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HIGHWAY CONSTRUCTION NOISE - ENVIRONMENTAL ASSESSMENT AND ABATEMENT

VOLUME IV

USER'S MANUAL FOR FHWA HIGHWAY CONSTRUCTION NOISE COMPUTER PROGRAM, HICNOM

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USER'S MANUAL FOR FHWA HIGHWAY CONSTRUCTION NOISE COMPUTER PROGRAM, HICNOM

For:

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16. Abstract
This series of reports represents a comprehensive treatment of highway construction noise characterization, measurement, prediction, and abatement, based on a literature review and original research. The major result of the study is a prediction model for highway construction noise with charts, calculator and computer program methods for its use. An extensive series of site and equipment noise measurements provided a data base for model development and validation.

Volume 4 is the user's manual and programmer's manual for the interactive Fortran program for the prediction model. Program features and data input and output are explained in detail, and five example problems are presented. The program models sources as points, lines or areas and includes noise barrier attenuation routines and data base for over fifty equipment models. The program structure is documented in the Appendices.

This volume is the fourth in a series. The others in the series are:

Vol. No.	FHWA No.	Short Title	NTIS(PB) No.
1		Executive Summary and Simplified Prediction Methods	
2		Understanding Highway Construction Process	
3		Analysis and Abatement of Construction Noise	
5		Measurement and Analysis Data	

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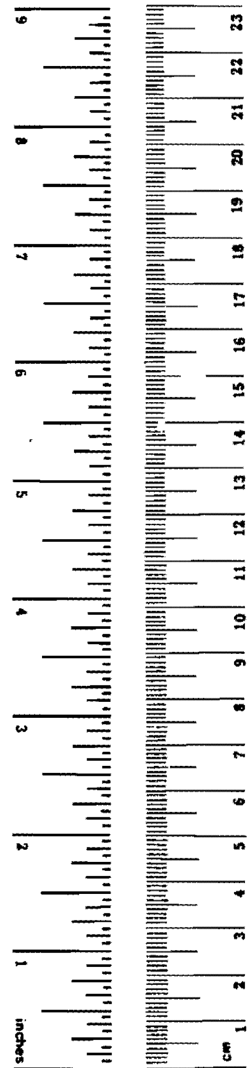
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

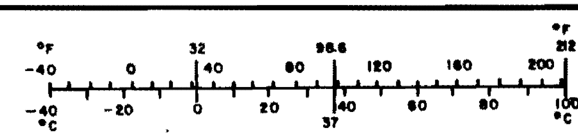
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

This report is one volume of the Federal Highway Administration (FHWA) Highway Construction Noise Handbook entitled Highway Construction Noise: Environmental Assessment and Abatement. It documents the formulation and use of HICNOM, the FHWA highway construction noise model and computer program.

The construction noise model is used to predict 8-hour equivalent sound levels, Leq(8h) at receiver locations near a highway construction site from a variety of equipment and operations. The program may be used during planning and design of highway projects to identify potential problem areas and to evaluate abatement strategies. It may also be used during construction to design abatement methods or to analyze different mitigation strategies for specific problem areas.

The model is designed for users with minimal background in acoustics and contains acoustic data for a large variety of construction equipment. However, it has options which permit the entry of user-supplied data bases and is therefore useful to acoustic specialists as well. While acoustics expertise is not required to operate this program, some knowledge of highway construction procedures and equipment is needed. Those desiring more background information on construction activities and noise, and on field measurements used in development of this model, should read the other volumes that make up the entire FHWA Highway Construction Noise Handbook. They are cited as References 2-5 at the end of the main body of this report.

The computer program as presented here is installed on the FHWA Amdahl computer system. It is an interactive program, where the user responds to data requests from the computer, and may be run from a video display or printing terminal. The program consists of two parts: HINPUT, which requests the input data from the user and performs initial acoustical and geometric calculations; and HICNOM, which performs the bulk of the acoustical calculations. HINPUT prepares a file containing the input data and initial calculations that then serves as the input file to HICNOM, which prepares a report of the results.

While the program is fairly simple to use for someone unfamiliar with computer programming or acoustics, it offers a variety of options to the more experienced user regarding the types and operations of construction equipment. The user who desires to take advantage of these options is urged to carefully read this manual to understand how they work.

Section 2.0 of this manual describes the capabilities and logical structure of the HICNOM program. Section 3.0 gives complete instructions for using the program, and presents coding worksheets for use in organizing input data. Section 4.0 discusses the output reports and their interpretation, while several example problems illustrating program use are given in Section 5.0. Section 6.0 lists error statements and how to recover from errors.

Appendix A discusses the model formulation and structure. It describes how construction activities and tasks are modeled and gives the acoustical formulation for the Leq calculations. Appendix B is the programmer's manual, containing hardware requirements, and descriptions of program subroutines and data configurations. Appendix C is the maintenance manual, which describes the main data blocks and procedures for updating them. Appendix D presents a series of blank coding worksheets.

Presented in Appendix E are the field data sheets and photographs for the construction sites that are modeled in Example Problems 3 and 4 in Sections 5.3 and 5.4. Finally, Appendix F presents the results of additional model validation work at three construction sites on Interstate 440 in Nashville, Tennessee.

2.0 PROGRAM DESCRIPTION

2.1 Capabilities

The program has the following capabilities:

- Calculation of an 8-hour equivalent sound level, Leq (8h) for construction activities representing various point, line, and area sources.
- Up to 10 receiver locations.
- Up to 10 point sources.
- Up to 6 line sources, each described by up to 10 points.
- Up to 5 area sources, each described by up to 10 centerline points and widths.
- Up to 3 barriers, each defined by up to 5 top edge points.
- Built-in data base for over 50 types and models of construction equipment.
- Easy user specification of additional data.
- Activity levels can be automatically balanced between equipment working together.
- Excess attenuation specified by user for each receiver location.*
- Automatic generation of haul road turnaround loops and acceleration/deceleration profiles.
- Diagnostic output identifying the contribution of each source to the overall noise.
- Alphabetic descriptions supplied by the user for each receiver, source and barrier for easy identification on the output.

The quantitative limits noted above are primarily due to the dimensioned size of arrays. They can be increased by changing appropriate dimensions, as discussed in Appendices B & C. The equipment data base can be increased to about 300 types and models within existing dimensions by modifying only the data statements described in Appendix C.

2.2 Logical Structure

The program is divided into two main sections: an input and task module, called HINPUT, that accepts geometric inputs and task descriptions and generates acoustic source quantities, and the acoustical part, called HICNOM, that computes receiver noise levels. These two sections are run separately. HINPUT interactively

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*Excess attenuation is specified in decibels per doubling of distance. It is related to the ground cover parameter "alpha" in the FHWA Highway Traffic Noise Prediction Model by being equal to three times alpha. For example, a "soft" site alpha of ½ corresponds to an excess attenuation of 1.5 dB.

accepts user data from a terminal, prompting the user for each line of data. HINPUT computes a reference emission level for each piece of equipment factored by the hours worked by the equipment, and a "source density" for line and area sources that is used by HICNOM in the Leq calculations. HINPUT also generates the coordinates for the points representing turn-around loops for haul roads, and average speeds on the segments defined by these points. HINPUT then creates a data file that is to be read and used by HICNOM. HICNOM then does the Leq calculations, basically as detailed in Section A.2 and produces a results report.

The following subsections describe the logical structure of the two programs.

2.2.1 HINPUT

Figure 1 is a flow chart of HINPUT. Indicated on the chart are the names of key subroutines used in each section. The subroutines are described in detail in Appendix B.

The user first enters the coordinates of receiver locations and a value of excess attenuation. These values are passed directly through to the data file. Construction activities are next specified by inputting the name of a particular piece of equipment. The subroutine DECODE checks the input name against a list of allowable names. An internal identification index is returned, together with an indicator as to whether the source is a point, line, or area. User-defined equipment may be specified. The input equipment type name is appended with a sequential number, e.g., the third backhoe input is called "BACKHOE 3", for identification in the data file.

Separate sections of code handle the remaining input and analysis for the three geometry types. The source location is input, then control is transferred to the appropriate task subroutine: PTTASK, LNTASK, or ARTASK. Each of these routines looks up the emission level of the equipment and adds its effective source height to the input location. If a user-defined piece of equipment is specified, the program requests the appropriate data. These data are stored so that this new equipment type may be referred to later in the same run. The task routines compute the production rate for appropriate equipment, and utilize this to obtain usage factors (fraction of time operating) when equipment is coordinated. The line and area sections divide the number of sources by total length or area to obtain source density.

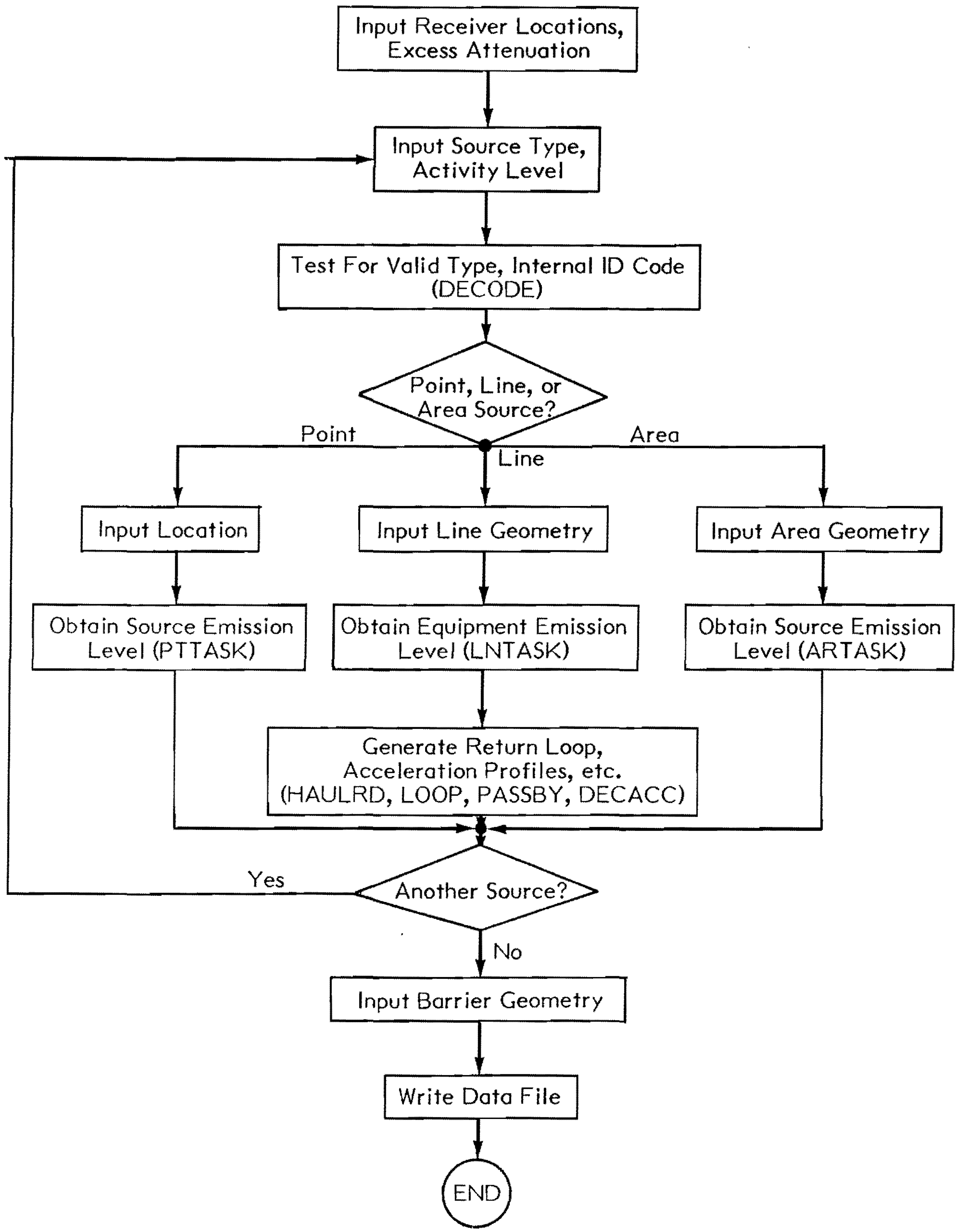


Figure 1. HINPUT Flow Chart

The line task section (via subroutine LNTASK) additionally contains routines to generate turnaround loops and acceleration/deceleration profiles. The available options are described in Section 3.0, and details of the computation are in Appendices A and B. Briefly, several options are available that result in the addition of a number of points to the input line geometry and that cause the calculation of average speed, source density, and emission level on each segment. These modified and/or computed values are returned to the main program for inclusion in the output data file.

Following input of source data, the geometries of any barriers are then entered. These are passed through unaltered to the output data file. Writing the data file is the final step of this program.

2.2.2 HICNOM

Figure 2 is a flow chart of HICNOM. The key subroutines parenthetically noted are described in detail in Appendix B.

Program structure is essentially linear. The data file created by HINPUT is read, then the noise at each receiver is computed for the point, line and area sources. When barriers are present, the noise contribution from each source element is first computed without barriers, then with barriers. The smaller value is taken, as discussed in Section A.2.4.

The point source calculation is quite straightforward, based on Equation A-1 in Section A.2.1, and the no-barrier case is handled entirely within the main program. The line and area cases are somewhat more complex. In order to standardize the line source calculation (Equation A-4 or A-9) each line segment is transformed to a local-coordinate system oriented as shown in Figure 3. For a line between points i and i + 1, point i is placed at the origin and i + 1 on the positive x-axis. Each receiver location is transformed to these coordinates, with the y value taken as $-|y|$. The quantities d, ϕ_1, and ϕ_2, are then directly obtained for use in subroutine LINSRC, which performs the calculation of Equations A-4 and A-9. The coordinate transformation is performed by subroutine GEOM. GEOM is a general-use transformation routine which is used for a variety of purposes in both HICNOM and HINPUT.

The area calculation requires division of areas into segments, then division of each segment into strips, as described in Section A.2.3. Figure 4 shows how areas are represented in the model. This task is performed by subroutine AREA. Each strip is treated as a separate line element, as are the segments of line sources.

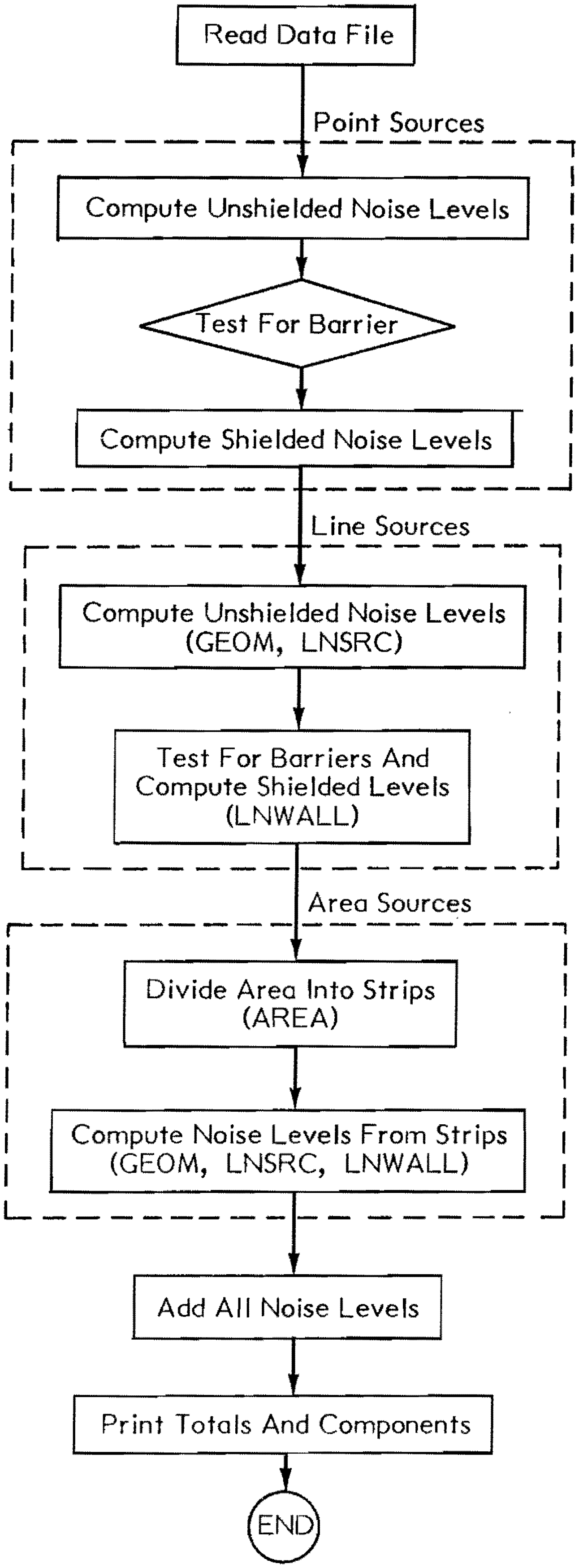
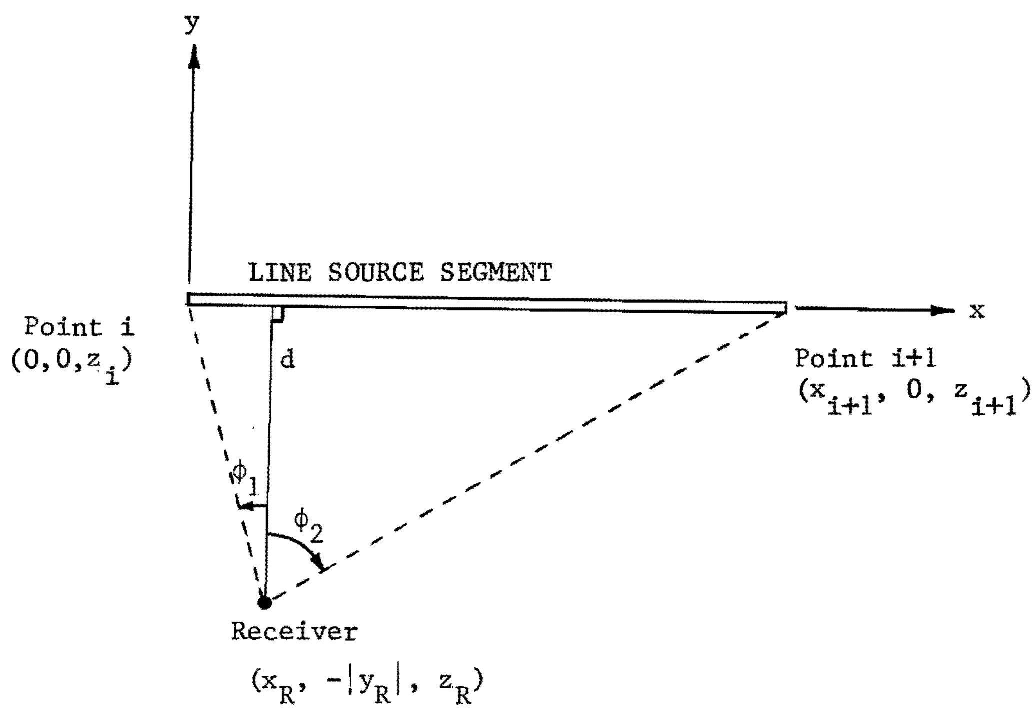


Figure 2. HICNOM Flow Chart



d = perpendicular distance from the receiver to the line source segment.

ϕ_1 = angle at the receiver from the perpendicular to the line to point i.

ϕ_2 = angle at the receiver from the perpendicular to the line to point i+1.

(This is a view of the x-y plane)

Figure 3. Geometry and Coordinates of Line Source Segment

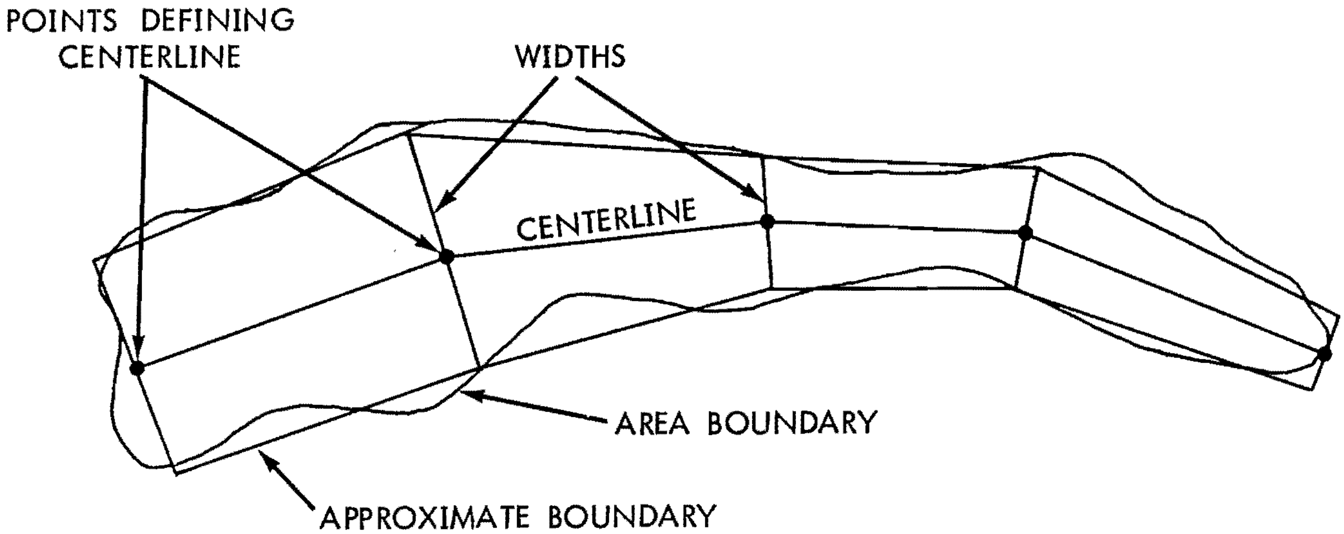


Figure 4. Representation of Area by Centerline and Width

Running indices are created in parallel to the main calculation. These keep the summation over subsources organized and permit identification of subsource components. The indices and the key to subsources are described in Section 4.2.

2.3 Validation

Validation was performed at two levels: computational validation, where the computer code was checked out, and application validation, where predictions were compared with field data. The latter includes effects due to non-ideal data, and is discussed in Section 5.

Extensive validation of the computer code was carried out as the program was developed by the original contractor, and as it was evaluated by this author. The procedure for testing subroutines was to use special input data through the actual main program, rather than dummy driver routines. All options were exercised, and results checked against hand calculations and/or exact solutions. Particular attention was paid to limiting cases of the algorithms used; for example, coordinate transformation involving rotation angles of exact multiples of $\pi/2$. Temporary output statements were used to check key intermediate results.

The last volume of the FHWA highway construction noise handbook contains a case study showing step-by-step how an actual construction site (I-440, Nashville, Tennessee) was modelled during construction operations.[5]

In addition, Appendix F of this volume contains the results of a small scale validation study performed at three construction sites on I-440.

3.0 DATA INPUT

This section describes in detail how to use the two parts of the computer program, HINPUT and HICNOM. Section 3.1 briefly describes the data requirements and presents the equipment source data contained in the program. Section 3.2 gives complete detailed instructions for data input including use of coding worksheets.

3.1 Data Requirements

The following data are required to run the program:

RECEIVERS - number of receiver locations, their Cartesian coordinates, the excess attenuation rate from the sources to each receiver (decibels per doubling distance), and a description of each receiver location;

EQUIPMENT - names and model numbers of the construction equipment at the site. Table 1 is a list of the equipment types and models that are built into the program, and will be discussed in more detail below;

SOURCE DATA - coordinates defining point, line, and area source geometries, and a description of each source;

BARRIER DATA - the number of noise barriers, coordinates defining the barrier top locations, and descriptions of each barrier.

Additional information which may be needed include speed and hourly volume data for haul operations, the nature of turn-around loops for haul roads, source activity data, and noise level and operational data for equipment defined by the user. All of the required input data will be discussed in detail in Section 3.2.

Source and receiver locations are specified by the user as sets of cartesian coordinates x, y, and z. The x and y coordinates are in the horizontal plane, and z is vertical location. The origin and orientation of the coordinates may be set by the user in any convenient way.

For the noise calculations described in Sections A.2.1 through A.2.3, only the x and y coordinates are considered. The difference between true three-dimensional distance and the horizontal component is generally negligible. In the field program,[5] no elevation differences were found which would cause a difference of more than a fraction of a dB due to increased distance. The neglect of z in this analysis provided great simplification in the program. Note that the user has control over the effect of elevation of a receiver on excess ground attenuation through specification of an excess attenuation rate for each receiver.

Table 1. Source Type Definition Information (page 1 of 2)
(See Table 2 for related information)

Source Type	Model No.*	Description	Allowable Geometry Types †	Is Production Rate Coordination Possible?	Type of Line Source
BACKHOE	1	# Nominal**	1 2 3	Yes	Non-Haul
	2	Caterpillar, Koehring	1 2 3	Yes	Non-Haul
	3	P & H	1 2 3	Yes	Non-Haul
	0	Defined by user	1 2 3	Yes	Non-Haul
LOADER	1	# Nominal	1 2 3	Yes	Non-Haul
	2	3-yard capacity	1 2 3	Yes	Non-Haul
	3	5-yard capacity	1 2 3	Yes	Non-Haul
	4	7-yard capacity	1 2 3	Yes	Non-Haul
	5	10-yard capacity	1 2 3	Yes	Non-Haul
	0	Defined by user	1 2 3	Yes	Non-Haul
COMPRESSOR	1	# Nominal	1	No	N/A ††
	2	Standard	1	No	N/A
	3	Quiet, doors open	1	No	N/A
	4	Quiet, doors closed	1	No	N/A
	0	Defined by user	1	No	N/A
PILE DRIVER	1	# Nominal	1	No	N/A
	2	Current data	1	No	N/A
	0	Defined by user	1	No	N/A
PUMP	1	63 dB @ 50 feet	1	No	N/A
	2	76 dB @ 50 feet	1	No	N/A
	3	# Nominal	1	No	N/A
	0	Defined by user	1	No	N/A
CRANE	1	# Nominal	1	Yes	N/A
	2	Low	1	Yes	N/A
	3	Medium	1	Yes	N/A
	4	High	1	Yes	N/A
	0	Defined by user	1	Yes	N/A
BREAKER	1	# Rock Drill	1 2 3	No	Non-Haul
	2	# Std. Jackhammer (Nominal)	1 2 3	No	Non-Haul
	3	Muffled Jackhammer	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
CONCRETE	1	# Concrete Pour	1	No	N/A
	2	# Nominal Batch Plant	1	No	N/A
	3	Batch Plant	1	No	N/A
	4	# Pump	1	No	N/A
	5	# Concrete Mixer	1	No	N/A
	0	Defined by user	1	No	N/A

* A model number of zero tells the program a new model number is being defined for this computer run.
** "Nominal" means that the data represents an averaging of data from previous literature.
† 1: Point, 2: Line, 3: Area
†† N/A means "not applicable".
\# Use this model number if a generalized value is needed.

