177	42	STO			78	*5		16
	95	=			00	0			55	+		17
	42	STO			09	9		105 217	43	RCL		18
030 142	01	1			05	5			01	1		19
	05	5			81	HLT			08	8		FLAGS
	01	1		070 182	46	*LBL			95	=		0
	51	SBR			13	C			42	STO		1
	23	ln x			42	STO		110 222	00	0		2
035 147	42	STO			00	0			07	7		3
	01	1			08	8		TEXAS INSTRUMENTS INCORPORATED				4
	07	7		075 187	06	6						

SR-52 Coding Form



LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112	41	GTO			81	HLT			93	.		A
	55	+			46	*LBL			01	1		B
	46	*LBL		040 152	22	INV			04	4		C
	23	ln x			94	+/-			02	2		D
	55	+			46	*LBL		080 192	08	8		E
005 117	43	RCL			15	E			45	y ^x		A'
	01	1			65	X			08	8		B'
	02	2		045 157	46	*LBL			65	X		C'
	54	)			27	*log			43	RCL		D'
	23	ln x			93	.		085 197	00	0		E'
010 122	65	X			04	4			09	9		REGISTERS
	43	RCL			04	4			65	X		00
	01	1		050 162	07	7			43	RCL		01
	06	6			95	=			01	1		02
	55	+			56	*RTN		090 202	00	0		03
015 127	93	.			46	*LBL			65	X		04
	04	4			16	*A'			43	RCL		05
	95	=		055 167	43	RCL			00	0		06
	56	*RTN			01	1			08	8		07
	46	*LBL			09	9		095 207	55	+		08
020 132	88	*2			55	+			43	RCL		09
	01	1			51	SBR			01	1		10
	03	3		060 172	27	*log			07	7		11
	85	+			81	HLT			95	=		12
	95	=			46	*LBL		100 212	42	STO		13
025 137	81	HLT			16	*B'			00	0		14
	46	*LBL			43	RCL			06	6		15
	77	*4		065 177	00	0			43	RCL		16
	05	5			09	9			00	0		17
	06	6			81	HLT		105 217	07	7		18
030 142	85	+			46	*LBL			65	X		19
	95	=			18	*C'			08	8		FLAGS
	81	HLT		070 182	43	RCL			07	7		0
	46	*LBL			00	0			05	5		1
	78	*5			08	8		110 222	95	=		2
035 147	02	2			81	HLT			81	HLT		3
	85	+			46	*LBL		TEXAS INSTRUMENTS INCORPORATED				4
	95	=		075 187	55	+						

SR-52 Coding Form



LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LABELS
000 112	60	*if flg			46	*LBL			65	X		A
	04	4			13	C			08	8		B
	77	*4		040 152	94	+/-			07	7		C
	03	3			80	*if pos			05	5		D
	05	5			79	*6		080 192	95	=		E
005 117	85	+			94	+/-			81	HLT		A'
	95	=			65	X			46	*LBL		B'
	81	HLT		045 157	14	D			17	*B'		C'
	46	*LBL			46	*LBL			43	RCL		D'
	77	*4			79	*6		085 197	00	0		E'
010 122	25	CLR			42	STO			03	3		REGISTERS
	81	HLT			00	0			51	SBR		00
	46	*LBL		050 162	00	0			22	INV		01
	222	INV			75	-			81	HLT		02
	55	+			03	3		090 202	46	*LBL		03
015 127	46	*LBL			93	.			16	*A'		04
	14	D			00	0			43	RCL		05
	93	.		055 167	04	4			00	0		06
	03	3			08	8			04	4		07
	00	0			95	=		095 207	51	SBR		08
020 132	04	4			80	*if pos			22	INV		09
	08	8			67	*7			75	-		10
	95	=		060 172	25	CLR			01	1		11
	56	*RTN			46	*LBL			00	0		12
	46	*LBL			67	*7		100 212	95	=		13
025 137	12	B			95	+			81	HLT		14
	94	+/-			43	RCL			46	*LBL		15
	80	*if pos		065 177	00	0			18	*C'		16
	78	*5			04	4			43	RCL		17
	65	X			95	=		105 217	00	0		18
030 142	14	D			42	STO			00	0		19
	94	+/-			00	0			51	SBR		FLAGS
	46	*LBL		070 182	02	2			22	INV		0
	78	*5			51	SBR			81	HLT		1
	42	STO			87	*1		110 222				2
035 147	00	0			43	RCL						3
	03	3			00	0		TEXAS INSTRUMENTS INCORPORATED				4
	81	HLT		075 187	02	2						

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