Table 1. Source Type Definition Information (page 2 of 2)
(See Table 2 for related information)

Source Type	Model No.*	Description	Allowable Geometry Types †	Is Production Rate Coordination Possible?	Type of Line Source
GENERATOR	1	Low Level	1	No	N/A
	2	# Nominal**	1	No	N/A
	0	Defined by user	1	No	N/A
MISCELLAN	1	# Grinder	1	No	N/A
	2	# Concrete Saw	1	No	N/A
	3	# Fan	1	No	N/A
	4	# Welder (Nominal)	1	No	N/A
	0	Defined by user	1	No	N/A
BULLDOZER	1	# Nominal**	1 2 3	No	Non-Haul
	2	Caterpillar D6, D7, D8	1 2 3	No	Non-Haul
	3	Caterpillar D9	1 2 3	No	Non-Haul
	4	D9 without muffler	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
GRADER	1	# Nominal	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
TRUCKS	1	10-yard dump, quiet	2	Yes	Haul
	2	10-yard dump, noisy	2	Yes	Haul
	3	Dual 20-yard trailers	2	Yes	Haul
	4	# Nominal	2	Yes	Haul
	0	Defined by user	2	Yes	Haul
SCRAPER	1	Caterpillar 631, muffled	2	Yes	Haul
	2	# Cat. 631, no muff. (Nominal)	2	Yes	Haul
	3	Caterpillar 623	2	Yes	Haul
	4	Caterpillar 637	2	Yes	Haul
	0	Defined by user	2	Yes	Haul
COMPACTOR	1	Low	3	No	N/A
	2	# Nominal	3	No	N/A
	3	High	3	No	N/A
	0	Defined by user	3	No	N/A
PAVING	1	# Nominal	1 2 3	No	Non-Haul
	2	Concrete Paver	1 2 3	No	Non-Haul
	3	Asphalt Paver	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
USER DEFINED	0	Defined by user	1 2 3	Yes	User-Defined

* A model number of zero tells the program a new model number is being defined for this computer run.
** "Nominal" means that the data was acquired from previous literature.
† 1: Point, 2: Line, 3: Area
†† N/A means "not applicable".
\# Use this model number if a generalized value is needed.

Vertical distances are of critical importance when barriers are involved, so that true three-dimensional distances are used when computing the path length difference as described in Section A.2.4. Coordinates specified for a barrier represent the spatial location of the top edge: the location of the ground at the barrier plus the height of the barrier above the ground. Similarly, receiver locations specified by the user must represent the actual height of the receiver.

Source elevations are specified somewhat differently. The height of the effective acoustic source location above the ground varies between various pieces of equipment, and forms part of the data base in the model. Source locations are therefore specified by the user as the ground-level location; the model adds the appropriate height to obtain the acoustic source location.

A key part of the model is the inclusion of an extensive data base of equipment noise levels and operating parameters. The bulk of the data incorporated into the model was gathered as part of the program's development, and is presented in a raw form in Volume 5 of the FHWA highway construction noise handbook.[5] Some additional data was obtained from a review of the literature, but this was generally limited to maximum emission levels and manufacturer specifications of equipment capacity.

Table 1 lists in its first three columns the equipment types and model numbers contained in the program, and a description of what each model number represents. The fourth column of Table 1 indicates whether the user may specify the equipment as operating at a point, along a line or over an area, or if the program assigns a particular geometry type to that source type. The fifth column indicates whether or not the production rate of the equipment may be tied to the operations of another piece of equipment. Only those sources with a "yes" answer may be coordinated with each other. The last column indicates for those sources that may be specified as a line source whether the program assumes them to be haul or non-haul line sources.

Each model number listed in Table 1 represents an average of a number of similar pieces of equipment. Items marked "nominal" are from the literature; The remainder are from Volume 5 of the FHWA construction noise handbook.[5] The descriptions in Table 1 vary from quite specific to somewhat vague. They are presented in the most descriptive manner that does not lead to overgeneralization. In some cases it will be necessary to examine the noise levels in Table 2, and make a judgement as to which model number is appropriate.

Table 2. Source Type Acoustical and Operational Data (page 1 of 2)
(See Table 1 for related information)

Source Type	Model No.*	L_{max} (dBA)	Delta (dBA)	Cycle Time (hrs.)	Capacity (cu. yds.)	Acoustic Height (ft.)	Acoustic Frequency (Hz.)	Reference Speed (mph)	Slope††	Critical Speed (mph)
BACKHOE	1	86.5	3	.00833	N/A†	6	500	--	--	--
	2	88.0	3	.00833	N/A	6	500	--	--	--
	3	92.0	3	.00833	N/A	6	500	--	--	--
	0	UD**	UD	UD	UD	UD	UD	--	--	--
LOADER	1	89.0	5	.00833	5	6	500	--	--	--
	2	81.0	5	.00833	3	6	500	--	--	--
	3	82.0	5	.00833	5	6	500	--	--	--
	4	83.0	5	.00833	7	6	500	--	--	--
	5	85.0	5	.00833	10	6	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
COMPRESSOR	1	91.3	2	0	N/A	4	1000	--	--	--
	2	88.0	2	0	N/A	4	1000	--	--	--
	3	77.0	2	0	N/A	4	1000	--	--	--
	4	67.0	2	0	N/A	4	1000	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
PILE DRIVER	1	97.3	6	0	0	20	1500	--	--	--
	2	103.0	6	0	0	20	1500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
PUMP	1	63.0	0	0	0	4	800	--	--	--
	2	76.0	0	0	0	4	800	--	--	--
	3	71.0	0	0	0	4	800	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
CRANE	1	89.0	7.5	0	0	15	500	--	--	--
	2	73.0	7.5	0	0	15	500	--	--	--
	3	81.5	7.5	0	0	15	500	--	--	--
	4	85.0	7.5	0	0	15	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
BREAKER	1	96.0	7	0	0	2	1500	--	--	--
	2	87.0	7	0	0	2	1500	--	--	--
	3	76.0	7	0	0	2	1500	--	--	--
CONCRETE	1	78.0	5	0	0	10	500	--	--	--
	2	90.0	0	0	0	10	500	--	--	--
	3	82.0	0	0	0	10	500	--	--	--
	4	85.0	0	0	0	6	500	--	--	--
	5	82.8	0	0	0	8	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--

* A Model Number of zero tells the program a new model number is being defined for the computer run.
** UD: User-defined (supplied by user)
† N/A means "not applicable".
†† Slope is "B" in the emission level equation: $Lo = L_{max} + B \log(\text{speed}/\text{reference speed})$.

Table 2. Source Type Acoustical and Operational Data (page 2 of 2)
(See Table 1 for related information)

Source Type	Model No.*	L_{max} (dBA)	Delta (dBA)	Cycle Time (hrs.)	Capacity (cu. yds.)	Acoustic Height (ft.)	Acoustic Frequency (Hz.)	Reference Speed (mph)	Slope††	Critical Speed (mph)
GENERATOR	1	73.5	0	0	0	4	1200	--	--	--
	2	81.0	0	0	0	4	1200	--	--	--
	0	UD**	UD	UD	UD	UD	UD	--	--	--
MISCELLAN	1	71.0	1	0	0	2	1200	--	--	--
	2	88.0	0	0	0	1	1200	--	--	--
	3	83.0	0	0	0	4	1200	--	--	--
	4	71.0	0	0	0	4	1200	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
BULLDOZER	1	90.1	2	0	0	6	500	--	--	--
	2	80.0	2	0	0	6	500	--	--	--
	3	85.0	2	0	0	6	500	--	--	--
	4	96.0	2	0	0	6	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
GRADER	1	83.0	0	0	0	8	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
TRUCKS	1	76.0	N/A†	N/A	10	8	500	35	20	35
	2	81.0	N/A	N/A	10	8	500	35	20	35
	3	86.0	N/A	N/A	40	8	500	35	20	35
	4	90.7	N/A	N/A	10	8	500	35	20	35
	0	UD	N/A	N/A	UD	UD	UD	UD	UD	
SCRAPER	1	84.0	N/A	N/A	25	6	500	30	0	30
	2	95.0	N/A	N/A	25	6	500	30	0	30
	3	90.0	N/A	N/A	25	6	500	30	0	30
	4	81.0	N/A	N/A	25	6	500	30	0	30
	0	UD	N/A	N/A	UD	UD	UD	UD	UD	UD
COMPACTOR	1	80.0	0	0	0	8	500	--	--	--
	2	86.0	0	0	0	8	500	--	--	--
	3	93.0	0	0	0	8	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
PAVING	1	83.8	0	0	0	4	500	--	--	--
	2	82.8	0	0	0	4	500	--	--	--
	3	82.5	0	0	0	4	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
USER DEFINED	0	UD	UD	UD	UD	UD	UD	--	--	--

* A Model Number of zero tells the program a new model number is being defined for the computer run.
** UD: User-defined (supplied by user)
† N/A means "not applicable".
†† Slope is "B" in the emission level equation: $Lo = L_{max} + B \log (speed/reference\ speed)$.

Table 2 presents the acoustical and operational data that are coded into the program for the different model numbers. A wide variation of noise levels is not uncommon. It was found in the field program that nominally identical pieces of equipment could produce noise levels which differ by 10 dB or more. Construction sites generally have small (in a statistical sense) numbers of equipment present, so that caution must be exercised in any use of average levels for a specific case. Data in the program does provide a good selection of the range encountered, however, so that reasonable choices can be made in the absence of specific data.

3.2 Preparation of Input Data

Data is interactively entered into the computer through requests by the program. The program asks for data in the following order: problem title, receiver data, source data, and barrier data. The same questions are asked from run to run for all of the above except the source data. Source data questions vary quite a bit depending on the type of source (point, line or area) and the user's responses to certain of the questions.

Seven worksheets have been prepared to help the user organize the data for input into the program. Each worksheet has appropriate information printed on it to help guide the user as to which pieces of data are required for a particular run. The seven worksheets are:

FORM 1: TITLE AND RECEIVER DATA
FORM 2: POINT SOURCE DATA
FORM 3: "HAUL" LINE SOURCE DATA
FORM 4: "NON-HAUL" LINE SOURCE DATA
FORM 5: AREA SOURCE DATA
FORM 6: BARRIER DATA
FORM 7: DATA INPUT GUIDE

All of the requests made by the program are discussed in this section, grouped by worksheet. In many cases, the answer to one request will determine the next request to be made; all such options and branching are explained in detail.

Phrases printed by the computer are capitalized and underlined. User responses for all data input are free format; that is, data items are separated by a comma or one or more blank spaces, with a carriage return at the end of an answer.

The discussion is set up for easy reference by the user if a question arises during data input. To make discussion of each form complete, there is some repetition for those requests that are asked for all source types. However, this repetition allows each section to stand on its own. At the beginning each section is a form with sample data. Then, for each program request, the request itself is presented, capitalized and underlined. The portion of the form showing the request and a typical response is shown, and then a discussion of the request is given.

Form 7 is set up as a guide to the user on allowable source types, model numbers, geometry types and production rate coordination. No user entries are made on Form 7. It is illustrated in Appendix D.

3.2.1 FORM 1: TITLE AND RECEIVER DATA

Form 1, including sample data, is shown in Figure 5.

STEP 1. ENTER TITLE FOR THIS PROBLEM

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE DATA

Up to 80 characters describing this computer run may be entered here. This title is printed at the top of the data file created by HINPUT and at the top of the results report prepared by HICNOM.

STEP 2. ENTER NUMBER OF RECEIVERS (MAXIMUM IS 10)

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

Enter the number of receivers in this run. Up to 10 receivers may be defined per run.

STEP 3. ENTER A DESCRIPTION OF RECEIVER # X
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #X

DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1012 MAIN	0	0	0	1.5

A set of answers, followed by a carriage return, has to be given for each receiver. The DESCRIPTION is a title that may be given to each receiver. It is printed on both the data input report and results report, and allows easy identification of the receivers. If no description is desired, simply press the carriage return key.

X, Y, and Z are the three-dimensional coordinates of the receiver location.

EXCESS ATTENUATION (dB/DD) indicates how fast the sound level will drop off from the sources to this receiver in addition to the attenuation due to geometric spreading of the sound waves. Geometric spreading for point and line sources is 6 dB and 3 dB, respectively. Typical values for excess ground attenuation are 0 dB and 1.5 dB. A value of 0 dB would be applicable to elevated receivers (such as second story windows) or for propagation over pavement or hard packed earth. A value of 1.5 dB would increase the attenuation to 7.5 dB and 4.5 dB, respectively, for point and line sources, which is typical for a "soft" site (e.g., freshly dug earth at a construction site).

Figure 5. FORM 1: TITLE AND RECEIVER DATA

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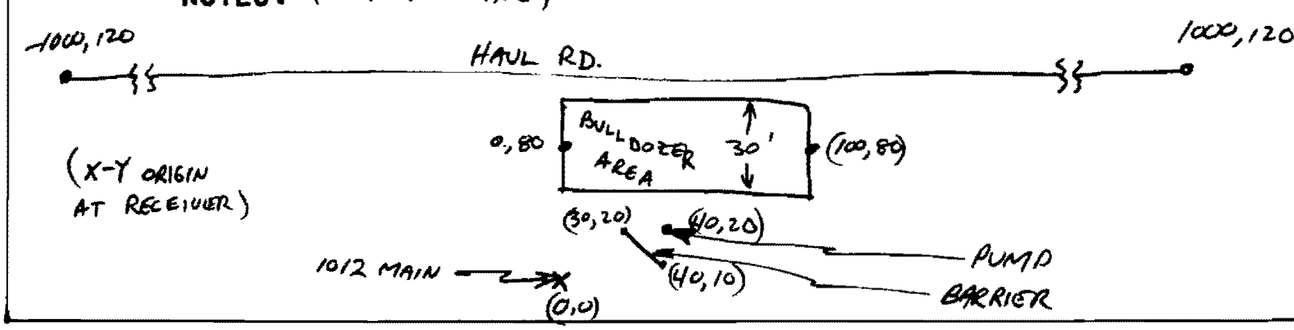
FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE DATA

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	1012 MAIN	0	0	0	1.5
2					
3					
4					
5					
6					
7					
8					
9					
10					

NOTES: (NOT TO SCALE)



3.2.2 FORM 2: POINT SOURCE DATA

Form 2 is designed to organize data for point sources. The user may choose from pre-programmed source types, or may create new source types. Figure 6 shows an example of Form 2.

STEP 1. ENTER SOURCE TYPE - BLANK IF FINISHED

ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)
PUMP	NEAR 1012 (ROW)

These two requests are made for each source. The following source types may be used as point sources:

COMPRESSOR	CRANE	GENERATOR	USER-DEFINED
PILE DRIVER	BACKHOE	MISCELLAN	BREAKER
PUMP	CONCRETE	LOADER	BULLDOZER
GRADER	PAVING		

These source types have to be entered exactly as shown above. If they are misspelled or some other word is entered, the program will respond INVALID SOURCE TYPE - REENTER. Tables 1 and 2 give full descriptions of these sources and the values associated with them in the program.

The DESCRIPTION is a 16-character identifier that may be given to the source by the user. It will be printed on the output. If no description is desired, simply press the carriage return key.

STEP 2. ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

MODEL NUMBER(2)
0

Enter a model number from the choices in column 2 of Table 1. Any other value will produce the message INVALID MODEL NUMBER - REENTER. Note that all of the non-zero model numbers have the data shown in Table 2 coded into the program.

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FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
PUMP	*NEAR 1012 (ROW)*	*0*	1	*8*	*40*	*20*	*0*
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				

NOTES:
(1) TO DEFINE SOURCE NOT LISTED ON FORM 7, ENTER: USER DEFINED
(2) 0 INDICATES NEW MODEL; NEGATIVE VALUE INDICATES NEW MODEL PREVIOUSLY CREATED IN THIS RUN
(3) IN 8 HOUR DAY; NEGATIVE VALUE MEANS MATCH PRODUCTION RATE WITH PRECEEDING SOURCE WITH PRODUCTION RATE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
75	*0*	*0*	*0*	*3*	*500*

Figure 6. FORM 2: POINT SOURCE DATA

To create a new model for a particular source type, enter 0 in response to this request. This will cause the program to later request noise level and operational data for this model. More than one new model can be created for each source type during a given run. However, the total number of models of a given type (highest value in Table 1 plus user-created models) may not exceed 10. This new data is not retained from one run to the next. Permanently adding a new model to the program requires changing the BLOCK DATA and SUBROUTINE DECODE sections of program as described in Appendix C of this manual.

A newly created model (MODEL NUMBER of 0) may be referred to later in the data input of a problem. This is done by entering the appropriate source type and then a MODEL NUMBER of -1. If two new models have been created for a particular source type during the same run, the second one may be referred to later in data input by using a MODEL NUMBER of -1 while the first would be referred to by a MODEL NUMBER of -2. In this case, the -1 indicates "last new model of this type" while the -2 indicates "next-to-last new model of this type". More than two newly created models may be referenced later during data input in the same manner: the greater the negative value for MODEL NUMBER, the earlier in data input that model was first specified. Example 1 in Section 5.1 illustrates use of a USER DEFINED source type and model numbers of 0, -1 and -2.

For the source type USER DEFINED, a MODEL NUMBER of 0 is always used the first time this source type is specified, and a negative value is used thereafter if referring back to this same source type. Note that more than one USER DEFINED source type can be created during the same run by using a MODEL NUMBER of 0 the first time each is specified.

STEP 3. ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

GEOMETRY TYPE
1

Certain source types may only be used as point sources; others may also be used as line or area sources (the latter are: LOADER, BACKHOE, BREAKER, BULLDOZER, GRADER, PAVING, and USER DEFINED). The above request will only be made for the latter sources, where there is a choice of geometries. In this case, a value of 1, indicating point source, would be the appropriate response.

STEP 4. ENTER HOURS WORKED DURING 8-HR DAY (ENTER -1 TO COORDINATE THIS SOURCE'S PRODUCTION WITH THAT OF THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

HOURS WORKED(3)
8

Enter the number of hours worked during the 8-hour day for this particular model. (The program is based on an 8-hour day and computes an 8-hour Leq. This value can be changed in the program as described in Appendix C of this manual.) If a piece of equipment was only working half of the day, for example, the correct entry for HOURS WORKED would be 4. Note that this time is the entire time when the equipment is in operation, not just the time when it is at maximum sound level. For example, a rock drill produces a much higher noise level when drilling than when the bit is being withdrawn and reset. Nonetheless, the entire time when the drilling/resetting process takes place is the proper value for HOURS WORKED.

As was discussed in Section 3.1, certain equipment types have production rates associated with them based on their capacity and cycle time for an operation. This is explained in more detail in Section A.1. Point sources with production rates are BACKHOE, LOADER, CRANE, and USER DEFINED. To tie the operation of such a piece of equipment to another piece of equipment with a production rate (for example, a loader filling trucks), enter the first source with the actual value for its HOURS WORKED and then enter the second source with a value of -1 for its HOURS WORKED. The program will then compute a value for HOURS WORKED for the second source for its Leq calculations based on equation A-3 shown in Section A.2.1. Note that the order of input of the sources is important: generally for a load-and-haul operation, the number of haul trucks would depend on the ability of the loader to fill them. This would mean that a positive value would be entered for HOURS WORKED for the loader, and the HOURS WORKED for the trucks would be set to -1. An example of production rate coordination is shown in Section 5.2.

STEP 5. POINT SOURCE: ENTER X, Y, Z OF SOURCE LOCATION

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
40	20	0

Enter the appropriate coordinates of this particular source. Note that the z-coordinate should be the ground level coordinate. The program has an acoustic height for the source built into it as shown in Table 2 (next-to-last column).

STEP 6. If a MODEL NUMBER of 0 was specified for this source, the following requests will be made by the program:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
75	0	0	0	3	500

Substep 6a. ENTER LMAX (DBA)

Enter the reference maximum level in dBA of this piece of equipment. LMAX is defined in Equation A-2 in Section A.2.1.

Substep 6b. ENTER DELTA (LMAX-LEQ) IN DBA

DELTA is defined as the difference in dBA between the maximum level of the equipment and its Leq over its operational cycle, which is referred to as the energy-averaged emission level, $(L0)_{E_i}$ in Section A.2.1.

Substep 6c. ENTER CAPACITY PER CYCLE (CUBIC YARDS)

If the piece of equipment has an earthwork capacity associated with it, enter the capacity per operational cycle in cubic yards. This will be used in calculations if this piece of equipment's production rate is tied to another piece of equipment with a production rate.

Substep 6d. ENTER CYCLE TIME (HOURS)

CYCLE TIME is the amount of time in hours that it takes this piece of equipment to cycle through one operation. This value is also used in calculations when this piece of equipment is being coordinated with another piece of equipment with a production rate. A typical value in the program is .00833 hours (30 seconds).

Substep 6e. ENTER ACOUSTIC HEIGHT (FEET)

ACOUSTIC HEIGHT is the effective or equivalent height in feet of the source for use in the barrier attenuation calculations. Lacking any detailed noise emission tests on the piece of equipment in question, this height could be the height of the major noise source on the piece of equipment. If there are no barriers in this problem, any value may be entered for ACOUSTIC HEIGHT; it will not be used in the calculations.

Substep 6f. ENTER FREQUENCY (HERTZ)

FREQUENCY is the equivalent or effective frequency of the source's sound for use in barrier attenuation calculations. Lacking detailed noise emission frequency data, the user could choose a frequency for this source by comparing the pitch of this equipment's noise to those of the sources listed in Table 2, and choosing an appropriate frequency from that list. If there are no barriers in this problem, any value for frequency may be entered; it will not be used in the calculations.

3.2.3 FORM 3: "HAUL" LINE SOURCE DATA

The program breaks line sources into two categories: "haul" and "nonhaul". While there are similarities in the data input requirements between the two, there are also enough important differences to warrant separate forms for each category. This section discussed haul sources while the next section will discuss nonhaul sources. Figure 7 shows the coding worksheet for haul line sources with sample data filled in.

STEP 1. ENTER SOURCE TYPE - BLANK IF FINISHED

SOURCE TYPE (1)
TRUCKS

The following are haul line sources that are coded in the program: TRUCKS and SCRAPER. To designate a haul line source enter one of those source types in response to this request. The only way to create a new haul line source is by creating a new model number for either TRUCKS or SCRAPER, as described in the next item.

STEP 2. ENTER DESCRIPTION OF THIS SOURCE (MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

DESCRIPTION (MAX. 16 CHAR.)
HAUL RD.

The DESCRIPTION is a 16-character title that may be given to each source. It is printed on both the data input report and the results report, and allows easy identification of the sources. If no description is desired, press the carriage return key.

Figure 7. FORM 3: "HAUL" LINE SOURCE DATA

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FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	HAUL RD.	0	8	2

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	-1000	120	0	40
2	1000	120	0	
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

VEHICLES PER HOUR	RETURN LOOP	
	TYPE(5)	RADIUS(6)
25	0	1

(5) SEE FORM 7; IF 0, ENTER POINT NUMBERS (SEE TO THE RIGHT)
(6) ENTER ANY VALUE IF TYPE IS 0 OR 7.

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)
0	0

(7) ENTER 0 IF NON-STOP
(8) ENTER 0 TO HAVE PROGRAM COMPUTE AVERAGE SPEED (ONLY IF (7) IS NON-ZERO); ENTER ANY VALUE IF (7) IS 0.

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	REFERENCE SPEED	SLOPE	CRITICAL SPEED	CAPACITY	ACOUSTIC HEIGHT	FREQUENCY
85	30	15	30	10	8	550

STEP 3. ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

MODEL NO.(2)
0

Enter the appropriate model number for the SOURCE TYPE just entered into the program from the second column of Table 1. Any other value not in Table 1 will produce the message INVALID MODEL NUMBER - REENTER. To define a new model for TRUCKS or SCRAPER for this computer run, enter a 0 for MODEL NUMBER. Then, later in the data input, the program will request information on this new model. To specify a previously created new model number later in the same run, enter a value of -1 for the "last previously specified new model of this source", -2 for the "next-to-last", etc.

STEP 4. ENTER HOURS WORKED DURING 8-HOUR DAY (ENTER -1 TO COORDINATE THIS SOURCE'S PRODUCTION WITH THAT OF THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

HOURS WORKED(3)
8

Enter either the hours worked during the 8-hour day or a -1 in response to this request. The program computes the Leq from haul line sources based on the hourly volume of the sources, which the program either requests or computes. If a positive value is entered for HOURS WORKED, the program will later request the hourly volume of this source. Note that in all but one case, the size of the positive value is unimportant; the positive number is just a code that tells the program to later request the hourly volume. The one case where the actual value provided for HOURS WORKED is used in calculations is where the next source's production is being tied to this source by a -1 for its HOURS WORKED. In this case, the actual hours worked for the next source is then computed from its capacity and cycle time and the capacity and hours worked of this source.

On the other hand, a value of -1 for <u>this</u> source's HOURS WORKED tells the program that this source's production is being tied to the last previously entered source with a production rate (BACKHOE, LOADER, or CRANE). In this case, the program will compute the number of haul vehicles per hour based on vehicle haul capacity, and the capacity and cycle time of the source with which it is being coordinated.

One type of operation where production rate coordination might be desirable, but is currently not possible is paving, where trucks supply the paver. A suggested analysis technique is to manually compute the volume of trucks based on their capacity and the capacity and paving rate of the paver. Then, based on the distance the paver covers in the day, a series of "average" unloading points for the trucks could be approximated along the paver's line. Each of these points would then serve as the endpoint for a separate haul line source.

<u>STEP 5.</u> <u>LINE SOURCE: ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20 (ENTER 0 TO REUSE POINTS FROM THE LAST PREVIOUSLY ENTERED LINE SOURCE)</u>

NO. OF PTS. IN LINE(4)
2

Enter the number of points defining the line. Coordinates for each point will then be requested. Note that the maximum is 20 points, but that includes both user-supplied <u>and</u> program-generated points. The program will generate a series of return points if it is later told that the trucks turn around at the end of the line and return to the starting point. For example, if 10 points are entered and then the program is told that the trucks made a U-turn and returned along the same line, the program would generate 9 return points to get the trucks back to the starting point, for a total of 19 points, one below the maximum allowable number. Specifying 11 points and a U-turn would cause the program to try to generate 21 points (11 out and 10 back), which would not work.

The program may also be told that the trucks turn around by means of a loop road of a given radius. The program will then generate a series of points to represent that loop. Eight points or more may be generated, which means that the user should enter no more than 6 points to not exceed the total limit of 20.

To re-use the points from the last previously-entered haul line source, enter a 0 for the number of points. An example of this would be where two different truck models are operating along the same haul road.

STEP 6. ENTER X, Y, Z OF THE POINTS

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
-1000	120	0
1000	120	0

Enter the x, y, and z-coordinates of each point on the line, following each z-coordinate by a carriage return. The z-coordinate should be the ground level coordinate. Note that if a return loop is to be defined (as described later in item 10), the last entered point is the loading or unloading point, and the next-to-last point must be at least 2.5 times the loop radius away from it. For example, if a loop radius is 20 feet, the next-to-last point must be at least 50 feet from the last point. As noted from the discussion for item 5 (above) no more than 6 points should be specified if a loop is to be created by the program.

STEP 7. If a MODEL NUMBER of 0 was specified for this source, the following requests will be made by the program:

MAXIMUM LEVEL	REFERENCE SPEED	SLOPE	CRITICAL SPEED	CAPACITY	ACOUSTIC HEIGHT	FREQUENCY
85	30	15	30	10	8	550

Substep 7a. ENTER LMAX (DBA)

LMAX corresponds to L_0 in the emission level equation:

$$(L_0)_E = L_0 + (\text{SLOPE}) \text{ Log } (V/V_{ref}),$$

where: $(L_0)_E$ is the reference emission level;

SLOPE is the coefficient of the log term;

V is the speed of the source; and

V_{ref} is the reference speed for the emission level equation.

This equation is discussed in more detail in Section A.2.2.2.

Substep 7b. ENTER REFERENCE SPEED, VREF (MPH)

VREF is the reference speed for the emission level equation for this source (see item a. above).

Substep 7c. ENTER SLOPE: LO(E) EQUALS LMAX + (SLOPE) LOG (V/VREF)

Enter the slope of the emission level equation for this source, as discussed in item (a) above.

Substep 7d. ENTER CRITICAL SPEED, VCRIT (MPH)

VCRIT represents the speed below which the emission level for the source remains constant (during acceleration only). In other words, for acceleration at or below the critical speed the emission level equals the level for a speed of VCRIT. However, during deceleration, the emission level will decrease at speeds below the critical speed based on the value for SLOPE and the specified speed.

Substep 7e. ENTER ACOUSTIC HEIGHT (FEET)

ACOUSTIC HEIGHT is an equivalent single height of the source for the barrier attenuation calculations. Lacking detailed noise emission information on piece of equipment in question, the user could choose the height of the major noise source on the piece of equipment. If there are no barriers in this problem, any value may be entered for ACOUSTIC HEIGHT; it will not be used in the calculations.

Substep 7f. ENTER FREQUENCY (HERTZ)

FREQUENCY is an equivalent single frequency used in barrier calculations that permits good approximation of the overall spectrum's A-weighted attenuation for this source. Lacking detailed noise emission frequency data, the user could choose a frequency for this source by comparing its pitch to those of the sources listed in Table 2, and selecting an appropriate frequency from that list. If there are no barriers in this problem, any value for FREQUENCY may be entered; it will not be used in the calculations.

STEP 8. ENTER SPEED ON EACH SEGMENT (MPH)

SEGMENT SPEED
40

Enter the average speed of the source on each segment of the line (enter a comma or a blank space between each speed). There will be one less segment than the number of line points previously specified.

Choosing a speed for the last segment requires care when a value of 0 is specified for LOOP TYPE (discussed in item 10). A zero LOOP TYPE, tells the program that the source is not turning around, but preceding straight through the site. In response to a value of 0 for LOOP TYPE, the programming requests a STOPPING POINT and a DECELERATION POINT. A value of 0 for the DECELERATION POINT tells the program to generate a deceleration profile for the source using the speed given for this last segment as the approach cruise speed, not the average speed. However, a positive value for the DECELERATION POINT tells the program that the speeds given on the segments between the DECELERATION POINT and STOPPING POINT are average speeds that the user has calculated.

To summarize then, specify the average speed for each segment unless values of 0 are to be given for LOOP TYPE and DECELERATION POINT; for this latter case, the speed for the last segment should be the approach cruise speed.

STEP 9. ENTER VEHICLES PER HOUR (ONE WAY VOLUME)

VEHICLES PER HOUR
25

This request will only be made if the value for HOURS WORKED was positive. The one way volume should be entered, even if a return loop is to be specified. If a value of -1 had been given for HOURS WORKED, the program would not request the number of vehicles per hour, but would calculate it based on the capacity of the haul source and the capacity, cycle time and hours worked of the source with which the haul source is being coordinated.

STEP 10. ENTER TYPE AND RADIUS (FEET) OF RETURN LOOP

RETURN LOOP	
TYPE(5)	RADIUS(8)
0	1

Enter a value from 0 to 7 to specify the type of return loop to be generated by the program (a value of 0 indicates straight-through traffic with no program-generated loop). The loops corresponding to values of 1 through 7 are shown in Figure 8. Note that loop type 7 actually does not represent a "loop", but signifies that the vehicles are turning around via a "U-turn" or a three-point turn. The program will read a value greater than 7 as 7.

The RADIUS of the loop should be entered in feet; any value may be given for the RADIUS for loop types 0 and 7, as this value is not used in the calculations for these types. In Figure 8, also note that the stopping point is the last point for which the user supplied coordinates. The point where the loop branches off from the main line is generated by the program based on the type and radius of the loop.

STEP 11. ENTER STOPPING POINT NUMBER

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)
0	0

This request will be made only if a value of zero was given for LOOP TYPE (straight-through operation). If the haul operation has a stopping point (usually for loading or unloading), specify the haul road point number (counting from the first point) that corresponds to the stopping point. This point does not have to be the last point for the line. Entering a value of 0 for the STOPPING POINT indicates that there is no stopping point, and a cruise is presumed at the previously entered average speed.

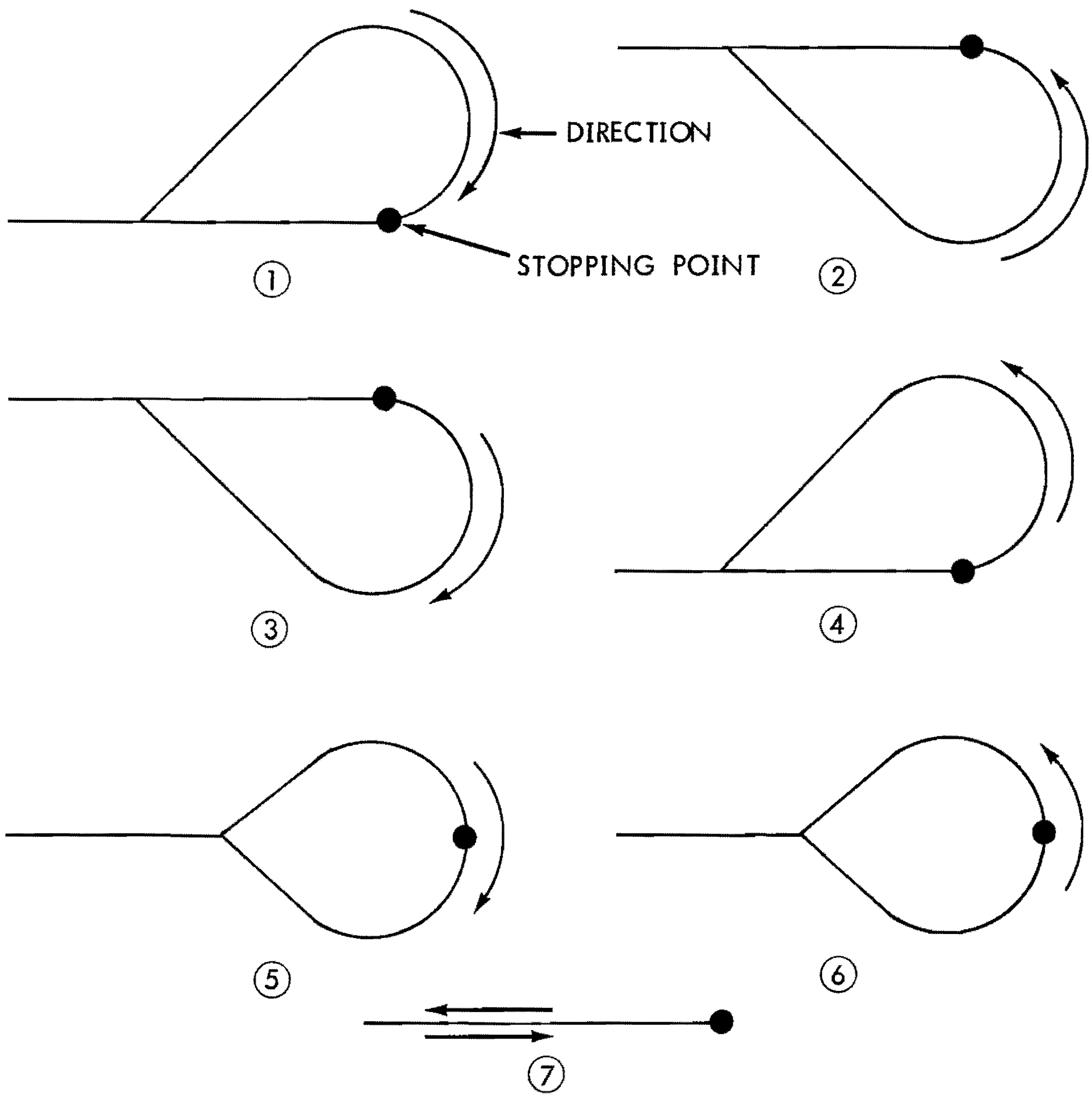

Figure 8. Haul Road Turn-around Loop Configuration

STEP 12. ENTER DECELERATION POINT NUMBER

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)
0	0

This request is only made if a value of 0 was entered for LOOP TYPE. If a value of zero was specified for STOPPING POINT, any value may be given for the DECELERATION POINT; it will not be used in the calculations.

If a positive value was given for the STOPPING POINT, either a zero or positive value may be given for the DECELERATION POINT. A value of 0 tells the program to generate deceleration (and acceleration) profiles and compute an average speed for the line segment under consideration, where the speed entered by the user for this line segment is assumed to be the approach cruise speed.

A positive value for DECELERATION POINT tells the program that the speeds entered for the segments between the deceleration and stopping points are the actual average speeds computed by the user, and that no deceleration or acceleration profile is to be generated by the program.

3.2.4 FORM 4: "NONHAUL" LINE SOURCE DATA

All line sources other than TRUCKS and SCRAPER are considered "nonhaul" line sources. Form 4, shown in Figure 9 is designed to organize data for these line sources. The user may choose from pre-programmed source types or may create new source types.

STEP 1. ENTER SOURCE TYPE - BLANK IF FINISHED

SOURCE TYPE(1)
GRADER

The following source types may be used as nonhaul line sources:

BACKHOE	LOADER	BREAKER	BULLDOZER
GRADER	PAVING	USER DEFINED	

The source type has to be entered exactly as spelled above. If misspelled or some other word is entered, the program will respond INVALID SOURCE TYPE - REENTER. Tables 1 and 2 gives a full description of these sources and values associated with them in the program.

STEP 2. ENTER DESCRIPTION OF THIS SOURCE (MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

DESCRIPTION (MAX. 16 CHAR.)
ON HAUL RD.

The DESCRIPTION is a title that may be given to the source for easy identification on the data input report and the results report. If no description is desired, simply press the carriage return key.

Figure 9. FORM 4: "NONHAUL" LINE SOURCE DATA

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
GRADER	ON HAUL RD.	0	2	4	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-1000	120	0	1
1000	120	0	2
			3
			4
			5
			6
			7
			8
			9
			10
			11
			12
			13
			14
			15
			16
			17
			18
			19
			20

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM NONHAUL LINE SOURCE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	SPEED	ACOUSTIC HEIGHT	FREQUENCY
78	0	0	25	6	500

STEP 3. ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

MODEL NUMBER(2)
0

Enter a model number from the choices in column 2 of Table 1. Note that all of the non-zero model numbers have the data shown in Table 2 coded into the program.

To create a new model of a particular source type, enter 0 in response to this request. This will cause the program to later request noise level and operational data for this model. More than one new model can be created for each source type during a given run. However, the total number of models of a given type (highest value in Table 1 plus user-created models) may not exceed 10. This new data is not retained from one run to the next. Permanently adding a new model to the program requires changing the BLOCK DATA and SUBROUTINE DECODE sections of program as described in Appendix C of this manual.

A newly created model (MODEL NUMBER of 0) may be referred to later in the data input of a problem by entering the appropriate source type and then a MODEL NUMBER of -1. If two new models have been created for a particular source type during the same run, the second one may be referred to by a MODEL NUMBER of -1, while the first one would be referred to by a MODEL NUMBER of -2. In this case, the -1 indicates "last new model of this type" while the -2 indicates "next-to-last new model of this type". More than two newly created models may be referenced later during data input in the same manner: the greater the negative value for MODEL NUMBER, the earlier in data input that model was first specified.

For the source type USER DEFINED, a MODEL NUMBER of 0 is always used the first time this source type is specified, and a negative value is used thereafter if referring back to this same source type. Note that more than one USER DEFINED source type can be created during the same run by using a MODEL NUMBER of 0 the first time each is specified. Section 5.1 shows an example with a USER DEFINED point source and model numbers of 0, -1 and -2.

STEP 4. ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

GEOMETRY TYPE
2

All of the allowable nonhaul line sources may also be used as point or area sources. Therefore, to indicate that this source is to be analyzed as a line source, enter a value of 2 in response to this request.

STEP 5. ENTER HOURS WORKED DURING 8-HOUR DAY (ENTER -1 TO COORDINATE SOURCE'S PRODUCTION WITH THAT OF THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE

HOURS WORKED(S)
4

Enter the number of hours worked during the 8-hour day for this particular model. (The program computes an 8-hour Leq. This value can be changed in the program code as described in Appendix C of this manual.) If a piece of equipment was only working half the day, for example, the correct entry for HOURS WORKED would be 4. Note that the value for HOURS WORKED should represent the total time the source is operating along the line, not just the time when it is in front of a receiver.

As mentioned in Section 2.0, and discussed in detail in Appendix A, certain equipment types have production rates associated with them based on their capacity and cycle time; nonhaul line source with production rates are BACKHOE and LOADER. To coordinate either source's operation with another piece of equipment with a production rate (for example, trucks coming onto a site to be filled by a loader), enter the first source with the actual value for its HOURS WORKED, and then enter the second source for the value of -1 for its HOURS WORKED. The program will then compute a value for HOURS WORKED for the second source based on Equation A-8 in Section A.2.2.1.

STEP 6. LINE SOURCE: ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20 (ENTER 0 TO REUSE POINTS FROM THE LAST PREVIOUSLY ENTERED LINE SOURCE)

NUMBERS OF POINTS IN LINE(4)
2

Enter the number of points defining the line. Coordinates for each point will then be requested. The maximum number of user-supplied points for a nonhaul line source is 20; the program does not generate its own points. Return loops may not be specified for nonhaul line sources even in reality if the piece of equipment turns around and returns to the starting point; the Leq calculations will still be correctly done, however.

For nonhaul line sources, emission level is independent of speed. This results in the Leq contribution from a nonhaul line source being dependent on only the length of the line and not the vehicle speed nor number of passbys during the analysis period. This is explained in more detail in Appendix A, but briefly: the number of passbys by the vehicle equals the vehicle's speed along the line divided by the length of the line. As speed increases, the number of passbys increases. However, the Leq from a line source is a function of the ratio of the number of passbys to speed. Hence, the increase in speed and the corresponding increase in the number of passby cancel each other out, which simplifies the calculations by making the Leq a function of only the length of the line.

STEP 7. ENTER X, Y, Z OF THE POINTS

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
-1000	120	0
1000	120	0

Enter the x, y, and z-coordinates of each point on the line. The z-coordinate should be the ground elevation. Follow each z-coordinate by a carriage return.

STEP 8. If a MODEL NUMBER of 0 was specified for this source, the following requests will be made by the program:

MAXIMUM LEVEL	DELTA	CAPACITY	SPEED	ACOUSTIC HEIGHT	FREQUENCY
78	0	0	25	6	500

Substep 8a. ENTER LMAX (DBA)

Enter the reference maximum level in dBA of this piece of equipment. LMAX is defined in Equation A-5 in Section A.2.2.

Substep 8b. ENTER DELTA (LMAX-LEQ) IN DBA

DELTA is defined as the difference between the maximum level of the equipment and its Leq over its operational cycle, as shown in Section A.2.2.

Substep 8c. ENTER CAPACITY PER CYCLE (CUBIC YARDS)

If the piece of equipment has a capacity associated with it, enter the capacity per operational cycle in cubic yards. This will be used if this piece of equipment's production rate is tied to another piece of equipment with a production rate.

Substep 8d. ENTER SPEED (MPH)

Enter any value for the speed for a newly created nonhaul line source; the value is currently not used by the program in its calculations.

Substep 8e. ENTER ACOUSTIC HEIGHT (FEET)

ACOUSTIC HEIGHT is the effective or equivalent height of the source for use in the barrier attenuation calculations. Lacking any detailed noise emission tests on the piece of equipment in question, this height could be the height of the major noise source on the piece of equipment. If there are no barriers in this problem, any value can be entered for ACOUSTIC HEIGHT; it will not be used in the calculations.

Substep 8f. ENTER FREQUENCY (HERTZ)

FREQUENCY is the equivalent or effective frequency of the source's sound for use in barrier attenuation calculations. Lacking detailed noise emission frequency data, the user could choose a frequency for this source by comparing the pitch of this equipment noise to those of the sources listed in Table 2, and choosing an appropriate frequency from that list. If there are not barriers in this problem, any value for FREQUENCY may be entered; it will not be used in the calculations.

3.2.5 FORM 5: AREA SOURCE DATA

Form 5, shown in Figure 10, permits the user to organize data for area sources. Data input for area sources is quite similar to that for nonhaul line sources; two differences are: more than one piece of equipment of a certain type may be specified as operating in the area, and a width (of the area) is required for each point defining the centerline.

STEP 1. ENTER SOURCE TYPE - BLANK IF FINISHED

SOURCE TYPE(1)
BULLDOZER

The following source types may be used as area sources:

BACKHOE	BREAKER	GRADER	COMPACTOR
LOADER	BULLDOZER	PAVING	USER DEFINED

These source types have to be entered exactly as shown above. If they are misspelled or something else is entered, the program will respond INVALID SOURCE TYPE - REENTER. Table 1 gives a full description of the sources and the values associated with them in the program.

STEP 2. ENTER DESCRIPTION OF THIS SOURCE (MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

DESCRIPTION (MAX. 16 CHAR.)
SPREADING FILL

The DESCRIPTION is a title that may be given to each source for easy identification on the data input report and the results report. If no description is desired, press the carriage return key.

Figure 10. FORM 5: AREA SOURCE DATA

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FORM 5: AREA SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 18 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
BULLDOZER	SPREADING FILL	0	3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES
6	2	1

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
0	80	0	30	1
100	80	0	30	2
				3
				4
				5
				6
				7
				8
				9
				10
				11
				12
				13
				14
				15
				16
				17
				18
				19
				20

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
83	5	0	.009	5	500

STEP 3. ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

MODEL NO.(2)
0

Enter a model number from the choices in column 2 of Table 1. Any value not in the table will produce the message INVALID MODEL NUMBER - REENTER. Note that all of the non-zero model numbers have the data shown in Table 2 coded into the program.

To create a new model of a particular source type, enter 0 in response to this request. This will cause the program to later request noise level and operational data for this model. More than one new model can be created for each source type during a given run. However, the total number of models of a given type (highest value in Table 1 plus user-created models) may not exceed 10. This new data is not retained from one run to the next. Permanently adding a new model to the program requires changing the BLOCK DATA and SUBROUTINE DECODE sections of program as described in Section 6.0 of this manual.

A newly created model (MODEL NUMBER of 0) may be referred to later in the data input of a problem by entering the appropriate source type and then a MODEL NUMBER of -1. If two new models have been created for a particular source type during the same run, the second one may be referred to later in data input by using a MODEL NUMBER of -1 while the first would be referred to by a MODEL NUMBER of -2. In this case, the -1 indicates "last new model of this type" while the -2 indicates "next-to-last new model of this type". More than two newly created models may be referenced later during data input in the same manner: the greater the negative value for MODEL NUMBER, the earlier in data input that model was first specified.

For the source type USER DEFINED, a MODEL NUMBER of 0 is always used the first time this source type is specified, and a negative value thereafter if referring back to this same source type. Note that more than one USER DEFINED source type can be created during the same run by using a MODEL NUMBER of 0 the first time each new model is specified. Section 5.1 shows an example with a USER DEFINED point source, and 0 and model numbers of 0, -1 and -2.

STEP 4. ENTER 1, 2 or 3 FOR WORKING OVER A POINT, LINE OR AREA

GEOMETRY TYPE
3

All of the sources listed in item 1 may be used as point, line or area sources, except for COMPACTOR; the latter is only assigned as an area source by the program. For the others, the above request will be made. The appropriate response to indicate an area source is a value of 0.

STEP 5. ENTER HOURS WORKED DURING 8-HOUR DAY (ENTER -1 TO COORDINATE THIS SOURCE'S PRODUCTION WITH THAT OF THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

HOURS WORKED(S)
6

Enter the number of hours worked during the 8-hour day for this particular model. (The program computes an 8-hour Leq.) If a piece of equipment worked only half a day, for example, the correct entry for HOURS WORKED would be 4. BACKHOE and LOADER are area sources that have production rates based on their capacity and cycle time. Their operation may be tied to another piece of equipment having a production rate by first entering the other source with the actual value for its HOURS WORKED, and then entering this area source with a value of -1 for its HOURS WORKED. The program will then compute a value for HOURS WORKED for the area source based on Equation A-14 in Section A.2.3.

STEP 6. AREA SOURCE: ENTER NUMBER OF POINTS THAT DEFINE CENTERLINE, MAX. IS 10 (ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY-ENTERED AREA SOURCE)

NO. OF PTS. ON C/L(4)
2

As mentioned in Section 2.0 and discussed in Appendix A, area sources are described by a centerline of straightline segments and a width of the area at each segment's end points. The correct response to this request is the number of points defining the centerline, noting that the maximum is 10 points. To reuse the points from the last previously-entered area source-- for example, to have two different bulldozers working in the same area-- enter a value of 0 for the number of points for the second source.

STEP 7. ENTER X, Y, Z AND WIDTH OF AREA AT EACH POINT

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT
0	80	0	30
100	80	0	30

Enter one line of data for each point consisting of the x, y and z-coordinates of the point and the width of the area at that point, followed by a carriage return. Be sure to remember to enter the width after the z-coordinate. When the program does its calculations, it approximates each area segment by a series of parallel line segments. The number of line segments used for each area segment depends on the distance from the nearest receiver to the centerline and the average of the width at each end of the segment. The maximum number of line segments that the program will generate on each side of the centerline for each area segment is 5.

STEP 8. If a MODEL NUMBER of 0 is specified for this source, the following requests will be made by the program:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
83	5	0	.009	5	500

Substep 8a. ENTER LMAX (DBA)

Enter the reference maximum level in dBA of this piece of equipment. LMAX is defined in Section A.2.4.

Substep 8b. ENTER DELTA (LMAX-LEQ) IN DBA

DELTA is defined as the difference in dBA between the maximum level of the equipment and its Leq over its operational cycle, which is referred to as the energy-averaged emission level, $(L_O)_E$, in section A.2.4.

Substep 8c. ENTER CAPACITY PER CYCLE (CUBIC YARDS)

If the piece of equipment has an earthwork capacity associated with it, enter the capacity per operational cycle in cubic yards. This will be used in calculations if this piece of equipment's production rate is tied to another piece of equipment with a production rate.

Substep 8d. ENTER CYCLE TIME (HOURS)

CYCLE TIME is the amount of time in hours that it takes this piece of equipment to cycle through one operation. This value is also used in the calculations when this piece of equipment is being coordinated with another piece of equipment with a production rate.

Substep 8e. ENTER ACOUSTIC HEIGHT (FEET)

ACOUSTIC HEIGHT is the effective or equivalent height in feet of the source for use in the barrier attenuation calculations. Lacking any detailed noise emission tests on the piece of equipment in question, this height could be the height of the major noise source on the piece of equipment. If there are no barriers in this problem, any value may be entered for ACOUSTIC HEIGHT; it will not be used in the calculations.

Substep 8f. ENTER FREQUENCY (HERTZ)

FREQUENCY is the equivalent or effective frequency of the source's sound for use in barrier attenuation calculations. Lacking detailed noise emission frequency data, the user could choose a frequency for this source by comparing the pitch of this equipment noise to those of the sources listed in Table 2, and choosing an appropriate frequency from that list. If there are no barriers in this problem, any value for FREQUENCY may be entered; it will not be used in the calculations.

STEP 9. ENTER NUMBER OF PIECES OF THIS TYPE AND MODEL OF EQUIPMENT IN THIS AREA

NUMBER OF VEHICLES
1

Unlike nonhaul line sources, where only one piece of equipment may be assigned to the line source, the program allows more than one piece of the same type of equipment to be assigned to an area source. Enter that number of pieces in response to the request.

Note that if there are different types or models of equipment operating in the same area, separate area sources have to be specified for each type and model. However, a value of 0 for number of points defining the centerline may be specified for the subsequent sources so that all of the point coordinates do not have to be reentered.

Figure 11. FORM 6: BARRIER DATA

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FORM 6: BARRIER DATA

NUMBER OF BARRIERS
1

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)
BY PUMP	2

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
30	20	10
40	10	10

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE

3.2.6 FORM 6: BARRIER DATA

Form 6, shown in Figure 11, allows the user to organize the data for noise barriers. The maximum number of barriers is 3 and each barrier may be defined by up to 5 points representing the top line of the barrier.

STEP 1. ENTER NUMBER OF BARRIERS (MAXIMUM IS 3)

NUMBER OF BARRIERS
/

Enter the number of barriers for this run, up to 3. If there are no barriers, enter a value of 0.

STEP 2. ENTER A DESCRIPTION FOR BARRIER # X (MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

DESCRIPTION (MAX. 16 CHAR.)
BY PUMP

This request and the following two requests are made for each barrier. Enter a description of the barrier in 16 or less characters. The description is for easy identification of the barrier in the data input report and the results report. If no description is desired, simply press the carriage return key.

STEP 3. ENTER NUMBER OF POINTS DEFINING BARRIER (MAXIMUM IS 5)

NUMBER OF POINTS (MAX. 5)
2

This request is made for each barrier after the request for the description of each barrier. The barrier is defined by up to 5 points representing its top edge. Enter a number from 1 to 5 in response to this request.

STEP 4. ENTER X, Y, Z OF POINTS (Z IS BARRIER TOP ELEVATION)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
30	20	10
40	10	10

Enter the x, y, and z-coordinates of the points defining the top edge of the barrier. The request will only be made once, so follow each point's z-coordinate with a carriage return and then enter the next point's coordinates. Note that barrier attenuation is computed only for the first barrier that the program encounters in its calculations for each source receiver pair; care should be taken when entering data for multiple barriers. Complex barrier layouts that intercept a particular receiver/source line-of-sight more than once may cause erroneous results.

4.0 OUTPUT

Two different types of output reports are produced by the program: input data file report and the results report. The results report is automatically printed out by the HICNOM program. The input data file report must be requested separately by the user, external to the program, through a TYPE or PRINT command, or as required by the user's computer system.

4.1 HINPUT Output (Input Data File Report)

The data values that the user enters through the terminal in response to program requests are either stored in memory without change (coordinates and descriptions), or are used in calculations to produce other values that are then stored in memory (adjusted emission levels and vehicle densities). HINPUT then prepares a formatted file of this data that is needed by HICNOM. The user names this file according to the procedures required for the computer running the program.

Figure 12 shows an example of the input data file report. The file contains some of the original input items, the calculated values, and the source frequency (from data already stored in the program).

Not all of the answers given by the user to the program requests are retained in the file. Therefore, if mistakes are made during data input, it is very difficult to correct them by changing the file using the computer's editing program. To have a complete record of these entries, use of a printing terminal during data input is recommended.

The input data is presented in the following order:

- Receivers
- Point Sources
- Line Sources
- Area Sources
- Barriers

```
EXAMPLE DATA
  1  RECEIVERS
     X          Y          Z      EX. ATT.(DB/DD)    DESCRIPTION
        .0         .0         .0         1.50      1012 MAIN
  1  POINT SOURCES
     X          Y          Z       LEQ(REF)    FREQ.   SOURCE        DESCRIPTION
     40.0       20.0        7.0        63.0    800   PUMP     1      NEAR 1012(ROW)
  2  LINE SOURCES
  3    POINTS              FREQ.:  500             TRUCKS  1         HAUL RD.
     X          Y          Z     LEQ(REF) VEH. DENS.
  -1000.0     120.0       14.0       76.0  .0001085
   1000.0     120.0       14.0       76.0  .0001085
  -1000.0     120.0       14.0         .0  .0000000
  2    POINTS              FREQ.:  500             GRADER  1         ON HAUL RD.
     X          Y          Z     LEQ(REF) VEH. DENS.
  -1000.0     120.0       14.0       83.0  .0005000
   1000.0     120.0       14.0         .0  .0000000
  1  AREA SOURCES
  2    POINTS              FREQ.:  500             BULLDOZER    1    SPREADING FILL
     X          Y          Z       LEQ(REF)    WIDTH
        .0       80.0      11.0       88.1       30.0
    100.0       80.0      11.0         .0       30.0
  1  BARRIERS
  2  POINTS      DESCRIPTION: BY PUMP
     X          Y          Z
     30.0       20.0      10.0
     40.0       10.0      10.0
```

Figure 12. Example of HINPUT Input Data File Report

```
EXAMPLE DATA

RECEIVER NUMBER          LEQ          DESCRIPTION


          1               81.5       1012 MAIN


COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER:  1

INDEX   INTENSITY     LEVEL      SOURCE             DESCRIPTION

    1    .117423E+06  50.7    PUMP     1        NEAR 1012(ROW)
  101    .125161E+06  51.0    TRUCKS   1        HAUL RD.
  201    .125161E+06  51.0    TRUCKS   1        HAUL RD.
  102    .289074E+07  64.6    GRADER   1        ON HAUL RD.
10101    .137249E+09  81.4    BULLDOZER    1    SPREADING FILL


KEY TO INDEX:
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALOGOUS TO LINE SOURCE VARIABLES.
```

Figure 13. HICNOM Results Report

The quantities created and the FORTRAN formats for the data items are:

• Title Line	20A4
• Number of Receivers	I3
• Receiver Coordinates (X,Y,Z)	3F10.1
Excess Attenuation Rate	F10.2
Description	4A4
• Number of Point Sources	I3
• Source Location (X,Y,Z)	3F10.1
Adjusted Emission Level (adjusted for hours worked)	F10.1
Effective Frequency	I5
Source Description	4A4
(Note that the Z value has the effective acoustic height (either stored in the program or entered by the user) added to the input Z.)	
• Number of Line Sources	I3
• For each line source	
- Number of points	I3
- Effective frequency	I5
- Source Description	4A4
- Point Coordinates (X,Y,Z)	3F10.1
- Vehicle Passby Level ($(L_0)_E$)	F10.1
- Source Density (N)	F10.7
(The coordinate points include loop points created by the program for haul line sources. The emission levels and source densities correspond to the segment that starts at this point; there is one fewer segment than there are points.)	
• Number of Area Sources	I3
• For each Area Source	
- Number of points	I3
- Effective Frequency	I5
- Centerline Point Coordinates (X,Y,Z)	3F10.1
- Effective Source Emission Level ($(L_0)_E$)	F10.1
- Width	F10.1
(The emission levels are for the levels are for the area segment starting at this centerline point.)	
• Number of Barriers	I3
• For Each Barrier	
- Number of Points	I3
- Description of Barrier	4A4
- Coordinates of Points (X,Y,Z)	3F10.1

Various identifying information is also printed in the data files. These labels are not read by HICNOM. Their formats may be seen in the program listings, Appendix B, and are available for use if it is desired to modify HICNOM to make use of them. Their main intent is to make the data file readable. Experienced users of this model may want to edit this file to make minor data changes, rather than reenter all the data through HINPUT.

4.2 HICNOM Output (Results Report)

To run HICNOM, the name of the input data file produced by HINPUT must be given to it by the standard procedures required by the computer running the program. HICNOM will then read that file and perform its calculations. At the conclusion of execution, HICNOM generates a report that presents the results of its calculation. Figure 13 shows an example of the results report. The report is organized into 4 sections: problem title, summary of total Leq(8h) at each receiver, contributions to each receiver's total Leq from each source, and a key to the indexing used in identifying the component contribution.

The component contribution for each receiver consists of the source identifying index, an intensity quantity, the Leq contribution, the source type and a number indicating the sequence of data input of this source type, and the description for the source given during data input in HINPUT. The intensity quantity is $10^{L/10}$ where L is the equivalent sound level, Leq.

As noted in the key printed on the results report, the index contains up to 5 digits. A one or two digit number represents a point source, a three or four digit number represents a line source, and a five digit number represents an area source. The two right most digits represent the sequential number of the source, counted separately for point, lines and areas, in the order the sources appear in the HINPUT data file. The third and fourth digits are the sequential number of the source segments, counted separately for line and area sources, in the order they appear in the data file. (The "level" in the third column of the component contribution sections corresponds to that particular segment only.) The fifth digit ("1") is used to identify an area source, in contrast to a line source. Note that the order of the source component levels corresponds exactly to the order in which the components appear in the input data file created by HINPUT and read by HICNOM.

5.0 EXAMPLES

Presented here are 5 examples for using HICNOM. The last three are taken from actual highway construction projects. Each section contains text describing the problem and how it was modelled, and presents figures showing a site sketch, the user responses to the program requests, the HINPUT input data file report, and HICNOM results report. The user responses during data input are underlined, and comments and notations are made on the output reports, as appropriate. In addition, all of the problems illustrate use of the coding worksheets to organize the data before sitting down at the computer terminal.

5.1 EXAMPLE ONE: USER DEFINED SOURCE TYPE AND ZERO AND NEGATIVE MODEL NUMBERS

This problem illustrates use of a "user defined" source type, a MODEL NUMBER of 0 for an existing source type, and reuse of a newly created model during a run by use of a negative value for MODEL NUMBER. There are one receiver, five point sources (a USER DEFINED hydraulic excavator, and two each of two new PUMP models), no line or area sources and no barriers. The data quantities are hypothetical. Figure 14a shows a site sketch.

Figure 14b shows filled-in coding worksheets for this problem.

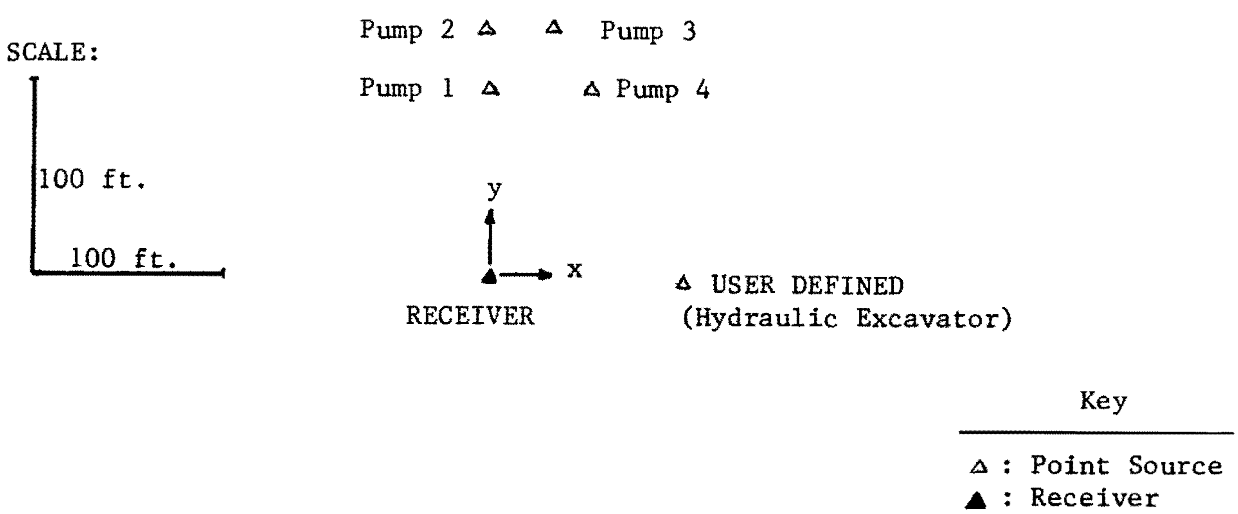

Figure 14a. Site Sketch

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 1 OF 4
DATE 4/2
PROJECT Ex1

FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE PROBLEM 1 : NEW SOURCES

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	1012 MAIN ST.	0	0	0	1.5
2					

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 2 OF 4
DATE 4/2
PROJECT Ex1

FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
USER DEFINED	HYDRAL. EXCAV.	0	1	4	100	0	0
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				

NOTES:

(1) TO DEFINE SOURCE NOT LISTED ON FORM 7, ENTER: USER DEFINED
(2) 0 INDICATES NEW MODEL; NEGATIVE VALUE INDICATES NEW MODEL PREVIOUSLY CREATED IN THIS RUN
(3) IN 8 HOUR DAY; NEGATIVE VALUE MEANS MATCH PRODUCTION RATE WITH PRECEEDING SOURCE WITH PRODUCTION RATE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
85	3	3	.00833	5	500

Figure 14b. Coding Worksheet (page 1 of 2)

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 3 OF 4
DATE 4/2
PROJECT Ex 1

FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
PUMP	QUIET TEST MODEL	0	1	8	0	100	0
PUMP	OLD NOISY MODEL	0	1	8	0	130	0
PUMP	SAME AS QUIET 1	-2	1	8	30	130	0
PUMP	SAME AS NOISY 2	-1	1	8	50	100	0
			1				
			1				
			1				
			1				
			1				
			1				

NOTES:
(1) TO DEFINE SOURCE NOT LISTED ON FORM 7, ENTER: USER DEFINED
(2) 0 INDICATES NEW MODEL; NEGATIVE VALUE INDICATES NEW MODEL PREVIOUSLY CREATED IN THIS RUN
(3) IN 8 HOUR DAY; NEGATIVE VALUE MEANS MATCH PRODUCTION RATE WITH PRECEEDING SOURCE WITH PRODUCTION RATE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
75	0	0	0	3	800
83	0	0	0	3	800

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 4 OF 4
DATE 4-2
PROJECT Ex 1

FORM 6: BARRIER DATA

NUMBER OF BARRIERS
0

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE

Figure 14b. Coding Worksheet (page 2 of 2)

```
EXAMPLE PROBLEM 1: NEW SOURCES
ENTER NUMBER OF RECEIVERS (MAXIMUM IS 10)

1
ENTER A DESCRIPTION OF RECEIVER #    1
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

1012 MAIN ST.
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       1

0 0 0 1.5
ENTER SOURCE TYPE - BLANK IF FINISHED

USER DEFINED
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

HYDRAL. EXCAV.
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

0
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

1
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

4
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

100 0 0
ENTER LMAX (DBA)

85
ENTER DELTA (LMAX-LEQ) IN DBA

3
ENTER CAPACITY PER CYCLE (CUBIC YARDS)

3
ENTER CYCLE TIME (HOURS)

0.00833
ENTER ACOUSTIC HEIGHT (FEET)

5
ENTER FREQUENCY (HERTZ)

500
ENTER SOURCE TYPE - BLANK IF FINISHED

PUMP
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

QUIET TEST MODEL
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

0
```

Figure 14c. User Responses to HINPUT (page 1 of 3)

```
PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

0 100 0
ENTER LMAX (DBA)

75
ENTER DELTA (LMAX-LEQ) IN DBA

0
ENTER CAPACITY PER CYCLE (CUBIC YARDS)

0
ENTER CYCLE TIME (HOURS)

0
ENTER ACOUSTIC HEIGHT (FEET)

3
ENTER FREQUENCY (HERTZ)

800
ENTER SOURCE TYPE - BLANK IF FINISHED

PUMP
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

OLD NOISY MODEL
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

0

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

0 130 0
ENTER LMAX (DBA)

83
ENTER DELTA (LMAX-LEQ) IN DBA

0
ENTER CAPACITY PER CYCLE (CUBIC YARDS)

0
ENTER CYCLE TIME (HOURS)
```

Figure 14c. User Responses to HINPUT (page 2 of 3)

```
0
ENTER ACOUSTIC HEIGHT (FEET)

3
ENTER FREQUENCY (HERTZ)

800
ENTER SOURCE TYPE - BLANK IF FINISHED

PUMP
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

SAME AS QUIET 1
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

-2

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

30 130 0
ENTER SOURCE TYPE - BLANK IF FINISHED

PUMP
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

SAME AS NOISY 2
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

-1

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

50 100 0
ENTER SOURCE TYPE - BLANK IF FINISHED


ENTER NUMBER OF BARRIERS (MAXIMUM IS 3)

0
ENTER THE NAME OF THE FILE FOR HICNOM USE;
AXIMUM OF 12 (8.3) CHARACTERS, DEFAULT = HINPUT.OUT :
```

Figure 14c. User Responses to HINPUT (page 3 of 3)

```
EXAMPLE PROBLEM 1: NEW SOURCES
  1  RECEIVERS
     X           Y            Z       EX. ATT.(DB/DD)    DESCRIPTION
        .0          .0          .0         1.50      1012 MAIN ST.
  5  POINT SOURCES
     X           Y            Z        LEQ(REF)    FREQ.    SOURCE          DESCRIPTION
     100.0          .0          5.0        79.0    500   USER DEFINED1   HYDRAL. EXCAV.
        .0       100.0          3.0        75.0    800   PUMP      1     QUIET TEST MODEL
        .0       130.0          3.0        83.0    800   PUMP      2     OLD NOISY MODEL
      30.0       130.0          3.0        75.0    800   PUMP      3     SAME AS QUIET 1
      50.0       100.0          3.0        83.0    800   PUMP      4     SAME AS NOISY 2
  0  LINE SOURCES
  0  AREA SOURCES
  0  BARRIERS
```

Figure 14d. Input Data File Report

```
EXAMPLE PROBLEM 1 : NEW SOURCES

RECEIVER NUMBER          LEQ          DESCRIPTION


         1                78.3      1012 MAIN ST.

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER:  1

INDEX   INTENSITY     LEVEL       SOURCE            DESCRIPTION

    1    .140419E+08  71.5    USER DEFINED1    HYDRAL. EXCAV.
    2    .559017E+07  67.5    PUMP      1      QUIET TEST MODEL
    3    .183049E+08  72.6    PUMP      2      OLD NOISY MODEL
    4    .271894E+07  64.3    PUMP      3      SAME AS QUIET 1
    5    .266862E+08  74.3    PUMP      4      SAME AS NOISY 2

KEY TO INDEX:
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                    AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALOGOUS TO LINE SOURCE VARIABLES.
```

Figure 14e. Results Report

Figure 14c presents the data requests by HINPUT and the user responses. Note that for the first source type, USER DEFINED, a MODEL NUMBER of 0 was entered and requests were made for L_{max}, delta, capacity, cycle time, height and frequency. The second source type, PUMP, is contained in the program as a point source. Through entry of a MODEL NUMBER of 0, new source data was requested. The third source type is also a PUMP, also with a MODEL NUMBER of 0, which indicates that it is also new, but different from the second source. Source data was also requested for it. The fourth source is also a PUMP, but of the same type and model as the first PUMP. A model number of -2 indicates for HINPUT to use the data for "the next-to-last newly created" PUMP model. The fifth source, also a PUMP, has a MODEL NUMBER of -1 to indicate use of the data for "the last newly created" PUMP model.

Figures 14d and 14e show the input data report and results report. Notice in the input data report that the frequencies for PUMPS 1 and 3 are equal, as are those for PUMPS 2 and 4, an indication that the negative model numbers worked as intended.

5.2 EXAMPLE TWO: PRODUCTION RATE COORDINATION AND USE OF NOISE BARRIERS

This section shows a simple example where the production rate of the haul trucks is being coordinated with that of a front end loader, and where noise barriers are present. A diagram of the site is shown in Figure 15a.

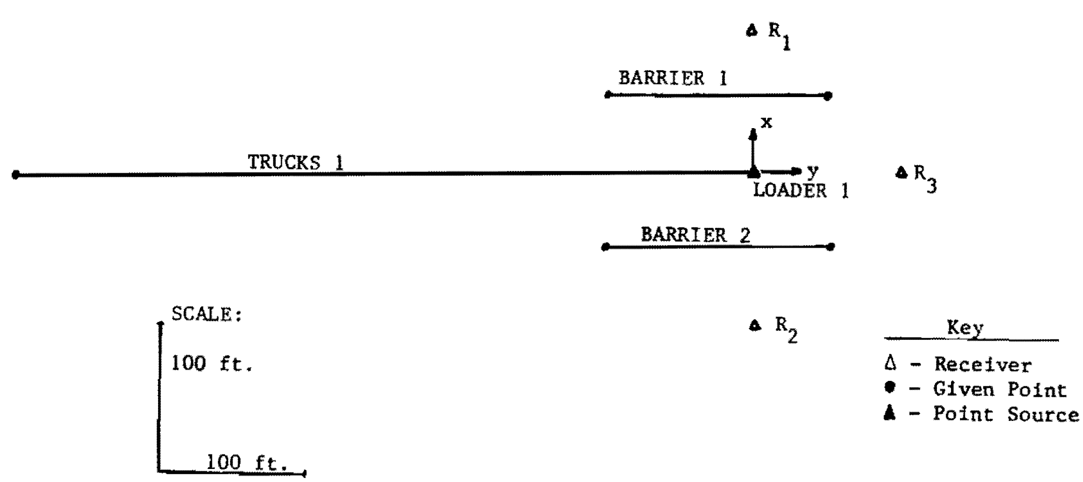

Figure 15a. Site Sketch

This is a hypothetical operation. There are two sources (a point source LOADER, and a line source TRUCKS), three receivers, and two barriers. The two barriers are symmetrical about the load/haul operation. They are physically identical but are specified with different numbers of points to illustrate program flexibility. Two of the three receivers are shielded by barriers, the third is not.

Figure 15b shows the worksheets used in organizing the data, while Figure 15c presents the user responses during execution of HINPUT. Again, user responses are underlined. Note that the point source (LOADER) is located at the origin of the coordinate system for ease of calculations, and to illustrate barrier symmetry. A three-yard capacity front end loader is present, which corresponds to a LOADER model number of 2. The trucks are assumed to be noisy 10-yard dump trucks, which correspond to a TRUCKS model number of 2. Their route is a straight in-and-out run that originates 500 ft. from the loader and ends at the loader (the origin of the coordinate system). Because they turn around without making a major loop, the LOOP TYPE is given as type "7". For a type "7" loop, any value for RADIUS may be given as it is not used by the program; a value of 25 is shown in this example.

Note that values of 8 and -1 are given for HOURS WORKED for the LOADER and TRUCKS respectively. Also note that the value of -1 for HOURS WORKED for TRUCKS results in the program not requesting the hourly volume of trucks. Instead, the program computes the hourly volume based on the hours worked, capacity and cycle time of the loader, and the capacity of the trucks, as contained in the program.

The barriers are both 150 ft. long and 15 ft. high, located 50 ft. from the truck path and loader, as illustrated in the site diagram and shown in the barrier coordinates in Figure 15b. The fact that one barrier is defined by 2 points and the other by 3 demonstrates that any convenient method of specifying barrier coordinates may be used; as will be seen in the results report, the levels for the two shielded receivers are identical.

Figure 15d shows the input data file produced by HINPUT. Note that a vehicle density (VEH. DENS.) was computed for TRUCKS even though no hourly volume was specified for the trucks. This illustrates that a volume was computed in coordination with the LOADER production rate. Figure 15e shows the results report produced by HICNOM. Note that the levels at receivers 1 and 2 are identical even though the barriers shielding them, while identical, were specified differently. The results also show how the unshielded receiver (receiver 3) did have a much higher noise level than the other receivers.

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 1 OF 4
DATE 4-2
PROJECT EX 2

FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE PROBLEM 2: BARRIERS + PROD. COORD.

NUMBER OF RECEIVERS (MAXIMUM OF 10)
3

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	R1	0	100	4	1.0
2	R2	0	-100	4	1.0
3	R3	100	0	4	1.0
4					
5					

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 2 OF 4
DATE 4-2
PROJECT EX 2

FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
LOADER	FILLING TRUCKS	2	1	8	0	0	0
			1				
			1				
			1				

Figure 15b. Coding Worksheet (page 1 of 2)

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 3 OF 4
DATE 4-2
PROJECT EX 2

FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	LOAD & HAUL	2	-1	2

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	-500	0	0	30
2	0	0	0	
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

VEHICLES PER HOUR	RETURN LOOP	
	TYPE(5)	RADIUS(6)
	7	25

(5) SEE FORM 7; IF 6, ENTER POINT

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)

(7) ENTER 0 IF NON-STOP

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 4 OF 4
DATE 4-2
PROJECT EX 2

FORM 6: BARRIER DATA

NUMBER OF BARRIERS
2

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)
BY R1	2

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
-100	50	15
50	50	15

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)
BY R2	3

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
-100	-50	15
0	-50	15
50	-50	15

Figure 15b. Coding Worksheet (page 2 of 2)

```
ENTER TITLE FOR THIS PROBLEM:

EXAMPLE PROBLEM 2: BARRIERS + PROD. COORD.
ENTER NUMBER OF RECEIVERS (MAXIMUM IS 10)

3
ENTER A DESCRIPTION OF RECEIVER #    1
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

R1
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       1

0 100 4 1.0
ENTER A DESCRIPTION OF RECEIVER #    2
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

R2
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       2

0 -100 4 1.0
ENTER A DESCRIPTION OF RECEIVER #    3
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

R3
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       3

100 0 4 1.0
ENTER SOURCE TYPE - BLANK IF FINISHED

LOADER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

FILLING TRUCKS
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

2
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

1
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

0 0 0
ENTER SOURCE TYPE - BLANK IF FINISHED

TRUCKS
```

Figure 15c. User Responses to HINPUT (page 1 of 2)

```
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

LOAD & HAUL
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

2

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

-1
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

2
ENTER X, Y, Z OF THE POINTS

-500 0 0
0 0 0
ENTER SPEED ON EACH SEGMENT (MPH)

30
ENTER TYPE AND RADIUS (FEET) OF RETURN LOOP

7 25
ENTER SOURCE TYPE - BLANK IF FINISHED


ENTER NUMBER OF BARRIERS (MAXIMUM IS 3)

2
ENTER A DESCRIPTION FOR BARRIER # 1
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

BY R1
ENTER NUMBER OF POINTS DEFINING BARRIER (MAXIMUM IS 5)

2
ENTER X, Y, Z OF THE POINTS (Z IS BARRIER ELEVATION)

-100 50 15
50 50 15
ENTER A DESCRIPTION FOR BARRIER # 2
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

BY R2
ENTER NUMBER OF POINTS DEFINING BARRIER (MAXIMUM IS 5)

3
ENTER X, Y, Z OF THE POINTS (Z IS BARRIER ELEVATION)

-100 -50 15 0 -50 15 50 -50 15
```

Figure 15c. User Responses to HINPUT (page 2 of 2)

```
EXAMPLE PROBLEM 2: BARRIERS + PROD. COORD.
  3  RECEIVERS
     X          Y            Z      EX. ATT.(DB/DD)     DESCRIPTION
        .0      100.0        4.0          1.00      R1
        .0     -100.0        4.0          1.00      R2
     100.0         .0        4.0          1.00      R3
  1  POINT SOURCES
     X          Y            Z       LEQ(REF)    FREQ.    SOURCE          DESCRIPTION
        .0         .0        6.0        76.0     500  LOADER  1       FILLING TRUCKS
  1  LINE SOURCES
  3    POINTS                FREQ.:  500            TRUCKS  1       LOAD & HAUL
     X          Y            Z      LEQ(REF) VEH. DENS.
   -500.0          .0        6.0        75.4  .0003710
        .0         .0        6.0        81.0  .0003710
   -500.0          .0        6.0          .0  .0000000
  0  AREA SOURCES
  2  BARRIERS
  2  POINTS      DESCRIPTION: BY R1
     X          Y            Z
   -100.0       50.0        15.0
     50.0       50.0        15.0
  3  POINTS      DESCRIPTION: BY R2
     X          Y            Z
   -100.0      -50.0        15.0
        .0     -50.0        15.0
     50.0      -50.0        15.0
```

Figure 15d. Input Data File Report

EXAMPLE PROBLEM 2 : BARRIERS + PROD. COORD.

RECEIVER NUMBER	LEQ	DESCRIPTION
1	60.1	R1
2	60.1	R2
3	69.4	R3

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 1

INDEX	INTENSITY	LEVEL	SOURCE	DESCRIPTION
1	.472863E+06	56.7	LOADER 1	FILLING TRUCKS
101	.308200E+06	54.9	TRUCKS 1	LOAD & HAUL
201	.232206E+06	53.7	TRUCKS 1	LOAD & HAUL

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 2

INDEX	INTENSITY	LEVEL	SOURCE	DESCRIPTION
1	.472863E+06	56.7	LOADER 1	FILLING TRUCKS
101	.308200E+06	54.9	TRUCKS 1	LOAD & HAUL
201	.232206E+06	53.7	TRUCKS 1	LOAD & HAUL

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 3

INDEX	INTENSITY	LEVEL	SOURCE	DESCRIPTION
1	.789945E+07	69.0	LOADER 1	FILLING TRUCKS
101	.173881E+06	52.4	TRUCKS 1	LOAD & HAUL
201	.631323E+06	58.0	TRUCKS 1	LOAD & HAUL

```
KEY TO INDEX:
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                 AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALOGOUS TO LINE SOURCE VARIABLES.
```

Figure 15e. Results Report

5.3 EXAMPLE THREE:
I-210 FILL SECTION

This example illustrates the modeling of a fill area on I-210 in Los Angeles, California, where the noise level was desired at three receiver locations. Figure 16a shows a sketch of the site while Figure 16b presents the worksheets used in organizing the data and Figure 16c shows data input through HINPUT.

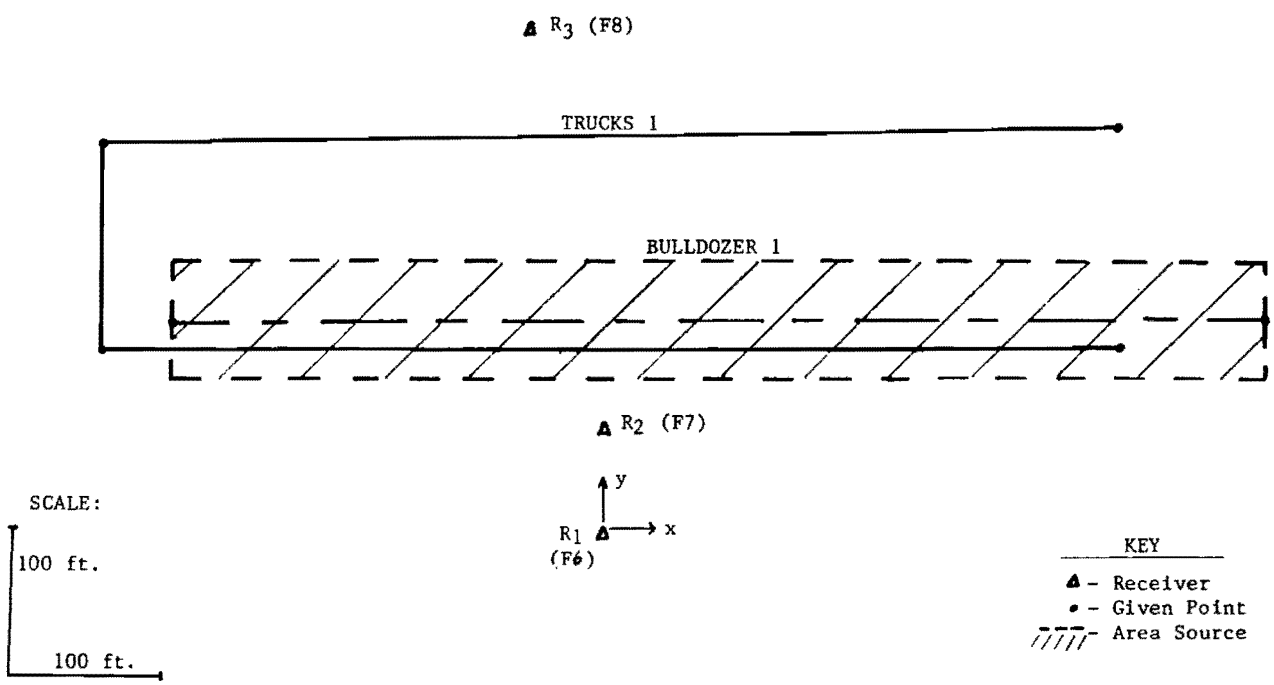

Figure 16a. Site Sketch

There was one haul line source consisting of Peterbilt tractors with tandem belly-dump 10-yard semi-trailers, which corresponded to a TRUCKS model number of "3". There was also one area source, a Caterpillar 834 wheeled tractor, which corresponded to a BULLDOZER model number of 3. In this area the bulldozer was working spreading the fill throughout the area.

The truck route was such that no loop type described its motions and therefore the LOOP TYPE was defined as type "0", where the route started above the fill area and then looped down and back through the fill area where the material was unloaded.

See Appendix E for field data sheets and photographs from this site.

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FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE 3: I-210 FILL AREA, RECEIVERS F6, F7, F8

NUMBER OF RECEIVERS (MAXIMUM OF 10)
3

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	F6: AT ORIGIN	0	0	4	1.0
2	F7: NEAR FILL	0	70	4	1.0
3	F8: NEAR TRUCKS	-50	340	4	1.0
4					
5					
6					
7					
8					
9					
10					

NOTES:

Figure 16b. Coding Worksheets (page 1 of 2)

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FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	HAULING FILL	3	8	4

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	350	270	0	30
2	-340	260	0	20
3	-340	120	0	10
4	350	120	0	
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

VEHICLES PER HOUR	RETURN LOOP TYPE(5)	RETURN LOOP RADIUS(6)
55	0	0

POINT NUMBERS STOPPING(7)	POINT NUMBERS DECELERATION(8)
0	0

(5) SEE FORM 7; IF 0, ENTER POINT

(7) ENTER 0 IF NON-STOP

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FORM 5: AREA SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
BULLDOZER	SPREADING FILL	3	3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES
8	2	1

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
-290	140	0	80	1
450	140	0	80	2
				3

Figure 16b. Coding Worksheets (page 2 of 2)

```
ENTER TITLE FOR THIS PROBLEM:

EXAMPLE 3: I-210 FILL AREA, RECEIVERS F6, F7, F8
ENTER NUMBER OF RECEIVERS (MAXIMUM IS 10)

3
ENTER A DESCRIPTION OF RECEIVER #    1
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

F6: AT ORIGIN
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       1

0 0 4 1.0
ENTER A DESCRIPTION OF RECEIVER #    2
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

F7: NEAR FILL
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       2

0 70 4 1.0
ENTER A DESCRIPTION OF RECEIVER #    3
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

F8: NEAR TRUCKS
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       3

-50 340 4 1.0
ENTER SOURCE TYPE - BLANK IF FINISHED

TRUCKS
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

HAULING FILL
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

4
```

Figure 16c. User Responses to HINPUT (page 1 of 2)

```
ENTER X, Y, Z OF THE POINTS

350 270 0
-340 260 0
-340 120 0
350 120 0
ENTER SPEED ON EACH SEGMENT (MPH)

30 20 10
ENTER VEHICLES PER HOUR (ONE WAY VOLUME)

55
ENTER TYPE AND RADIUS (FEET) OF RETURN LOOP

0 0
ENTER STOPPING POINT NUMBER

0
ENTER DECELERATION POINT NUMBER

0
ENTER SOURCE TYPE - BLANK IF FINISHED

BULLDOZER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

SPREADING FILL
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

3
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
AREA SOURCE:  ENTER NUMBER OF POINTS THAT DEFINE CENTERLINE, MAX. IS 10
(ENTER 0 TO REUSE POINTS FROM THE LAST PREVIOUSLY-ENTERED AREA SOURCE)

2
ENTER X, Y, Z, AND WIDTH OF AREA AT EACH POINT

-290 140 0 80  450 140 0 80
ENTER NUMBER OF PIECES OF THIS TYPE AND MODEL OF EQUIPMENT IN THIS AREA

1
ENTER SOURCE TYPE - BLANK IF FINISHED


ENTER NUMBER OF BARRIERS (MAXIMUM IS 3)

0
```

Figure 16c. User Responses to HINPUT (page 2 of 2)

The value for 0 for the STOPPING POINT indicates the trucks did not stop (they dropped their loads while moving forward) and that the speeds on the line segments were average speeds determined by the user.

The results shown in Figures 16d and 16e indicate that at all three of the receiver locations the trucks were the most significant noise contributor. Receiver 2, being closest to the fill area, was most affected by the bulldozer, and had the higher overall noise level. The two receivers more distant from the fill area had significantly lower noise levels.

```
EXAMPLE 3: I-210 FILL AREA, RECEIVERS F6, F7, F8
  3  RECEIVERS
     X          Y          Z      EX. ATT.(DB/DD)     DESCRIPTION
        .0         .0       4.0          1.00      F6: AT ORIGIN
        .0       70.0       4.0          1.00      F7: NEAR FILL
     -50.0      340.0       4.0          1.00      F8: NEAR TRUCKS
  0  POINT SOURCES
  1  LINE SOURCES
  4    POINTS              FREQ.:  500          TRUCKS  1        HAULING FILL
     X          Y          Z      LEQ(REF) VEH. DENS.
     350.0      270.0       6.0        86.0  .0003464
    -340.0      260.0       6.0        86.0  .0005197
    -340.0      120.0       6.0        86.0  .0010393
     350.0      120.0       6.0          .0  .0000000
  1  AREA SOURCES
  2    POINTS              FREQ.:  500          BULLDOZER    1   SPREADING FILL
     X          Y          Z      LEQ(REF)   WIDTH
    -290.0      140.0       6.0        83.0       80.0
     450.0      140.0       6.0          .0       80.0
  0  BARRIERS
```

Figure 16d. Input Data File Report

EXAMPLE 3: I-210 FILL AREA, RECEIVERS F6, F7, F8

RECEIVER NUMBER	LEQ	DESCRIPTION
1	73.8	F6: AT ORIGIN
2	79.0	F7: NEAR FILL
3	72.9	F8: NEAR TRUCKS

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 1

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
101	.130053E+07	61.1	TRUCKS 1		HAULING FILL
201	.240830E+06	53.8	TRUCKS 1		HAULING FILL
301	.144167E+08	71.6	TRUCKS 1		HAULING FILL
10101	.783707E+07	68.9	BULLDOZER	1	SPREADING FILL

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 2

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
101	.221696E+07	63.5	TRUCKS 1		HAULING FILL
201	.286105E+06	54.6	TRUCKS 1		HAULING FILL
301	.511810E+08	77.1	TRUCKS 1		HAULING FILL
10101	.256986E+08	74.1	BULLDOZER	1	SPREADING FILL

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 3

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
101	.944725E+07	69.8	TRUCKS 1		HAULING FILL
201	.362711E+06	55.6	TRUCKS 1		HAULING FILL
301	.536969E+07	67.3	TRUCKS 1		HAULING FILL
10101	.420221E+07	66.2	BULLDOZER	1	SPREADING FILL

KEY TO INDEX:

```
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                  AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALOGOUS TO LINE SOURCE VARIABLES.
```

Figure 16e. Results Report

5.4 EXAMPLE FOUR: I-210 CUT SECTION

This example represents a cut area on I-210 in Los Angeles, California, where noise levels were desired at four receiver locations, as shown in Figure 17a. Figure 17b presents the coding worksheets and Figure 17c shows the user responses to HINPUT's requests.

The area had two point sources, both Caterpillar 992 wheeled front end loaders with 10 yard buckets (which corresponded to LOADER model numbers of 5); four nonhaul line sources: one Fiat Allis 31 tractor dozer, one Fiat Allis 41 tractor dozer, and two Caterpillar D9G tractor dozers (all of which, based on the user's experience and judgement, corresponded to a BULLDOZER model number of 3); and two haul line sources that consisted of Peterbilt tractors with double belly-dump 20-yard semi-trailers, which corresponded to TRUCKS model 3.

The four bulldozers worked in two tandem groups that pushed the cut material to the loaders that, in turn, loaded the trucks. The first truck route worked in a type "1" loop where the trucks veered off to the left then circled around to the load point from which they continued straight out. The second truck route was modeled as type "5", in which the trucks made a clockwise teardrop shaped loop where the trucks were loaded at the midpoint of the loop. The site diagram illustrates the program-generated points along each route by open circles and the user-specified points by closed circles.

The coordinate system was set up so that the fourth receiver is at the origin. From field observations, data was gathered and all activity factored for working for the entire 8-hour period.

The data input report and results report are shown in Figures 17d and 17e. The results of the modeling program showed that the noise levels of the four receivers varied from 67.7 at Receiver 3 to 77.7 at Receiver 2. The greatest contributor of noise to the first receiver were BULLDOZERS 3 and 4 which are located closest to it. The LOADER 2 and TRUCKS 2 contributed the most to Receiver 2 while Receivers 3 and 4 were most greatly affected by BULLDOZERS 1 and 2.

See Appendix E for field data sheets and photographs from this site.

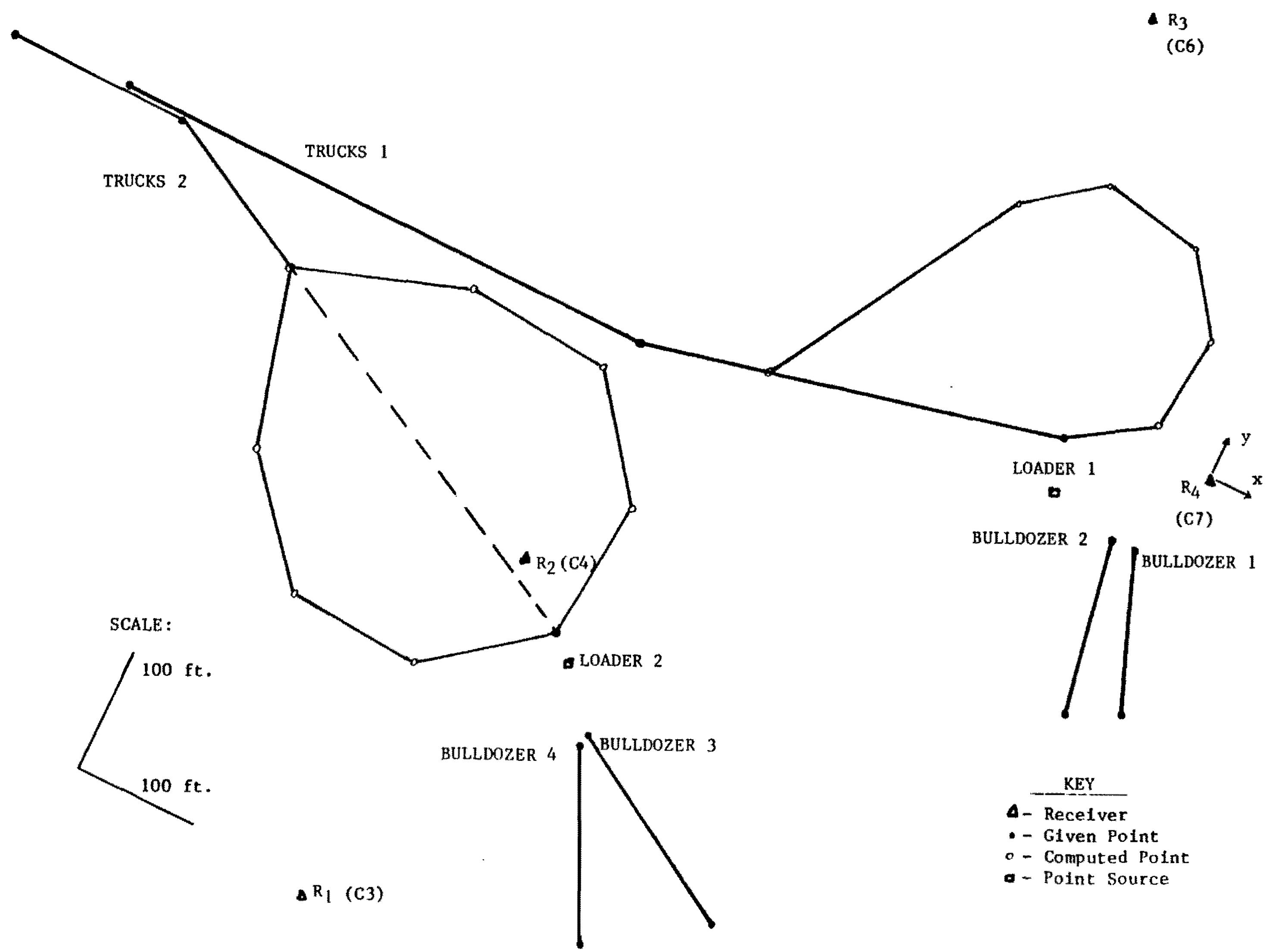

Figure 17a. Site Sketch

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FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE 4: I-210 CUT AREA, RECEIVERS C3, C4, C6, C7

NUMBER OF RECEIVERS (MAXIMUM OF 10)
4

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	C3: BY DOZERS 3,4	-500	-610	0	1.0
2	C4: BY LOADER 2	-460	-300	0	1.0
3	C6: BY TRUCKS 1	-200	300	0	1.0
4	C7: AT ORIGIN	0	0	0	1.0
5					

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FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
LOADER	NO.1 NEAR C7	5	1	8	-110	-65	0
			1				
			1				
			1				

Figure 17b. Coding Worksheets (page 1 of 4)

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FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	FOR LOADER 1	3	-1	3

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	-900	-105	0	35
2	-450	-105	0	35
3	-120	-25	0	
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

VEHICLES PER HOUR	RETURN LOOP	
	TYPE(5)	RADIUS(6)
—	1	100

(5) SEE FORM 7: IF 0, ENTER POINT

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)

(7) ENTER 0 IF NON-STOP

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FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
LOADER	NO.2 NEAR C4	5	1	8	-390	-355	0
			1				
			1				

Figure 17b. Coding Worksheets (page 2 of 4)

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FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	LOADER 2	3	-1	3

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	-1000	-105	0	35
2	-850	-105	0	35
3	-410	-340	0	
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

VEHICLES PER HOUR	RETURN LOOP TYPE(5)	RETURN LOOP RADIUS(6)
—	5	150

POINT NUMBERS STOPPING(7)	POINT NUMBERS DECELERATION(8)

(5) SEE FORM 7; IF 0, ENTER POINT ... (7) ENTER 0 IF NON-STOP ...

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	WITH LOADER 1	3	2	8	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-30	-80	0	1
15	-200	0	2
			3
			4
			5

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM NONHAUL LINE SOURCE

Figure 17b. Coding Worksheets (page 3 of 4)

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	WITH LOADER1	3	2	8	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-50	-80	0	1
-25	-220	0	2
			3
			4

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM NONHAUL LINE SOURCE

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	WITH LOADER2	3	2	8	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-355	-410	0	1
-285	-550	0	2
			3
			4

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM NONHAUL LINE SOURCE

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	WITH LOADER2	3	2	8	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-355	-400	0	1
-200	-490	0	2
			3
			4
			5

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM NONHAUL LINE SOURCE

Figure 17b. Coding Worksheets (page 4 of 4)

```
ENTER TITLE FOR THIS PROBLEM:

EXAMPLE 4: I-210 CUT AREA, RECEIVERS C3, C4, C6, C7
ENTER NUMBER OF RECEIVERS (MAXIMUM IS 10)

4
ENTER A DESCRIPTION OF RECEIVER #    1
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

C3: BY DOZERS 3,4
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       1

-500 -610 0 1.0
ENTER A DESCRIPTION OF RECEIVER #    2
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

C4: BY LOADER 2
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       2

-460 -300 0 1.0
ENTER A DESCRIPTION OF RECEIVER #    3
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

C6: BY TRUCKS1
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       3

-200 300 0 1.0
ENTER A DESCRIPTION OF RECEIVER #    4
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

C7: AT ORIGIN
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #       4

0 0 0 1.0
ENTER SOURCE TYPE - BLANK IF FINISHED

LOADER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

NO. 1 NEAR C7
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

5
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

1
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

-110 -65 0
ENTER SOURCE TYPE - BLANK IF FINISHED

TRUCKS
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

FOR LOADER 1
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3
```

Figure 17c. User Responses to HINPUT (page 1 of 4)

```
PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

-1
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

3
ENTER X, Y, Z OF THE POINTS

-900 -105 0  -450 -105 0  -120 -25 0
ENTER SPEED ON EACH SEGMENT (MPH)

35 35
ENTER TYPE AND RADIUS (FEET) OF RETURN LOOP

1 100
ENTER SOURCE TYPE - BLANK IF FINISHED

LOADER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

NO. 2 NEAR C4
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

5
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

1
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

-390 -355 0
ENTER SOURCE TYPE - BLANK IF FINISHED

TRUCKS
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

FOR LOADER 2
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

-1
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

3
```

Figure 17c. User Responses to HINPUT (page 2 of 4)

```
ENTER X, Y, Z OF THE POINTS

-1000 -105 0  -850 -105 0  -410 -340 0
ENTER SPEED ON EACH SEGMENT (MPH)

35 35
ENTER TYPE AND RADIUS (FEET) OF RETURN LOOP

5 150
ENTER SOURCE TYPE - BLANK IF FINISHED

BULLDOZER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

WITH LOADER 1
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

2
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

2
ENTER X, Y, Z OF THE POINTS

-30 -80 0  15 -200 0
ENTER SOURCE TYPE - BLANK IF FINISHED

BULLDOZER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

WITH LOADER 1
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

2
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

2
ENTER X, Y, Z OF THE POINTS

-50 -80 0  -25 -220 0
ENTER SOURCE TYPE - BLANK IF FINISHED

BULLDOZER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

WITH LOADER 2
```

Figure 17c. User Responses to HINPUT (page 3 of 4)

```
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

2
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

2
ENTER X, Y, Z OF THE POINTS

-355 -410 0  -285 -550 0
ENTER SOURCE TYPE - BLANK IF FINISHED

BULLDOZER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

WITH LOADER 2
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

2
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
WARNING.  YOU HAVE REACHED LIMIT OF 6 LINE SOURCES. ENTERING MORE SOURCES
OF THIS TYPE WILL CAUSE ERROR IN EXECUTION

LINE SOURCE:  ENTER NUMBER OF POINTS ON THE LINE, MAXIMUM IS 20
(ENTER 0 TO REUSE POINTS FROM LAST PREVIOUSLY ENTERED LINE SOURCE)

2
ENTER X, Y, Z OF THE POINTS

-355 -400 0  -200 -490 0
ENTER SOURCE TYPE - BLANK IF FINISHED

ENTER NUMBER OF BARRIERS (MAXIMUM IS 3)

0
```

Figure 17c. User Responses to HINPUT (page 4 of 4)

```
EXAMPLE 4: I-210 CUT AREA, RECEIVERS C3, C4, C6, C7
  4  RECEIVERS
    X          Y           Z      EX. ATT.(DB/DD)    DESCRIPTION
   -500.0     -610.0         .0         1.00      C3: BY DOZERS 3,
   -460.0     -300.0         .0         1.00      C4: BY LOADER 2
   -200.0      300.0         .0         1.00      C6: BY TRUCKS1
      .0         .0          .0         1.00      C7: AT ORIGIN
  2  POINT SOURCES
    X          Y           Z       LEQ(REF)   FREQ.    SOURCE          DESCRIPTION
   -110.0      -65.0        6.0       80.0     500   LOADER  1        NO. 1 NEAR C7
   -390.0     -355.0        6.0       80.0     500   LOADER  2        NO. 2 NEAR C4
  6  LINE SOURCES
 10    POINTS               FREQ.:  500          TRUCKS   1        FOR LOADER 1
    X          Y           Z      LEQ(REF) VEH. DENS.
   -900.0     -105.0        6.0       86.0  .0003241
   -450.0     -105.0        6.0       86.0  .0003241
   -354.2      -81.8        6.0       86.0  .0001624
   -229.3      124.5        6.0       85.2  .0001771
   -167.1      169.4        6.0       84.1  .0002010
    -91.3      157.9        6.0       82.6  .0002385
    -46.4       95.7        6.0       80.3  .0003108
    -57.8       19.9        6.0       72.7  .0007502
   -120.0      -25.0        6.0       86.0  .0004232
   -354.2      -81.8        6.0         .0  .0000000
 11    POINTS               FREQ.:  500          TRUCKS   2        FOR LOADER 2
    X          Y           Z      LEQ(REF) VEH. DENS.
  -1000.0     -105.0        6.0       86.0  .0003241
   -850.0     -105.0        6.0       86.0  .0003241
   -728.9     -169.7        6.0       86.0  .0001652
   -586.1     -125.2        6.0       84.4  .0001947
   -471.6     -137.0        6.0       82.1  .0002537
   -398.2     -225.6        6.0       74.4  .0006126
   -410.0     -340.0        6.0       86.0  .0006126
   -498.5     -413.4        6.0       86.0  .0002537
   -613.0     -401.6        6.0       86.0  .0001947
   -686.4     -313.1        6.0       86.0  .0001652
   -728.9     -169.7        6.0         .0  .0000000
  2    POINTS               FREQ.:  500          BULLDOZER    1    WITH LOADER 1
    X          Y           Z      LEQ(REF) VEH. DENS.
    -30.0      -80.0        6.0       83.0  .0078027
     15.0     -200.0        6.0         .0  .0000000
  2    POINTS               FREQ.:  500          BULLDOZER    2    WITH LOADER 1
    X          Y           Z      LEQ(REF) VEH. DENS.
    -50.0      -80.0        6.0       83.0  .0070316
    -25.0     -220.0        6.0         .0  .0000000
  2    POINTS               FREQ.:  500          BULLDOZER    3    WITH LOADER 2
    X          Y           Z      LEQ(REF) VEH. DENS.
   -355.0     -410.0        6.0       83.0  .0063888
   -285.0     -550.0        6.0         .0  .0000000
  2    POINTS               FREQ.:  500          BULLDOZER    4    WITH LOADER 2
    X          Y           Z      LEQ(REF) VEH. DENS.
   -355.0     -400.0        6.0       83.0  .0055793
   -200.0     -490.0        6.0         .0  .0000000
  0  AREA SOURCES
  0  BARRIERS
```

Figure 17d. Input Data File Report

EXAMPLE 4: I-210 CUT AREA, RECEIVERS C3, C4, C6, C7

RECEIVER NUMBER	LEQ	DESCRIPTION
1	71.7	C3: BY DOZERS 3,4
2	77.7	C4: BY LOADER 2
3	67.7	C6: BY TRUCKS1
4	77.6	C7: AT ORIGIN

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 1

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
1	.234334E+06	53.7	LOADER	1	NO. 1 NEAR C7
2	.183036E+07	62.6	LOADER	2	NO. 2 NEAR C4
101	.222040E+06	53.5	TRUCKS	1	FOR LOADER 1
201	.524457E+05	47.2	TRUCKS	1	FOR LOADER 1
301	.387628E+05	45.9	TRUCKS	1	FOR LOADER 1
401	.669158E+04	38.3	TRUCKS	1	FOR LOADER 1
501	.521370E+04	37.2	TRUCKS	1	FOR LOADER 1
601	.443438E+04	36.5	TRUCKS	1	FOR LOADER 1
701	.391919E+04	35.9	TRUCKS	1	FOR LOADER 1
801	.204033E+04	33.1	TRUCKS	1	FOR LOADER 1
901	.117190E+06	50.7	TRUCKS	1	FOR LOADER 1
102	.471750E+05	46.7	TRUCKS	2	FOR LOADER 2
202	.655252E+05	48.2	TRUCKS	2	FOR LOADER 2
302	.477461E+05	46.8	TRUCKS	2	FOR LOADER 2
402	.313939E+05	45.0	TRUCKS	2	FOR LOADER 2
502	.308294E+05	44.9	TRUCKS	2	FOR LOADER 2
602	.228052E+05	43.6	TRUCKS	2	FOR LOADER 2
702	.764206E+06	58.8	TRUCKS	2	FOR LOADER 2
802	.403022E+06	56.1	TRUCKS	2	FOR LOADER 2
902	.150369E+06	51.8	TRUCKS	2	FOR LOADER 2
1002	.700622E+05	48.5	TRUCKS	2	FOR LOADER 2
103	.450207E+06	56.5	BULLDOZER	1	WITH LOADER 1
104	.498873E+06	57.0	BULLDOZER	2	WITH LOADER 1
105	.590725E+07	67.7	BULLDOZER	3	WITH LOADER 2
106	.362091E+07	65.6	BULLDOZER	4	WITH LOADER 2

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 2

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
1	.691125E+06	58.4	LOADER	1	NO. 1 NEAR C7
2	.260274E+08	74.2	LOADER	2	NO. 2 NEAR C4
101	.116851E+07	60.7	TRUCKS	1	FOR LOADER 1
201	.425026E+06	56.3	TRUCKS	1	FOR LOADER 1
301	.177988E+06	52.5	TRUCKS	1	FOR LOADER 1
401	.193368E+05	42.9	TRUCKS	1	FOR LOADER 1
501	.135639E+05	41.3	TRUCKS	1	FOR LOADER 1
601	.109619E+05	40.4	TRUCKS	1	FOR LOADER 1
701	.981969E+04	39.9	TRUCKS	1	FOR LOADER 1
801	.563726E+04	37.5	TRUCKS	1	FOR LOADER 1
901	.538316E+06	57.3	TRUCKS	1	FOR LOADER 1
102	.901512E+05	49.5	TRUCKS	2	FOR LOADER 2
202	.176712E+06	52.5	TRUCKS	2	FOR LOADER 2
302	.233932E+06	53.7	TRUCKS	2	FOR LOADER 2
402	.300187E+06	54.8	TRUCKS	2	FOR LOADER 2
502	.624004E+06	58.0	TRUCKS	2	FOR LOADER 2
602	.113613E+07	60.6	TRUCKS	2	FOR LOADER 2
702	.104599E+08	70.2	TRUCKS	2	FOR LOADER 2
802	.100765E+07	60.0	TRUCKS	2	FOR LOADER 2
902	.354100E+06	55.5	TRUCKS	2	FOR LOADER 2
1002	.220852E+06	53.4	TRUCKS	2	FOR LOADER 2
103	.101192E+07	60.1	BULLDOZER	1	WITH LOADER 1
104	.118429E+07	60.7	BULLDOZER	2	WITH LOADER 1
105	.673942E+07	68.3	BULLDOZER	3	WITH LOADER 2
106	.671519E+07	68.3	BULLDOZER	4	WITH LOADER 2

Figure 17e. Results Report (page 1 of 2)

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 3

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
1	.902973E+06	59.6	LOADER 1		NO. 1 NEAR C7
2	.224957E+06	53.5	LOADER 2		NO. 2 NEAR C4
101	.172422E+06	52.4	TRUCKS 1		FOR LOADER 1
201	.789274E+05	49.0	TRUCKS 1		FOR LOADER 1
301	.312786E+06	55.0	TRUCKS 1		FOR LOADER 1
401	.333754E+06	55.2	TRUCKS 1		FOR LOADER 1
501	.291733E+06	54.6	TRUCKS 1		FOR LOADER 1
601	.112620E+06	50.5	TRUCKS 1		FOR LOADER 1
701	.449157E+05	46.5	TRUCKS 1		FOR LOADER 1
801	.138055E+05	41.4	TRUCKS 1		FOR LOADER 1
901	.408359E+06	56.1	TRUCKS 1		FOR LOADER 1
102	.276991E+05	44.4	TRUCKS 2		FOR LOADER 2
202	.335507E+05	45.3	TRUCKS 2		FOR LOADER 2
302	.260076E+05	44.2	TRUCKS 2		FOR LOADER 2
402	.237309E+05	43.8	TRUCKS 2		FOR LOADER 2
502	.186955E+05	42.7	TRUCKS 2		FOR LOADER 2
602	.556194E+04	37.5	TRUCKS 2		FOR LOADER 2
702	.553737E+05	47.4	TRUCKS 2		FOR LOADER 2
802	.184376E+05	42.7	TRUCKS 2		FOR LOADER 2
902	.139404E+05	41.4	TRUCKS 2		FOR LOADER 2
1002	.181725E+05	42.6	TRUCKS 2		FOR LOADER 2
103	.104120E+07	60.2	BULLDOZER	1	WITH LOADER 1
104	.105541E+07	60.2	BULLDOZER	2	WITH LOADER 1
105	.321589E+06	55.1	BULLDOZER	3	WITH LOADER 2
106	.360114E+06	55.6	BULLDOZER	4	WITH LOADER 2

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 4

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
1	.112013E+08	70.5	LOADER 1		NO. 1 NEAR C7
2	.409874E+06	56.1	LOADER 2		NO. 2 NEAR C4
101	.150199E+06	51.8	TRUCKS 1		FOR LOADER 1
201	.939254E+05	49.7	TRUCKS 1		FOR LOADER 1
301	.249661E+06	54.0	TRUCKS 1		FOR LOADER 1
401	.107898E+06	50.3	TRUCKS 1		FOR LOADER 1
501	.143933E+06	51.6	TRUCKS 1		FOR LOADER 1
601	.308129E+06	54.9	TRUCKS 1		FOR LOADER 1
701	.956605E+06	59.8	TRUCKS 1		FOR LOADER 1
801	.320084E+06	55.1	TRUCKS 1		FOR LOADER 1
901	.146329E+07	61.7	TRUCKS 1		FOR LOADER 1
102	.212396E+05	43.3	TRUCKS 2		FOR LOADER 2
202	.274883E+05	44.4	TRUCKS 2		FOR LOADER 2
302	.231249E+05	43.6	TRUCKS 2		FOR LOADER 2
402	.237372E+05	43.8	TRUCKS 2		FOR LOADER 2
502	.251461E+05	44.0	TRUCKS 2		FOR LOADER 2
602	.934080E+04	39.7	TRUCKS 2		FOR LOADER 2
702	.895133E+05	49.5	TRUCKS 2		FOR LOADER 2
802	.256264E+05	44.1	TRUCKS 2		FOR LOADER 2
902	.164615E+05	42.2	TRUCKS 2		FOR LOADER 2
1002	.177862E+05	42.5	TRUCKS 2		FOR LOADER 2
103	.224285E+08	73.5	BULLDOZER	1	WITH LOADER 1
104	.178384E+08	72.5	BULLDOZER	2	WITH LOADER 1
105	.663550E+06	58.2	BULLDOZER	3	WITH LOADER 2
106	.819354E+06	59.1	BULLDOZER	4	WITH LOADER 2

KEY TO INDEX:
X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
XX
YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
YYXX AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALOGOUS TO LINE SOURCE VARIABLES.

Figure 17e. Results Report (page 2 of 2)

5.5 EXAMPLE FIVE: I-440 ROCK CUT SECTION

This example illustrates the modeling of a rock cut site on I-440 in Nashville, Tennessee, based on field observations of the operation. Modeling an existing site is a good technique for evaluating abatement strategies. The site, shown in Figure 18a, had two rock drills each with their own compressor, and a bulldozer and grader working in a nearby area. The barrier in this example was actually the top edge of a 17-foot deep cut section that defines the edge of work area.

The example has one receiver, designated Receiver 1, located away from the work site 20 feet higher than the working plane. There is a 17-foot rock ledge located 60 feet from the receiver. On the work site, there is an area 375 feet long and 50 feet wide where a Caterpillar D8H bulldozer and a Caterpillar 12E grader are operating. Beyond this area there are 4 point sources. There are two rock drills and two compressors, one a new quiet model with closed doors and the other a much louder older model. By observing the working condition of the site for half an hour it was possible to determine the "hours worked" and the motion of the equipment. The coordinate system was set up with the receiver at the origin and from this the data for the program was able to be determined.

Figure 18b shows the coding worksheets for the problem and Figure 18c shows the user responses to HINPUT. The two rock drills were modeled as BREAKER, model 1. The compressor located in the negative x-direction corresponded to model number 3 (quiet, with closed doors), while the other compressor, being a standard type, corresponded to a model number of 2. For the area sources, the bulldozer was considered as model number 2 and the grader as model number 1.

For the 30-minute observation period the compressors worked the entire 30 minutes, and the bulldozer and grader both worked 18 3/4 minutes. These durations were then factored to "hours worked" based on an 8-hour day.

However, it was also observed that while the two rock drills were in operation the entire measurement period, they were only at maximum noise level 60% and 72% of the time, respectively. Examining the data in the program for rock drills, as shown in Table 2 for BREAKER model 1, the value for DELTA, the difference between the maximum level and the Leq of the drill over its work cycle was 7 dBA. A seven dBA value translates to the equipment working at maximum level for only 20 percent of the time (7 dBA = 10Log(100%/20%).

Because the drills on the site worked at maximum level for much higher percentages of time, it was decided to model these as new BREAKER models, with values of DELTA computed based on the field operation percentages. DELTA for the first drill was computed as 10 Log(100%/60%) or 2.2 dBA. DELTA for the second drill was 1.4 dBA (10 Log(100%/72%)). The other data required for a new BREAKER model was taken from Table 2 for BREAKER Model 1. Because the drills were in operation for the entire measurement period, even though not at maximum level for the entire period, the value for hours worked was 8, corresponding to operation during the entire time period.

The input data file report and the HICNOM results report are shown in Figures 18d and 18e. As expected, the major noise sources were the rock drills. Note that the bulldozer and motor grader contributed little to the total Leq and that the contribution from the quiet compressor was much lower than the standard compressor. To determine the amount of shielding provided by the edge of the cut acting as a barrier, the reader is invited to run the problem with no barrier (the answer is 81.8 dBA).

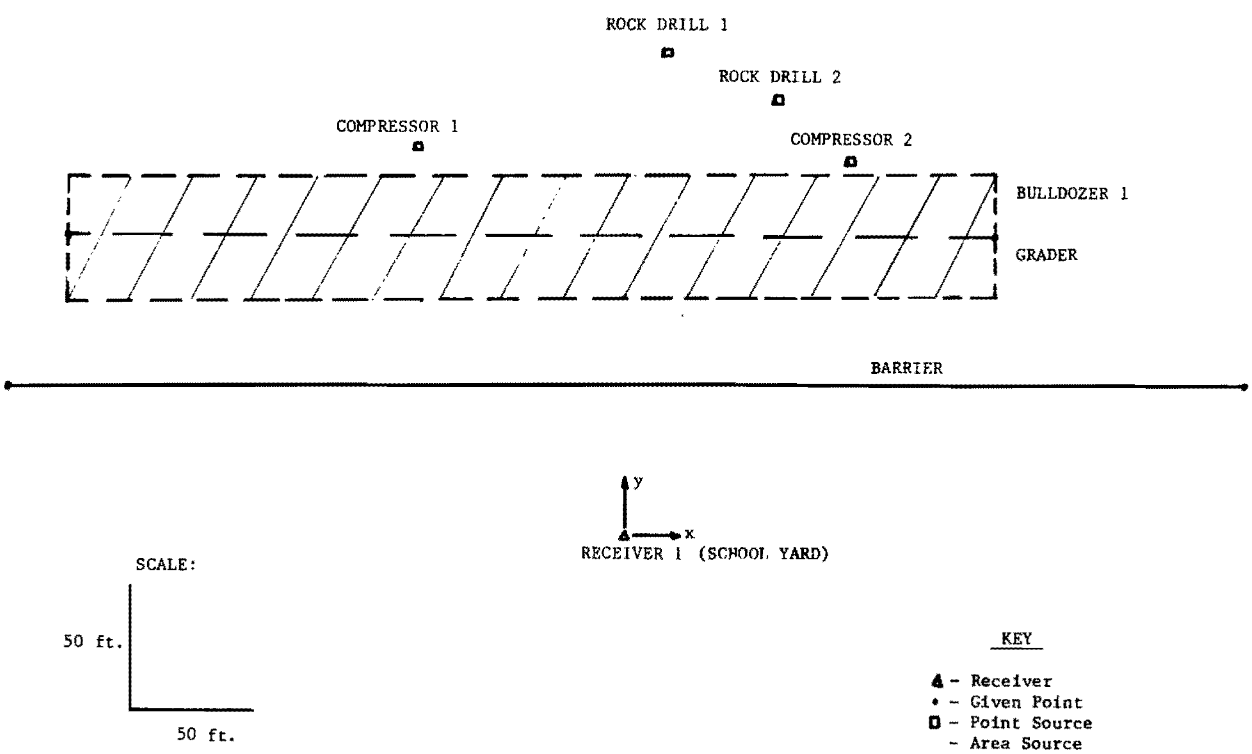

Figure 18a. Site Sketch

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 1 OF 5
DATE 4-2
PROJECT EX 5

FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
EXAMPLE 5: I-440 ROCK DRILL CUT AREA

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	SCHOOL YARD	0	0	0	1.5
2					

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 2 OF 5
DATE 4-2
PROJECT EX 5

FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
BREAKER	ROCK DRILL 1	0	1	8	15	195	-20
BREAKER	ROCK DRILL 2	0	1	8	60	175	-20
COMPRESSOR	WITH DRILL 1	3	1	8	-85	155	-20
COMPRESSOR	WITH DRILL 2	2	1	8	90	150	-20
			1				
			1				
			1				
			1				
			1				
			1				

NOTES:
(1) TO DEFINE SOURCE NOT LISTED ON FORM 7, ENTER: USER DEFINED
(2) 0 INDICATES NEW MODEL; NEGATIVE VALUE INDICATES NEW MODEL PREVIOUSLY CREATED IN THIS RUN
(3) IN 8 HOUR DAY; NEGATIVE VALUE MEANS MATCH PRODUCTION RATE WITH PRECEEDING SOURCE WITH PRODUCTION RATE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY
96	2.2	0	0	2	1500
96	1.4	0	0	2	1500

Figure 18b. Coding Worksheets (page 1 of 2)

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 3 OF 5
DATE 4-2
PROJECT EX 5

FORM 5: AREA SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
BULLDOZER	CAT D8H	2	3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES
5	2	1

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
-225	120	-20	50	1
150	120	-20	50	2
				3

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 4 OF 5
DATE 4-2
PROJECT EX 5

FORM 5: AREA SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
GRADER	CAT RE: 87 D8H	1	3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES
5	0	1

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
				1

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 5 OF 5
DATE 4-2
PROJECT EX 5

FORM 6: BARRIER DATA

NUMBER OF BARRIERS
1

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 6)
TOP OF CUT AT RW	2

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
-250	60	-3
250	60	-3

Figure 18b. Coding Worksheets (page 2 of 2)

```
ENTER TITLE FOR THIS PROBLEM:

EXAMPLE 5: I-440 ROCK DRILL CUT AREA
ENTER NUMBER OF RECEIVERS (MAXIMUM IS 10)

1
ENTER A DESCRIPTION OF RECEIVER #    1
MAXIMUM OF 16 CHARACTERS - BLANK IF NONE)

SCHOOL YARD
ENTER X, Y, Z AND EXCESS ATTENUATION (DB/DD) FOR RECEIVER #      1

0 0 0 1.5
ENTER SOURCE TYPE - BLANK IF FINISHED

BREAKER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

ROCK DRILL 1
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

0
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

1
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

15 195 -20
ENTER LMAX (DBA)

96
ENTER DELTA (LMAX-LEQ) IN DBA

2.2
ENTER CAPACITY PER CYCLE (CUBIC YARDS)

0
ENTER CYCLE TIME (HOURS)

0
ENTER ACOUSTIC HEIGHT (FEET)

2
ENTER FREQUENCY (HERTZ)

1500
ENTER SOURCE TYPE - BLANK IF FINISHED

BREAKER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

ROCK DRILL 2
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

0
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

1
```

Figure 18c. User Responses to HINPUT (page 1 of 3)

```
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

60 175 -20
ENTER LMAX (DBA)

96
ENTER DELTA (LMAX-LEQ) IN DBA

1.4
ENTER CAPACITY PER CYCLE (CUBIC YARDS)

0
ENTER CYCLE TIME (HOURS)

0
ENTER ACOUSTIC HEIGHT (FEET)

2
ENTER FREQUENCY (HERTZ)

1500
ENTER SOURCE TYPE - BLANK IF FINISHED

COMPRESSOR
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

WITH DRILL 1
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

3

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

-85 155 -20
ENTER SOURCE TYPE - BLANK IF FINISHED

COMPRESSOR
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

WITH DRILL 2
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

2

PROGRAM HAS AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

8
POINT SOURCE:  ENTER X, Y, Z OF SOURCE LOCATION

90 150 -20
```

Figure 18c. User Responses to HINPUT (page 2 of 3)

```
ENTER SOURCE TYPE - BLANK IF FINISHED

BULLDOZER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

CAT D8H
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

2
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

3
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

5
AREA SOURCE:  ENTER NUMBER OF POINTS THAT DEFINE CENTERLINE, MAX. IS 10
(ENTER 0 TO REUSE POINTS FROM THE LAST PREVIOUSLY-ENTERED AREA SOURCE)

2
ENTER X, Y, Z, AND WIDTH OF AREA AT EACH POINT

-225 120 -20 50 150 120 -20 50
ENTER NUMBER OF PIECES OF THIS TYPE AND MODEL OF EQUIPMENT IN THIS AREA

1
ENTER SOURCE TYPE - BLANK IF FINISHED

GRADER
ENTER A DESCRIPTION OF THE SOURCE
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

CAT 12E: BY D8H
ENTER MODEL NUMBER (ENTER 0 TO DEFINE NEW MODEL NUMBER)

1
ENTER 1, 2 OR 3 FOR WORKING OVER A POINT, LINE OR AREA

3
ENTER HOURS WORKED DURING 8-HOUR DAY
(ENTER -1 TO COORDINATE PRODUCTION RATE OF THIS SOURCE WITH THAT OF
THE LAST PREVIOUSLY-ENTERED SOURCE HAVING A PRODUCTION RATE)

5

AREA SOURCE:  ENTER NUMBER OF POINTS THAT DEFINE CENTERLINE, MAX. IS 10
(ENTER 0 TO REUSE POINTS FROM THE LAST PREVIOUSLY-ENTERED AREA SOURCE)

0
ENTER NUMBER OF PIECES OF THIS TYPE AND MODEL OF EQUIPMENT IN THIS AREA

1
ENTER SOURCE TYPE - BLANK IF FINISHED


ENTER NUMBER OF BARRIERS (MAXIMUM IS 3)

1
ENTER A DESCRIPTION FOR BARRIER # 1
(MAXIMUM OF 16 CHARACTERS - BLANK IF NONE):

TOPOF CUT AT RW
ENTER NUMBER OF POINTS DEFINING BARRIER (MAXIMUM IS 5)

2
ENTER X, Y, Z OF THE POINTS (Z IS BARRIER ELEVATION)

-250 60 -3 250 60 -3
```

Figure 18c. User Responses to HINPUT (page 3 of 3)

```
EXAMPLE 5: I-440 ROCK DRILL CUT AREA
 1  RECEIVERS
    X          Y          Z      EX. ATT.(DB/DD)    DESCRIPTION
       .0         .0         .0          1.50      SCHOOL YARD
 4  POINT SOURCES
    X          Y          Z       LEQ(REF)   FREQ.    SOURCE          DESCRIPTION
     15.0      195.0     -18.0        93.8  1500  BREAKER 1         ROCK DRILL 1
     60.0      175.0     -18.0        94.6  1500  BREAKER 2         ROCK DRILL 2
    -85.0      155.0     -16.0        75.0  1000  COMPRESSOR   1    WITH DRILL 1
     90.0      150.0     -16.0        86.0  1000  COMPRESSOR   2    WITH DRILL 2
 0  LINE SOURCES
 2  AREA SOURCES
 2    POINTS                FREQ.:  500           BULLDOZER    1    CAT D8H
    X          Y          Z     LEQ(REF)    WIDTH
   -225.0      120.0     -14.0        76.0       50.0
    150.0      120.0     -14.0          .0       50.0
 2    POINTS                FREQ.:  500           GRADER  1         CAT 12E: BY D8H
    X          Y          Z     LEQ(REF)    WIDTH
   -225.0      120.0     -12.0        81.0       50.0
    150.0      120.0     -12.0          .0       50.0
 1  BARRIERS
 2  POINTS       DESCRIPTION: TOPOF CUT AT RW
    X          Y          Z
   -250.0       60.0      -3.0
    250.0       60.0      -3.0
```

Figure 18d. Input Data File Report

```
EXAMPLE 5: I-440 ROCK DRILL CUT AREA

RECEIVER NUMBER          LEQ          DESCRIPTION


         1                77.0      SCHOOL YARD

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER:  1

INDEX   INTENSITY    LEVEL      SOURCE           DESCRIPTION

    1   .198369E+08  73.0    BREAKER 1         ROCK DRILL 1
    2   .220000E+08  73.4    BREAKER 2         ROCK DRILL 2
    3   .314491E+06  55.0    COMPRESSOR   1    WITH DRILL 1
    4   .385679E+07  65.9    COMPRESSOR   2    WITH DRILL 2
10101   .226811E+07  63.6    BULLDOZER    1    CAT D8H
10102   .229308E+07  63.6    GRADER  1         CAT 12E: BY D8H

KEY TO INDEX:
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                  AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALOGOUS TO LINE SOURCE VARIABLES.
```

Figure 18e. Results Report

6.0 ERROR MESSAGES AND RECOVERY

This section lists in alphabetical order all of the error messages that may be printed by HINPUT or HICNOM.

1. ERROR - D IS LESS THAN OR EQUAL TO 0

Corrective Action: This message is generated by subroutine LINSRC of HICNOM if the calculations yield a negative or zero value for the perpendicular distance from the receiver to the line source. Check the receiver and line segment coordinates for errors.

2. ERROR - PHI2 IS GREATER THAN PI/2

Corrective Action: This message is generated by subroutine LINSRC of HICNOM if during calculations the angle from the normal line between the receiver and the line source to either the left or right endpoint of the line is less than -90 degrees. Check the receiver and line segment coordinates.

3. ERROR - PHI1 or PHI2 IS GREATER THAN PI/2

Corrective Action: This message is generated by subroutine LINSRC of HICNOM if during calculations, the angle from the normal line between the receiver and line source to either the left or right endpoint of the line segment is greater than 90 degrees. Check receiver and line segment coordinates.

4. ERROR - PHI2 IS LESS THAN PHI1

Corrective Action: This message is generated by subroutine LINSRC of HICNOM if during calculations, the angle from the normal line to the second endpoint of the road segment is less than the angle from normal line to the first endpoint of the segment. Check receiver and line segment coordinates.

5. ERROR - RECEIVER WILL GET RUN OVER

Corrective Action: This message is generated by subroutine LINSRC of HICNOM if the receiver was located on the line defining the line source. Check receiver and line segment coordinates, and adjust as needed.

6. ERROR - SERIES DID NOT CONVERGE

Corrective Action: This message is generated by function BX of

HICNOM (Section B.5.5) during calculations of the finite line segment adjustment for line sources. Check the receiver and line segment coordinates and adjust as needed.

7. ERROR IN GAMMA FUNCTION

Corrective Action: This message is generated by function BX of HICNOM during calculations of the finite line segment adjustment. Check receiver and line segment coordinates and adjust as necessary.

8. INVALID MODEL NUMBER - REENTER

Corrective Action: This message is generated by HINPUT when the MODEL NUMBER entered by the user is greater than the highest model number in Table 1 for the SOURCE TYPE under consideration. Check Table 1, choose a valid model number and enter the correct value. Note that negative model numbers may be used to refer to previously-entered new models, as was illustrated in Section 5.1.

9. INVALID SOURCE TYPE - REENTER

Corrective Action: This message is generated by HINPUT when the SOURCE TYPE entered by the user did not exactly match any of the source types listed in the first column of Table 1. Check Table 1 and enter the correct SOURCE TYPE.

10. PROGRAM AUTOMATICALLY ASSIGNED A GEOMETRY TYPE TO THIS SOURCE

Corrective Action: This message, generated by HINPUT, does not signify an error, but serves to inform the user that the program has decided if the source type under consideration is to be treated as a point, line or area source based on the data coded in the program's data block. After printing this message, the program will not ask for a geometry type, but will proceed directly to the appropriate data requests for this geometry type.

11. YOU HAVE REACHED LIMIT OF 5 AREA SOURCES. ENTERING MORE SOURCES OF THIS TYPE WILL CAUSE ERROR IN EXECUTION

Corrective Action: HINPUT is set to accept up to 5 area sources. It counts the number of area sources entered by the user during a run and generates this message during entry of the fifth area source. Complete the data entries for this source, but do not try to enter more area sources during the run or the program will not execute.

12. YOU HAVE REACHED LIMIT OF 6 LINE SOURCES. ENTERING MORE SOURCES OF THIS TYPE WILL CAUSE ERROR IN EXECUTION

Corrective Action: HINPUT is set to accept up to six line sources. It counts the number of line sources entered by the user during a run and generates this message during entry of the sixth line source. Complete the data entries for this source, but do not try to enter more line sources during the run or the program will not execute.

13. YOU HAVE REACHED LIMIT OF 10 POINT SOURCES. ENTERING MORE SOURCES OF THIS TYPE WILL CAUSE ERROR IN EXECUTION.

Corrective Action: HINPUT is set to accept up to 10 point sources. It counts the number of point sources entered by the user during a run and generates this message during entry of the tenth point source. Complete the data entries for this source, but do not try to enter more point sources during the run or the program will not execute.

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5. Highway Construction Noise - Environmental Assessment and Abatement, Volume V - Examples of Highway Construction Site Data: Measurements and Analysis, Vanderbilt University, Report VTR 82-4, 1982.

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APPENDIX A: MODEL FORMULATION AND STRUCTURE

This Appendix describes in detail the acoustical formulation of the highway construction noise model, HICNOM. Section A.1 describes some of the geometrical considerations by the program, and Section A.2 develops the equations for predicting the equivalent sound level at a receiver location from a variety of construction equipment and operations. The second section also describes the barrier shielding routine used in the model.

A.1 Construction Activities

The highway construction noise model, HICNOM, was developed to permit computation of the 8-hour equivalent sound level at various receiver locations from various noise sources working at the construction site. The sources may be geometrically considered as working at a point, along a line (series of straight line segments), or over an area. The model generates the contributions from each source to the 8-hour Leq at each receiver, as well as the total 8-hour Leq at each receiver.

In the following discussion, the phrase "geometry type" will be used to refer to the categories "point", "line" or "area". Examples of point sources include stationary equipment such as a compressor or mobile equipment that move over a very small area (a front end loader loading trucks). Examples of line sources include scrapers on a haul road and a motor grader moving back and forth over a road on the site. An example of an area source is a bulldozer spreading dirt at a fill section of a project.

The program has a data base built into it for 53 different types of equipment grouped into 16 different "source types". A source type and a model number are used to uniquely designate a particular piece of equipment. Some model numbers represent different models of the same type of equipment (such as a Caterpillar D6 bulldozer or a Caterpillar D9 bulldozer) while others represent different types of equipment (BREAKER Model No. 1 is a rock drill, while Model No. 2 is a jackhammer).

Table A-1 shows the 16 different "source types", and their corresponding model numbers and descriptions in the first three columns. If data is available to the user on the operating characteristics of a particular piece of equipment not already included in the program, a "new" source or model may be created

Table A-1. Source Type Definition Information (page 1 of 2)
(See Table A-2 for related information)

Source Type	Model No.*	Description	Allowable Geometry Types †	Is Production Rate Coordination Possible?	Type of Line Source
BACKHOE	1	# Nominal**	1 2 3	Yes	Non-Haul
	2	Caterpillar, Koehring	1 2 3	Yes	Non-Haul
	3	P & H	1 2 3	Yes	Non-Haul
	0	Defined by user	1 2 3	Yes	Non-Haul
LOADER	1	# Nominal	1 2 3	Yes	Non-Haul
	2	3-yard capacity	1 2 3	Yes	Non-Haul
	3	5-yard capacity	1 2 3	Yes	Non-Haul
	4	7-yard capacity	1 2 3	Yes	Non-Haul
	5	10-yard capacity	1 2 3	Yes	Non-Haul
	0	Defined by user	1 2 3	Yes	Non-Haul
COMPRESSOR	1	# Nominal	1	No	N/A ††
	2	Standard	1	No	N/A
	3	Quiet, doors open	1	No	N/A
	4	Quiet, doors closed	1	No	N/A
	0	Defined by user	1	No	N/A
PILE DRIVER	1	# Nominal	1	No	N/A
	2	Current data	1	No	N/A
	0	Defined by user	1	No	N/A
PUMP	1	63 dB @ 50 feet	1	No	N/A
	2	76 dB @ 50 feet	1	No	N/A
	3	# Nominal	1	No	N/A
	0	Defined by user	1	No	N/A
CRANE	1	# Nominal	1	Yes	N/A
	2	Low	1	Yes	N/A
	3	Medium	1	Yes	N/A
	4	High	1	Yes	N/A
	0	Defined by user	1	Yes	N/A
BREAKER	1	# Rock Drill	1 2 3	No	Non-Haul
	2	# Std. Jackhammer (Nominal)	1 2 3	No	Non-Haul
	3	Muffled Jackhammer	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
CONCRETE	1	# Concrete Pour	1	No	N/A
	2	# Nominal Batch Plant	1	No	N/A
	3	Batch Plant	1	No	N/A
	4	# Pump	1	No	N/A
	5	# Concrete Mixer	1	No	N/A
	0	Defined by user	1	No	N/A

* A model number of zero tells the program a new model number is being defined for this computer run.

** "Nominal" means that the data represents an averaging of data from previous literature.

† 1: Point, 2: Line, 3: Area

†† N/A means "not applicable".

Use this model number if a generalized value is needed.

Table A-1. Source Type Definition Information (page 2 of 2)
(See Table A-2 for related information)

Source Type	Model No.*	Description	Allowable Geometry Types †	Is Production Rate Coordination Possible?	Type of Line Source
GENERATOR	1	Low Level	1	No	N/A
	2	# Nominal**	1	No	N/A
	0	Defined by user	1	No	N/A
MISCELLAN	1	# Grinder	1	No	N/A
	2	# Concrete Saw	1	No	N/A
	3	# Fan	1	No	N/A
	4	# Welder (Nominal)	1	No	N/A
	0	Defined by user	1	No	N/A
BULLDOZER	1	# Nominal**	1 2 3	No	Non-Haul
	2	Caterpillar D6, D7, D8	1 2 3	No	Non-Haul
	3	Caterpillar D9	1 2 3	No	Non-Haul
	4	D9 without muffler	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
GRADER	1	# Nominal	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
TRUCKS	1	10-yard dump, quiet	2	Yes	Haul
	2	10-yard dump, noisy	2	Yes	Haul
	3	Dual 20-yard trailers	2	Yes	Haul
	4	# Nominal	2	Yes	Haul
	0	Defined by user	2	Yes	Haul
SCRAPER	1	Caterpillar 631, muffled	2	Yes	Haul
	2	# Cat. 631, no muff. (Nominal)	2	Yes	Haul
	3	Caterpillar 623	2	Yes	Haul
	4	Caterpillar 637	2	Yes	Haul
	0	Defined by user	2	Yes	Haul
COMPACTOR	1	Low	3	No	N/A
	2	# Nominal	3	No	N/A
	3	High	3	No	N/A
	0	Defined by user	3	No	N/A
PAVING	1	# Nominal	1 2 3	No	Non-Haul
	2	Concrete Paver	1 2 3	No	Non-Haul
	3	Asphalt Paver	1 2 3	No	Non-Haul
	0	Defined by user	1 2 3	No	Non-Haul
USER DEFINED	0	Defined by user	1 2 3	Yes	User-Defined

* A model number of zero tells the program a new model number is being defined for this computer run.
** "Nominal" means that the data was acquired from previous literature.
† 1: Point, 2: Line, 3: Area
†† N/A means "not applicable".
# Use this model number if a generalized value is needed.

by the user during a computer run, or it can be permanently built into the data base in the program. Section 3.2 of the main body of this report discusses how to create new sources during a computer run, while Appendix C describes how to permanently add a source to the program.

The program automatically assigns a geometry type for certain equipment types as shown in the fourth column of Table A-1 (e.g., a PUMP can only operate at a point, TRUCKS can only operate along a line, and a COMPACTOR can only operate in an area).

Certain types of equipment in the model have production rates; that is, they are constrained in their operation by their capacity (an example is the size of a dump truck) or by how long it takes them to perform one cycle of operation (an example is the time it takes a front end loader to dig into a pile of dirt, lift it, turn, dump it into a truck, and return to the pile). If two such pieces are working together on an actual construction site, their activities will be coordinated; for example, the number of trucks on a haul road in a specified period of time depends on the ability of the loader to fill them. The program is set up to compute this working relationship based on the production capability of each piece of equipment. The fifth column of Table A-1 indicates which pieces may be coordinated to each other. Section A.2 discusses how the model considers coordinations, while Section 3.0 of the main report describes how to tell the program to coordinate activities.

The model divides line sources into two sub-categories: Haul and Nonhaul. A nonhaul line source could be one piece of equipment that moves slowly along a line (paving operations) or could be one piece of equipment that moves back and forth over a line (motor grader).

A haul line source would be a series of trucks or scrapers moving on a haul road. Their operations are discussed in terms of vehicles per hour and travel speed. Haul vehicles typically turn around either before or after loading or unloading to return to the other end of the haul road. The prediction model includes routines to generate a series of straight line segments that approximate different types of turn-around loops. The model also computes average speeds on each segment based on the type of loop, the approach and departure speeds, and the size of the loop. Seven loop types are built into the model, which includes one type that represents a straight turn-around with no loop. Figure A-1 illustrates the loop types in the model.

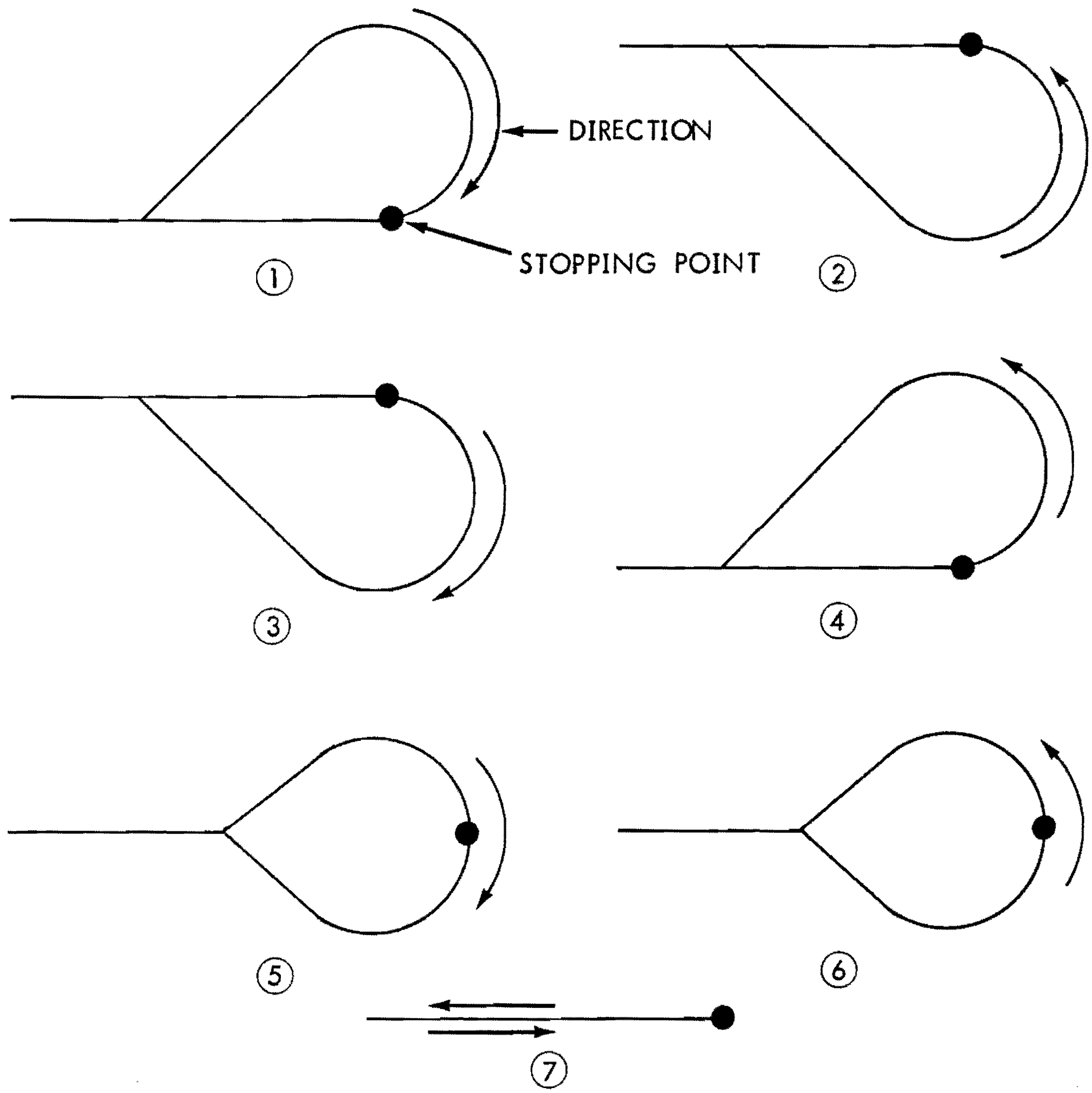


Figure A-1. Haul Road Turn-around Loop Configuration

Table A-2. Source Type Acoustical and Operational Data (page 1 of 2)
(See Table A.1 for related information)

Source Type	Model No.*	L_{max} (dBA)	Delta (dBA)	Cycle Time (hrs.)	Capacity (cu. yds.)	Acoustic Height (ft.)	Acoustic Frequency (Hz.)	Reference Speed (mph)	Slope††	Critical Speed (mph)
BACKHOE	1	86.5	3	.00833	N/A†	6	500	--	--	--
	2	88.0	3	.00833	N/A	6	500	--	--	--
	3	92.0	3	.00833	N/A	6	500	--	--	--
	0	UD**	UD	UD	UD	UD	UD	--	--	--
LOADER	1	89.0	5	.00833	5	6	500	--	--	--
	2	81.0	5	.00833	3	6	500	--	--	--
	3	82.0	5	.00833	5	6	500	--	--	--
	4	83.0	5	.00833	7	6	500	--	--	--
	5	85.0	5	.00833	10	6	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
COMPRESSOR	1	91.3	2	0	N/A	4	1000	--	--	--
	2	88.0	2	0	N/A	4	1000	--	--	--
	3	77.0	2	0	N/A	4	1000	--	--	--
	4	67.0	2	0	N/A	4	1000	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
PILE DRIVER	1	97.3	6	0	0	20	1500	--	--	--
	2	103.0	6	0	0	20	1500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
PUMP	1	63.0	0	0	0	4	800	--	--	--
	2	76.0	0	0	0	4	800	--	--	--
	3	71.0	0	0	0	4	800	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
CRANE	1	89.0	7.5	0	0	15	500	--	--	--
	2	73.0	7.5	0	0	15	500	--	--	--
	3	81.5	7.5	0	0	15	500	--	--	--
	4	85.0	7.5	0	0	15	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
BREAKER	1	96.0	7	0	0	2	1500	--	--	--
	2	87.0	7	0	0	2	1500	--	--	--
	3	76.0	7	0	0	2	1500	--	--	--
CONCRETE	1	78.0	5	0	0	10	500	--	--	--
	2	90.0	0	0	0	10	500	--	--	--
	3	82.0	0	0	0	10	500	--	--	--
	4	85.0	0	0	0	6	500	--	--	--
	5	82.8	0	0	0	8	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--

* A Model Number of zero tells the program a new model number is being defined for the computer run.
** UD: User-defined (supplied by user)
† N/A means "not applicable".
†† Slope is "B" in the emission level equation: $Lo = L_{max} + B \log(\text{speed}/\text{reference speed})$.

Table A-2. Source Type Definition Information (page 2 of 2)
(See Table A-1 for related information)

Source Type	Model No.*	L_{max} (dBA)	Delta (dBA)	Cycle Time (hrs.)	Capacity (cu. yds.)	Acoustic Height (ft.)	Acoustic Frequency (Hz.)	Reference Speed (mph)	Slope††	Critical Speed (mph)
GENERATOR	1	73.5	0	0	0	4	1200	--	--	--
	2	81.0	0	0	0	4	1200	--	--	--
	0	UD**	UD	UD	UD	UD	UD	--	--	--
MISCELLAN	1	71.0	1	0	0	2	1200	--	--	--
	2	88.0	0	0	0	1	1200	--	--	--
	3	83.0	0	0	0	4	1200	--	--	--
	4	71.0	0	0	0	4	1200	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
BULLDOZER	1	90.1	2	0	0	6	500	--	--	--
	2	80.0	2	0	0	6	500	--	--	--
	3	85.0	2	0	0	6	500	--	--	--
	4	96.0	2	0	0	6	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
GRADER	1	83.0	0	0	0	8	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
TRUCKS	1	76.0	N/A†	N/A	10	8	500	35	20	35
	2	81.0	N/A	N/A	10	8	500	35	20	35
	3	86.0	N/A	N/A	40	8	500	35	20	35
	4	90.7	N/A	N/A	10	8	500	35	20	35
	0	UD	N/A	N/A	UD	UD	UD	UD	UD	
SCRAPER	1	84.0	N/A	N/A	25	6	500	30	0	30
	2	95.0	N/A	N/A	25	6	500	30	0	30
	3	90.0	N/A	N/A	25	6	500	30	0	30
	4	81.0	N/A	N/A	25	6	500	30	0	30
	0	UD	N/A	N/A	UD	UD	UD	UD	UD	UD
COMPACTOR	1	80.0	0	0	0	8	500	--	--	--
	2	86.0	0	0	0	8	500	--	--	--
	3	93.0	0	0	0	8	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
PAVING	1	83.8	0	0	0	4	500	--	--	--
	2	82.8	0	0	0	4	500	--	--	--
	3	82.5	0	0	0	4	500	--	--	--
	0	UD	UD	UD	UD	UD	UD	--	--	--
USER DEFINED	0	UD	UD	UD	UD	UD	UD	--	--	--

* A Model Number of zero tells the program a new model number is being defined for the computer run.
** UD: User-defined (supplied by user)
† N/A means "not applicable".
†† Slope is "B" in the emission level equation: $Lo = L_{max} + B \log (\text{speed/reference speed})$.

A.2 Acoustical Formulation

The model considers noise from point, line and area sources. Attenuation with distance consists of geometrical spreading plus excess ground attenuation function. Attenuation by noise barriers is also considered. The mathematical representations are described in the following sub-sections.

A.2.1 Point Sources

For a source and receiver separated by a distance d, the 8-hour equivalent sound level (Leq(8h)) is:

$$\text{Leq(8h)} = (L_0)_E + 10\ \text{Log}(T/8) + 20\ \text{Log}(d_0/d)^{1 + (n/6)} \qquad \text{(A-1)}$$

where: $(L_0)_E$ is the energy-averaged emission level over some time period (such as the equipment operation cycle) measured at a reference distance d_0;

T is the number of hours that the equipment is working in its operational cycle during the 8-hour day; and

n is the excess attenuation rate in decibels per doubling of distance (dB/DD).

A value of 0 for n would correspond to an overall attenuation rate of 6 dB/DD, or normal geometrical spreading for a point source. A value of 1.5 dB/DD for n would result in an overall attenuation rate of 7.5 dB/DD, a typical rate for propogation of a point source's sound over "soft" ground.

The energy-averaged emission level, $(L_0)_E$, may be represented by:

$$(L_0)_E = L_{max} - \Delta \qquad \text{(A-2)}$$

where: L_{max} is the maximum level during the operating cycle of the equipment, and Δ is the difference between L_{max} and the L_{eq} over the duty cycle. The emission level is presented in this manner because L_{max} is much more widely reported than the literature (virtually all standard equipment noise measurement procedures obtain L_{max}), and Δ varies much less than L_{max} for a given type of equipment. Both L_{max} and Δ , as used in the construction noise model, are derived from the field data presented in Volume 5 of the construction noise handbook.[5]

If this piece of equipment has a production rate associated with it (an entry of "yes" in column 5 of Table A-1), and its production is being coordinated with that of another piece of equipment with a production rate, the value for the hours worked during the day for the piece of equipment being coordinated, T_2, is computed by:

$$T_2 = T_1(C_1/C_2)\ (t_2/t_1) \tag{A-3}$$

where: C_1 and C_2 are the capacities of the two pieces of equipment;
t_1 and t_2 are the cycle times for one operation for each source, and
T_1 represents the hours worked during the 8-hour day for the first source.

A.2.2 Line Sources

The program divides line sources into two categories: nonhaul and haul. Because it treats them separately, they will be described separately here even though their conceptual treatment is fairly similar. Two main differences deal with production rate coordination, and the allowable number of vehicles, on the line (only one vehicle for nonhaul lines, while more than one for haul lines).

The Leq computation for both types of line sources is analogous to that for the FHWA Highway Traffic Noise Prediction Model.[6] The Leq of a point source (or series of point sources) moving along a line is determined by computing the Leq contributions from the source at a series of points along the line and then integrating those values over the time period under consideration. Figure A-2 shows the geometric considerations.

A.2.2.1 Nonhaul Line Sources

Following the general formulation in the FHWA Highway Traffic Noise Model, Leq(8h) for an unshielded nonhaul line source is given by:

$$\text{Leq(8h)} = (L_0)_E + 10\ \text{Log}(T/8) + 10\ \text{Log}(d_0\pi/\ell) + 10\ \text{Log}(d_0/d)^{1+(n/3)} + 10\ \text{Log}\ G(n,\phi_1\phi_2) \tag{A-4}$$

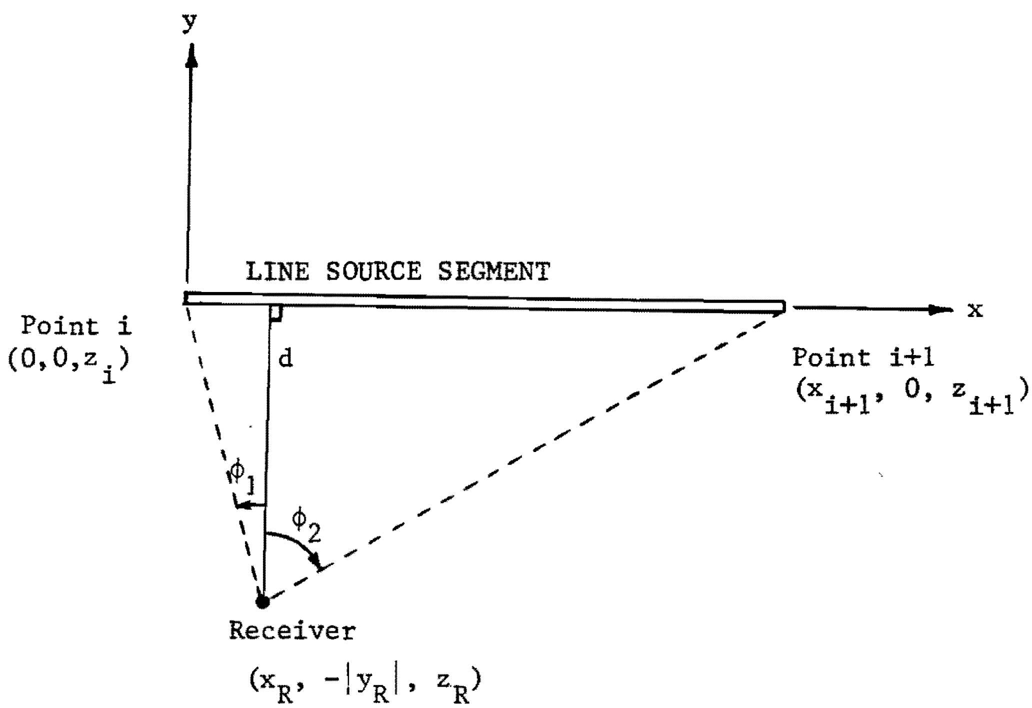
where: $(L_0)_E$ is the energy averaged emission level at a reference distance d_0;
T is the hours that the piece of equipment is in operation in the 8-hour day;

ℓ is the length of the line;

d is the perpendicular (normal) distance from the receiver to the line (or extension of the line);

n is the excess attenuation due to ground cover in dB/DD; and

$G(n,\phi_1,\phi_2)$ is a function representing the finite line segment adjustment, which is a function of the excess ground attenuation rate and the angles



d = perpendicular distance from the receiver to the line source segment.

ϕ_1 = angle at the receiver from the perpendicular to the line to point i.

ϕ_2 = angle at the receiver from the perpendicular to the line to point i+1.

(This is a view of the x-y plane)

Figure A-2. Geometry and Coordinates of Line Source Segment from the normal line between the receiver and the line segment to the left and right endpoints of the line segment, ϕ_1, and ϕ_2 respectively.*

The energy-averaged emission level, $(L_0)_E$, is given by:

$$(L_0)_E = L_{max} - \Delta \tag{A-5}$$

where L_{max} is the maximum level during the operating cycle of the equipment, and Δ is the difference between L_{max} and Leq over the duty cycle of the equipment.

Note that the fourth term in the equation, 10 Log $(d_0\pi/\ell)$, is analogous to the traffic flow adjustment in the FHWA traffic noise model, 10 Log $(Nd_0\pi/ST)$. In the construction noise model, only one vehicle is assumed to be operating along the line. However, it may make more than one pass-by on the line during the time period, T. The number of pass-bys, N, is a function of the speed of the vehicle (S), the length of the line (ℓ), and the time period (T). The exact relation is:

$$N = T(S/\ell) \tag{A-6}$$

Rearranging terms:

$$N/ST = 1/\ell \tag{A-7}$$

which may be substituted directly into the traffic flow adjustment for the FHWA traffic noise model to give the fourth term of the Leq equation for nonhaul construction line sources. Conceptually, Leq becomes a function of only the length of the line because, as the speed of the vehicle increases, the number of pass-bys proportionately increases, with the two increases cancelling out each other.

A curved line section may be analyzed by approximating it as a series of connecting straight line segments. In that case, Equation A-4 is applied to each section where ℓ is the length of each section. The resulting Leq(8h)'s for each section are then combined at the end of the calculation to yield the total Leq(8h) for the line source.

---

* $G(n,\phi_1,\phi_2)$ is analogous to $\psi_\alpha(\phi_1,\phi_2)$ in the FHWA Highway Traffic Noise Prediction Model.[6] It is defined as:

$$G(n, \phi_1, \phi_2) = 1/\pi \int_{\tan\phi_1}^{\tan\phi_2} \frac{d\xi}{\left(1+\xi^2\right)^{1+n}} \tag{1}$$

where ϕ_1 and ϕ_2 are the angles to the end points of the line segment, as shown in Figure A-2. Equation (1) was first derived in Reference 6 for an infinite length road, and closed-form solutions presented for arbitrary n. The generalization to a finite road was presented in the FHWA Highway Traffic Noise

(Footnote continued from previous page): Prediction Model, together with two tables of numerical values for one value of n and a range of road lengths, in terms of the angles ϕ_1, ϕ_2. For n = 0, Equation (1) reduces to the factor $(\phi_2 - \phi_1)/\pi$ appearing in the commonly used finite road adjustment 10 $\log_{10}(\Delta\phi_1\pi)$,[8] where $\Delta\phi = \phi_2 - \phi_1$.

A closed-form representation of Equation (1) can be derived. The integral may be written in two parts:

$$G = 1/\pi \left[\int_0^{\tan \phi_2} \frac{d\xi}{(1+\xi^2)^{1+n}} - \int_0^{\tan \phi_1} \frac{d\xi}{(1+\xi^2)^{1+n}} \right] \tag{2}$$

Each integral has form similar to the incomplete beta function:[9]

$$B_x(a, b) = \int_0^x t^{a-1} (1-t)^{b-1} \, dt \tag{3}$$

Letting $t = \xi^2 / (1 + \xi^2)$, (4)

$$B_x(a, b) = 2 \int_0^{\sqrt{x/(1-x)}} \xi^{2a-1} \frac{d\xi}{(1+\xi^2)^{a+b}}$$

The integral in Equation (4) matches those in Equation (2) providing that

$$x = \sin^2 \phi$$
$$a = 1/2 \tag{5}$$
$$b = n + 1/2$$

Thus,

$$G(n, \phi_1, \phi_2) = (1/2\pi) \left[B_{\sin^2 \phi_2}(1/2, n + 1/2) - B_{\sin^2 \phi_1}(1/2, n + 1/2) \right] \tag{6}$$

The incomplete beta function may be evaluated from the following series:

$$B_x(a, b) = \frac{x^a (1-x)^b}{a} \left\{ 1 + \sum_{j=0}^{\infty} \left[\prod_{i=0}^{j} \left(\frac{a+b+i}{a+1+i} \right) \right] x^{j+1} \right\} \tag{7}$$

Equation (7) converges for x <1, and poses no computational difficulties. To include the point x = 1, the following inversion relation may be used:

$$B_x(a, b) = B(a, b) - B_{1-x}(b, a) \tag{8}$$

where B(a, b) is the beta function, and may be written in terms of the gamma function:[9]

$$B(a, b) = \frac{\Gamma(a)\,\Gamma(b)}{\Gamma(a, b)} \tag{9}$$

To minimize computation time, Equation (7) is used only for x<0.5 (the series converges slowly near 1) and Equation (8) is used to obtain values in the range 0.5<x<1.0. (End of footnote)

If this nonhaul line source has a production rate associated with it (an answer of "yes" in column 5 of Table A-1), and its production is being coordinated with that of another piece of equipment with a production rate, the value for the hours worked during the day for the nonhaul line source, T_2, is computed by:

$$T_2 = T_1 (C_1/C_2) (t_2/t_1) \qquad \text{(A-8)}$$

where: C_1 and C_2 are the capacities of the two pieces of equipment;

t_1 and t_2 are the operation cycle times for each source; and

T_1 represents the hours worked during the 8-hour day for the first source.

A.2.2.2 Haul Line Sources

The expression for the 8-hour Leq for a haul line source is identical to that for the FHWA Highway Traffic Noise Prediction Model, and is given by:

$$Leq(8h) = (L_0)_E + 10 \text{ Log}\left(\frac{Nd_0\pi}{ST}\right) + 10 \text{ Log}(d_0/d)^{1+(n/3)} + 10 \text{ Log } G(n,\phi_1,\phi_2) \qquad \text{(A-9)}$$

where: $(L_0)_E$ is the energy-average emission level at a reference distance d_0;

N is the number of vehicles per hour operating along the line, averaged over the 8-hour day;

S is the average speed of the vehicles along the line under consideration;

d is the normal distance from the receiver to the line (or extension of the line);

n is the excess ground attenuation due to ground cover in dB/DD; and

$G(n, \phi_1, \phi_2)$ is a function representing the finite line segment adjustment, which is a function of the excess ground attenuation rate and the angles from the normal line between the receiver and the line segments to the left and right endpoints of the line segments.**

The energy-averaged emission level, $(L_0)_E$, is a function of the speed of the equipment, and is computed separately for deceleration and acceleration/cruise:[10]

Deceleration: $$(L_0)_E = L_0 + B\cdot\text{Log}(S/S_{ref}) \qquad \text{(A-10a)}$$

Acceleration/cruise: $$(L_0)_E = L_0 + B\cdot\text{Log}\left[\frac{\max(S,S_{crit})}{S_{ref}}\right] \qquad \text{(A-10b)}$$

** See footnote in Section A.2.2.1

where: L_0 is the emission level of the vehicle at some reference speed, S_{ref};

S is the average speed of the equipment;

S_{crit} is the "critical" speed, below which the emission level remains constant during acceleration.

In the program, the critical speed (S_{crit}) is equal to the reference speed for the haul line sources. Thus, for speeds below the critical speed, the energy-averaged emission level will be equal to the reference emission level, L_0.

Note that in Equation A-9, there is no term for the hours worked, T, during the 8-hour day. Hours worked is implicitly considered in the value given for N, in that the number of vehicles per hour is averaged over the 8-hour day. For example, if 100 vehicles per hour operated on the haul road for four hours, the correct value for N would be 50 vehicles per hour (100 vehicles per hour times 4 hours, averaged over the 8-hour day).

If the haul equipment has a production rate associated with it (an entry of "yes" in column 5 of Table A-1), and its production is being coordinated with that of a previously specified piece of equipment with a production rate, the value for the number of vehicles per hour, N, will be computed by:

$$N = (T_1/8)(C_1/C_2)(1/t_1) \qquad \text{(A-11)}$$

where: C_1 and C_2 are the capacities of the two pieces of equipment;

t_1 is the operation cycle time of the source that is being coordinated; with the haul source; and

T_1 represents the hours worked during the 8-hour day for the first source.

A.2.3 Area Sources

Areas are described to the model in terms of a series of points defining a centerline of the area, plus the width of the area at each point, as illustrated in Figure A-3. The points and widths thus define a series of interconnected segments. Each area segment is separated analyzed and the results combined to get the total Leq from the area source. In practice, areas tend to be quite regularly shaped, following the geometry of lanes under construction, so that this representation is very good for highway construction.

No simple closed relationship exists for noise from an arbitrary area source with excess attenuation; some numerical integration is required. The approach taken here is to divide an area into strips, each strip sufficiently narrow relative to receiver distance that it may be modeled as a line. Each area segment is divided into strips parallel to the centerline of that segment. One strip is centered on the centerline, and the others are symmetrically defined on either side.

The number of strips taken is based on the ratio between the strip width and the distance to the receiver, with an upper limit of 5 strips on either side of the centerline. N_{st}, the number of strips, is given by:

$$N_{st} = 10 \left[\frac{w/2}{d_{min} - w/2}\right] \qquad \text{(A-12)}$$

where: w is the width of the area, and d_{min} is the shortest of the normal distances from all receivers to the centerline.

N_{st} is truncated (rounded down) to a whole number, and that value or 5, whichever is less, is used for the number of strips on each side of the centerline.

The ratio is adjusted so that each strip can be approximated by a line with a worst-case error of less than 0.2 dB; this is essentially negligible. The 8-hour Leq for each strip is then computed by:

$$Leq(8h)_i = (L_0)_E + 10\ Log(T/8) + 10\ Log\left(\frac{N\pi d_0}{\ell_S}\right)\left(\frac{A_i}{A_T}\right) + 10Log(d_0/d_i)^{1+(n/3)} + 10\ Log\ G(n,\phi_1,\phi_2) \qquad \text{(A-13)}$$

where: $(L_0)_E$ is the energy-averaged emission level for the operational cycle of the equipment, measured at a reference distance d_0;

T is the number of hours that the equipment is working in its operational cycle during the 8-hour day;

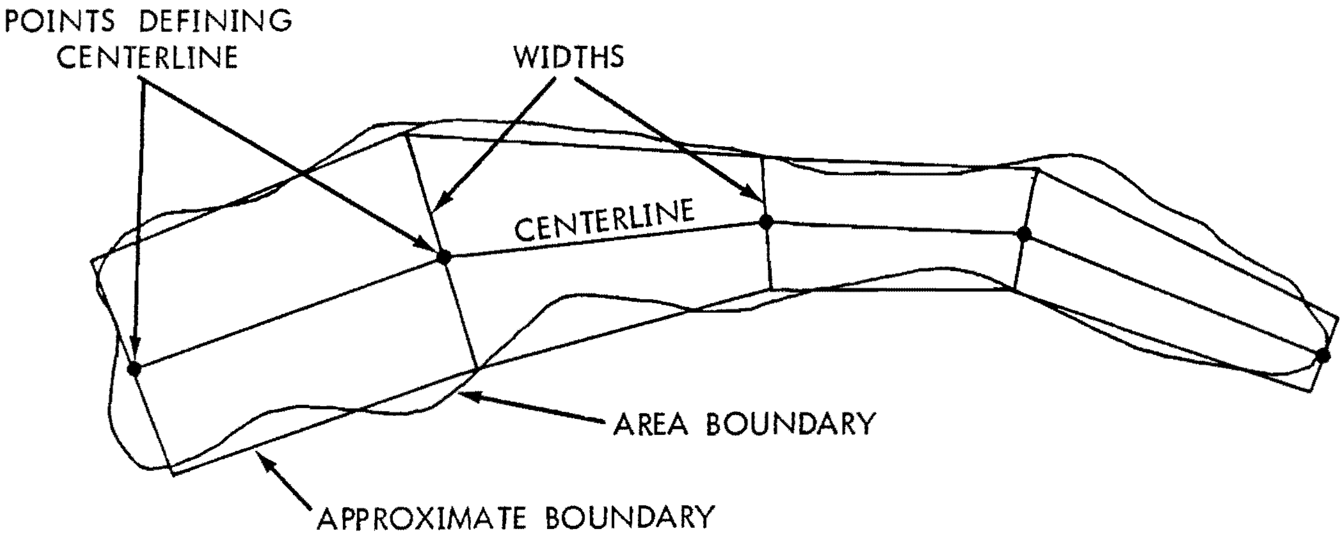


Figure A-3. Representation of Area by Centerline and Widths

N is the number of pieces of equipment of this type operating in the area;

ℓ_S is the sum of the length of all strips in the jth area segment;

d_i is the normal distance from the receiver to the ith strip;

n is the excess attenuation rate in dB/DD; and

$G(n,\phi_1,\phi_2)$ is a function representing the finite line segment adjustment, which is a function of the excess ground attenuation rate and the angles from the normal line from the receiver to the line segment to the left and right endpoints of the line segment;

A_j is the area of the jth area segment; and

A_T is the total area of all area segments.

The energy-averaged emission level, $(L_O)_E$, is defined as the maximum level, L_{max}, minus Δ, an adjustment to the maximum level to get the Leq over one cycle of the equipment's operation. The Leq(8h) for the entire area segment is computed by combining the results for all strips, each computed by Equation A-13.

If this equipment has a production rate associated with it (an entry of "yes" in column 5 of Table A-1), and its production is being coordinated with that of a previously given piece of equipment with a production rate, the value for hours worked during the day for the area source, T_2, is computed by:

$$T_2 = T_1(C_1/C_2)(t_2/t_1) \qquad \text{(A-14)}$$

where: C_1 and C_2 are the capacities for the two equipment types;

t_1 and t_2 are operation cycle times for each equipment type; and

T_1 represents the hours worked during the 8-hour day for the first source.

A.2.4 Noise Barrier Attenuation

Shielding by barriers is handled by Maekawa's formulation for screens.[10] Barriers are specified by providing a series of coordinates defining the top edge as a series of straight lines. Several barriers may be specified. The model checks each source/receiver pair for shielding by each barrier. Double shielding is not considered; once a barrier is found to shield a given path, subsequent barriers are neglected for that path. When there is barrier shielding, ground attenuation is initially set equal to zero. However, in the event that this results in an amplification (as might happen for a low barrier), the barrier section is neglected and ground attenuation restored (which avoids a physically unrealistic case).

For point sources, Maekawa's methodology is applied directly. Each source type has a nominal or effective frequency assigned to it which is used for computing the Fresnel number. This procedure is a generalization of the use of 500 Hz to represent highway noise.[8] The nominal frequency for each type of equipment is the peak of the A-weighted spectrum. This reasonably approximates the shielding which would be obtained if an exact calculation were performed over the complete A-weighted spectrum.

Barrier shielding for line sources is computed by the method of Kurze and Anderson,[12] wherein point source shielding is integrated along the line. A numerical integration scheme is used in the program. An initial mesh consisting of the line end and center points is used. The mesh is successively doubled until the calculated shielding converges within about 0.4 dB. This shielding calculation is carried out for each section.

Barrier shielding for area sources is carried out by applying the line source methodology to each strip.

APPENDIX B: PROGRAMMER'S MANUAL AND PROGRAM LISTING

B.1 Conventions and Annotation

The programs are written in FORTRAN IV. Standard default conventions apply to variable types. All real variables are single precision, R*4. All fixed-point variables are 1*2. Two arrays in subroutine DECODE are declared LOGICAL*1 to simplify string manipulations. No proprietary routines, machine-dependent instructions, etc., are utilized. The program is fully transportable to other machines provided the data file specification in HINPUT and HICNOM is changed to conform with available hardware.

Extensive use is made of subroutines in order to provide reasonably well-structured code. Variable names are reasonably consistent between subroutines, although in many cases the mnemonics are similar but not identical. Executable statement labels begin with 1 in each program; format labels begin at 100. Variable names and formats are identical in HINPUT and HICNOM. This was done so as to facilitate possible merging of the two programs. Executable statement labels were not made non-conflicting between the two; this is to discourage casual merging without a thorough review of the combined program. COMMON blocks are consistent throughout both programs.

All routines are heavily commented so as to facilitate review of code. A complete variable dictionary is included in each program.

B.2 HINPUT

Figure B-1 is A SUBROUTINE HIERARCHY CHART FOR HINPUT, which is described in Section 2.2. The description in Section 2.2 should be read together with the source listing if a detailed understanding of the code is desired.

B.3. SUBROUTINES TO HINPUT

The following subsections describe each subroutine to HINPUT, presented in the order they appear in the hierarchy charts.

B.3.1 DECODE

This subroutine CHECKS AN INPUT NAME SRCNAM AGAINST A DATA LIST OF ALLOWABLE NAMES. The corresponding type identification number is placed in INFO(2). The model number is requested and placed in INFO(1). IGEOM is set to indicate whether it is a point, line, or area source. The input name SRCNAM is appended with a sequential number.

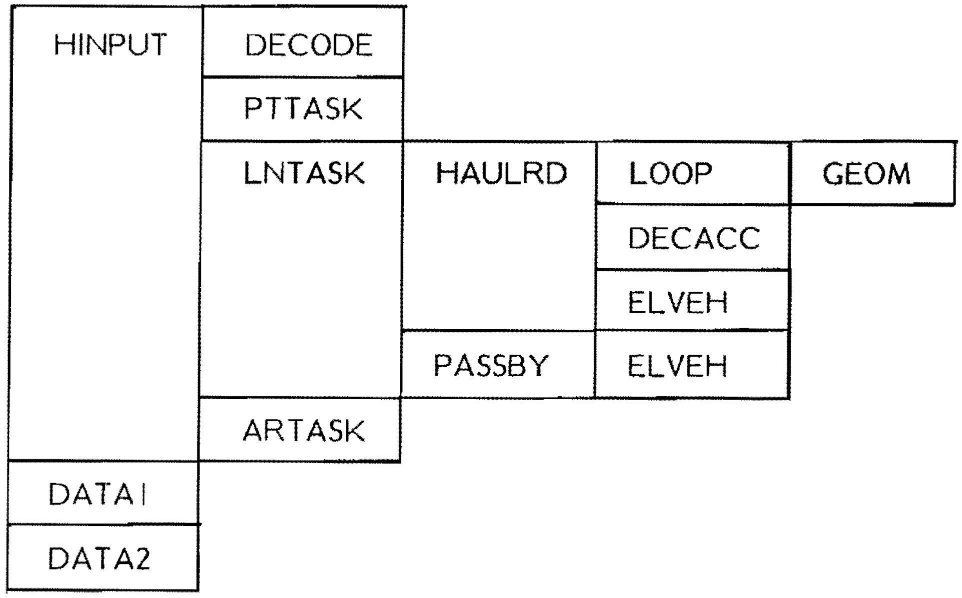


Figure B-1. Subroutine Hierarchy Chart, HINPUT

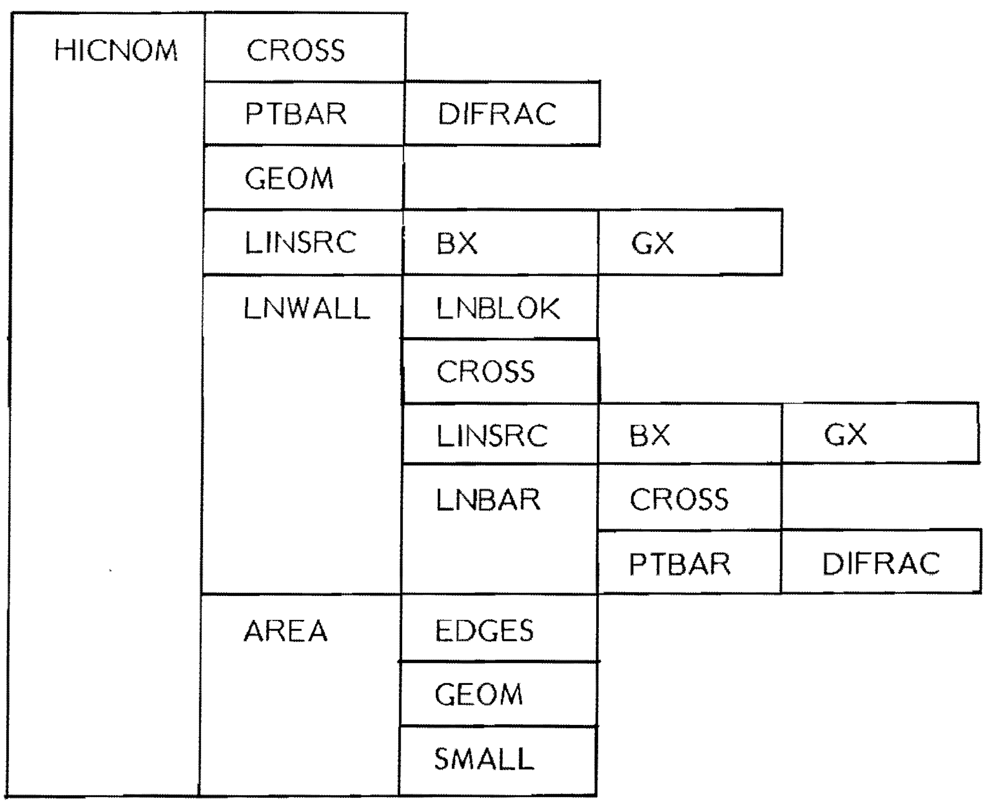


Figure B-2. Subroutine Hierarchy Chart, HICNOM

B.3.2 PTTASK

This routine RETURNS THE ADJUSTED LEQ EMISSION LEVEL AND EFFECTIVE SOURCE HEIGHT (INPUT HEIGHT PLUS ACOUSTIC HEIGHT) FOR POINT SOURCES. These data are obtained from data files or input for newly created sources. The production rate per full workday is computed for appropriate pieces of equipment. Hours worked per day is then used to compute daily production. This is saved as PROD. If a "production coordination" case has been specified, equivalent hours worked per day are computed by matching production to the value of PROD left from the last piece of equipment. The matching procedure and value of PROD here are shared in common with LNTASK and ARTASK.

B.3.3 LNTASK

This routine HANDLES LINE SOURCES. It is divided into two parts. THE FIRST PART HANDLES NONHAUL EQUIPMENT, and is logically similar to PTTASK. One piece of equipment is considered, moving at a constant speed, and production is based on the number of hours worked.

THE SECOND PART OF LNTASK HANDLES HAUL OPERATIONS. Production is related to number of vehicles per hour. Speeds can vary from segment to segment. If a loop is to be generated by the program, this is done by a call to HAULRD which returns an increased value of NLNPTS and an expanded array XLNPTS. Adding a loop can add 8 or more points to the array. To ensure that the limit of 20 points is not exceeded, the input line array should not exceed 6 points if a loop is to be generated.

If a loop is not to be created, the acceleration/deceleration profiles are handled by a call to PASSBY.

B.3.4 HAULRD

This routine is CALLED WHEN A TURN-AROUND LOOP IS TO BE GENERATED. The loop points are added to RDPTS by subroutine LOOP, making the last input point the loading/unloading point. Speed profiles are generated by DECACC, which may add additional points so as to complete the acceleration/deceleration profiles if they extend beyond the loop points. Emission levels are obtained from the function ELVEH, which accounts for operating mode and speed.

B.3.5 LOOP

This routine GENERATES TURN-AROUND LOOPS AS SHOWN IN FIGURE 8. Two basic geometries are stored: a half loop (types 1 through 4) and a full circle (types 5 and 6). The loop data are stored in the orientation shown in Figure 8. Subroutine GEOM is called to determine the angle of the last input road segment. The loop data are transformed through this angle, so as to be aligned with the last segment. They are multiplied by the input radius and then combined with RDPTS. Various details of adding the points, setting direction, etc., are described by comments in the listing.

B.3.6 GEOM

This routine, used by both HINPUT and HICNOM, PERFORMS A COORDINATE TRANSFORMATION OF A LINE SEGMENT DEFINED BY X1, X2. Quantities returned are the cosine and sine of the transformation rotation angle, the transformed coordinates of one receiver position, d, ϕ_1, and ϕ_2 as defined in Figure 3, and the length of the line segment. A switch variable ISKIP permits the use of only parts of this routine.

B.3.7 DECACC

This routine COMPUTES AVERAGE SPEEDS ON A TURN-AROUND LOOP. Kinematics are based on constant deceleration and acceleration rates stored in the two-element array ACCRAT. Values of 0.1 g are in data statements. The kinematic calculations begin at the stopping point and continues until the speed on a segment matches the input speed on that segment. If necessary, the segments outside the loop are split into separate acceleration and deceleration segments. The expanded point array defining the lines and the computed average speeds are returned.

B.3.8 ELVEH

This function subroutine COMPUTES THE EMISSION LEVEL OF HAUL EQUIPMENT FROM EQUATION (A-10) in Section A.2.2.2.

B.3.9 PASSBY

This routine PREPARES HAUL EQUIPMENT SPEEDS AND EMISSION LEVELS WHEN THE HAUL ROAD HAS BEEN DIRECTLY DEFINED BY THE USER. i.e., a loop is not generated by the program. Where kinematics are to be computed, the calculation is essentially the same as in DECACC.

B.3.10 ARTASK

This routine COMPUTES THE ADJUSTED EMISSION INTENSITY IN EACH SECTION OF AN AREA. The logic is essentially the same as in PTTASK and the nonhaul section of LNTASK. More than one piece of equipment can be specified.

B.3.11 DATA1

This block data routine CONTAINS VARIOUS DATA ITEMS DESCRIBED IN SECTION C.1 including unit declarations and reference distance.

B.3.12 DATA2

This block data routine CONTAINS ALL EQUIPMENT DATA. The program is commented and tabulated so as to provide an easily read table of values. See Section C.3 for a detailed description.

B.4 HICNOM

Figure B-2 is a subroutine hierarchy chart for HICNOM, which is described in Section 2.2. The description in Section 2.2 should be read together with the source listing if a complete understanding of the code is desired.

B.5 SUBROUTINES TO HICNOM

B.5.1 CROSS

This subroutine DETERMINES IF A LINE BETWEEN A SOURCE AND RECEIVER INTERSECTS WITH A BARRIER SEGMENT. If so, the crossing point and the barrier height at that point are computed.

B.5.2 PTBAR

Given the source and receiver locations and the barrier height at the shielding point, this routine COMPUTES PATH LENGTH DIFFERENCE, then OBTAINS BARRIER SHIELDING from subroutine function DIFRAC.

B.5.3 DIFRAC

This function routine COMPUTES FRESNEL NUMBER from path length difference and frequency, then OBTAINS BARRIER SHIELDING from Maekawa's curve. For Fresnel number between -0.3 and 1.0, a table look-up/interpolation scheme is used. Above 1.0, a logarithmic approximation is used.

B.5.4 LINSRC

This routine COMPUTES LEQ from a single straight line segment, using Equation A-4 or A-9. The program contains an alternate expression for the case of a receiver directly in line with the line source, and contains some error checking of input geometry.

B.5.5 BX

This function routine COMPUTES THE INCOMPLETE BETA FUNCTION from a power series using the methodology described in Equation (7) in the footnote in Section A.2.2.1. A convergence criterion of one part in 10^4 is specified as a data item.

B.5.6 GX

This function subroutine COMPUTES THE GAMMA FUNCTION for real arguments, using a polynomial approximation and a recursion, as described in the footnote in Section A.2.2.1.

B.5.7 LNWALL

This subroutine COMPUTES THE CONTRIBUTION OF A LINE SOURCE IN THE PRESENCE OF BARRIERS. The input parameters are one line source section, one receiver location, and the set of barrier coordinates. Subroutine LNBLOK is called to test whether a barrier shields the source/receiver combination. If so, the line segment is divided into three parts: a center shielded section and two unshielded ends. Any of these may have zero length. LINSRC is used to compute noise from the unshielded sections and LNBAR is used to compute noise from the shielded part. Logic is included to properly handle multiple-segment barriers. If no shielding is found, a very large number is returned to HICNOM. The HICNOM logic which takes the smaller of the shielded versus unshielded calculation then selects the unshielded result from LINSRC.

B.5.8 LNBLOK

This subroutine TESTS WHETHER ANY OF THE INPUT BARRIERS SHIELD A GIVEN LINE SOURCE SEGMENT AND RECEIVER. If so, the line segment is divided into three segments as described in Section B.4.7. Each segment is defined by a pair of angles ϕ_1, ϕ_2 as shown in Figure 3. Setting the angles equal to each other indicates no segment. The program contains logic to ensure that the sense of the angles corresponds to the convention following the order of line points.

B.5.9 LNBAR

This routine COMPUTES THE BARRIER SHIELDING OF A SHIELDED LINE SEGMENT. A numerical integrating process is used, utilizing point source shielding computed by PTBAR and DIFRAC. This method is described in detail in Section A.2.4.

B.5.10 AREA

This subroutine DIVIDES AN AREA INTO STRIPS, as described in Section A.2.3. The widths are positions such that they bisect the normals to the centerline segments on either side. Subroutine EDGES is used to determine the coordinates of the resultant corners. Each area segment and all receivers are transformed into coordinates relative to the segment centerline. Each segment is then divided into strips consisting of the centerline plus 0 to 5 strips each to the right and left of the centerline. The average source density on the strips is obtained by dividing total strength in the segment by the length of all strips in the segment.

B.5.11 EDGES

This subroutine is USED BY AREA TO FIND THE COORDINATES OF THE EDGE POINTS defined by the width lines, as described in Section B.5.10.

B.5.12 SMALL

This routine FINDS THE SMALLEST VALUE IN AN ARRAY.

B.6 COMMON Blocks

The following COMMON blocks and their contents are used in the programs:

- /CONSTS/ PI, TWOPI,PIOV2
- /EDGE/ EDGEL (3, 10), EDGER (3, 10)
- /EQUIPT/ EQUIP (5, 10, 30), IFREQ (10,10)
- /KINEM/ ACCRAT (2)
- /NMODLS/ NMODS (30), NVTYP
- /TSKARG/ INFO (2), HOURS, PRODUC
- /TYPES/ IPROD (30), IHAUL (10), IVEH (5, 5)
- /UNITS/ DO, DO2
- /VEHLEV/ HAULEQ (6, 10)
- /WKDAY/ DAYHRS

The variable names vary somewhat between subroutines. In particular, EQUIP in block data routine DATA2 appears as a large number of smaller arrays, each named for the corresponding equipment.

Figure B-3 is a chart showing the location of the COMMON blocks in the programs. An open circle indicates the COMMON is in the program. A solid circle indicates that some or all of the contents of the block are defined by data statements within that routine. Note that data statements for /UNITS/ are in both HINPUT and DATA1. If the programs are merged, one set of these data statements would have to be deleted.

Program	COMMON Block									
	CONSTS	EDGE	EQUIPT	KINEM	NMODLS	TSKARG	TYPES	UNITS	VEHLEV	WKDAY
HINPUT						O				
HICNOM								●		
DECODE					O					
PTTASK			O		O	O	O			O
LNTASK			O		O	O	O	O	O	O
HAULRD										
LOOP										
GEOM	●									
DECACC				O				O		
ELVEH								O	O	
PASSBY				O				O		
ARTASK			O		O	O	O			O
DATA1				●				●		●
DATA2			●		●		●		●	
CROSS										
PTBAR										
DIFRAC										
LINSRC	O							O		
BX										
GX										
LNWALL										
LNBLOK	O									
LNBAR										
AREA		O								
EDGES	O	O								
SMALL										

Figure B-3. COMMON Block Location

Program maintenance consists of modifications to the data statements as additional data become available and/or to change units and constants. Data are contained in two block data programs, DATA1 and DATA2. Distance units for barrier calculations are set by a data item in DIFRAC. Additional equipment types may be defined, with names incorporated in DECODE.

C.1 BLOCK DATA DATA1

This routine contains several constants which implicitly set units. They are:

- DO and DO2, the sound level reference distance and distance squared. Current values are 50 and 2500, representing a 50-foot reference distance. Setting these to a reference distance, inputting coordinates in the same units, and providing appropriate levels in DATA2 (described in Section C.3) automatically set the units for all non-barrier calculations.

- GRAV is the value of the acceleration of gravity in the units being used. A value of 32.2 has been used, for ft/sec^2. GRAV converts the values of ACCRAT from fractions of a g to physical units. If ACCRAT is left as fraction of a g(0.1 in the program presented here), GRAV should be changed to the appropriate value for other units. Alternatively, GRAV may be set equal to 1.0 and ACCRAT expressed in physical units.

- VELCON is a conversion factor from speed in units convenient for input to consistent physical units. A value of 1.47 has been used, converting speed in mph to feet per second. If metric units are adopted, km/hr for input speed and meters for distance, VELCON should be changed to 0.278.

- DAYHRS is the number of hours in a full work day. The program computes L_{eq} based on this time. A value of 8 hours is in the program.

C.2 SUBROUTINE DIFRAC

The Fresnel number is given by $2\delta f/c$, where c is the speed of sound. The program has a data item VOV2, representing c/2, which sets the units. A value of 580 has been used, setting the units as feet when frequency IFREQ is in Hz. To change units, replace VOV2 with c/2 in the appropriate units. For meters, this is 176.8.

C.3 BLOCK DATA DATA2

This data routine contains the equipment data base. Definitions may be found in the variable dictionaries in PTTASK, LNTASK, and ARTASK. The data statements are arranged and commented so as to form tables, with the main data table corresponding to the values in Table 2. The annotation in columns 73 to 80 identifies the equipment. A * next to the annotation indicates the level was obtained from a review of the literature, Reference 13.

Modification of the basic data bases, HAULEQ and EQUIP (split into smaller individually named arrays in this program) is straightforward. Additional lines for new models may be added, up to a total of 10 for each type. The tabular format should be retained for ease in reading. When adding new lines, the zeros and the value of NMODS on the last continuation line of each set should be appropriately adjusted. New types may be defined, making room by reducing the size of the dummy arrays EMPTY1, EMPTY2, and EMPTY3. Corresponding new names must be added to DECODE, described below. Default geometries are point sources for the first 15 data blocks, line for the next 10, and area for the last 5, where the block number corresponds to the third index of EQUIPT. Alternate geometries may be specified in DECODE.

Haul equipment has its type numbers in sequence with nonhaul, but the data are contained in the array HAULEQ. The array IVEH provides a mapping from EQUIP type and model numbers to HAULEQ; see the listing of LNTASK for the specific relationship. Up to 5 models are permitted for each type. Equipment types which are haul are listed in array IHAUL. This is a grocery list arrangement, with type numbers listed in any order. Array IPROD is a similar list which specifies which equipment have production rates associated with them.

The spectrum frequency data required by the barrier calculation is contained in array IFREQ, a two-dimensional array which serves as an additional column to EQUIP. Haul and nonhaul data are in the array. The separate array--rather than another column on EQUIP--is used to permit these data to be in integer form. This will facilitate any future replacement of DIFRAC with a routine using calculations for particular spectra. IFREQ may then be treated as an index with no other recoding.

C.4 SUBROUTINE DECODE

This routine contains the list of equipment type names. Adding additional names is simply a matter of replacing the 'XXXX' blocks in the data statement for array ALNAMS. Three 4-character blocks are premitted. In addition to checking the name, an ordinal index from array NTH is appended. Its position is determined by data in arrays IPOS and NPOS. They are set us so as to place the index in the first position of the third or fourth 4-character block, as indicated in array IPOS. If it is desired to adjust the number of blanks (as has been done for the existing names), values of IPOS and NPOS should be changed. NPOS indicates in which four character block that the index is placed, and IPOS is the position.

As noted above, model types 1 to 15 are nominally point sources, 16 to 25 are line, and 26 to 30 are area. The array NGEOM is a grocery-list of models which may have alternate geometries. By adding a model number to the NGEOM data statement, the program will request the geometry from the user.

APPENDIX D

BLANK WORKSHEETS

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME________
PAGE____ OF____
DATE________
PROJECT________

FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)

NUMBER OF RECEIVERS (MAXIMUM OF 10)

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

NOTES:

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME__________
PAGE____OF____
DATE__________
PROJECT________

FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				
			1				

NOTES:
(1) TO DEFINE SOURCE NOT LISTED ON FORM 7, ENTER: USER DEFINED
(2) 0 INDICATES NEW MODEL; NEGATIVE VALUE INDICATES NEW MODEL PREVIOUSLY CREATED IN THIS RUN
(3) IN 8 HOUR DAY; NEGATIVE VALUE MEANS MATCH PRODUCTION RATE WITH PRECEEDING SOURCE WITH PRODUCTION RATE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME ________
PAGE ____ OF ____
DATE ________
PROJECT ________

FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

VEHICLES PER HOUR	RETURN LOOP	
	TYPE(5)	RADIUS(6)

(5) SEE FORM 7; IF 0, ENTER POINT NUMBERS (SEE TO THE RIGHT)
(6) ENTER ANY VALUE IF TYPE IS 6 OR 7.

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)

(7) ENTER 0 IF NON-STOP
(8) ENTER 0 TO HAVE PROGRAM COMPUTE AVERAGE SPEED (ONLY IF (7) IS NON-ZERO); ENTER ANY VALUE IF (7) IS 0.

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	REFERENCE SPEED	SLOPE	CRITICAL SPEED	CAPACITY	ACOUSTIC HEIGHT	FREQUENCY

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME______
PAGE____ OF____
DATE______
PROJECT______

FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
			2		

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
			1
			2
			3
			4
			5
			6
			7
			8
			9
			10
			11
			12
			13
			14
			15
			16
			17
			18
			19
			20

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM NONHAUL LINE SOURCE

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	SPEED	ACOUSTIC HEIGHT	FREQUENCY

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME ______
PAGE ___ OF ___
DATE ______
PROJECT ______

FORM 5: AREA SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
			3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
				1
				2
				3
				4
				5
				6
				7
				8
				9
				10
				11
				12
				13
				14
				15
				16
				17
				18
				19
				20

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	DELTA	CAPACITY	CYCLE TIME	ACOUSTIC HEIGHT	FREQUENCY

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME________
PAGE____ OF____
DATE________
PROJECT________

FORM 6: BARRIER DATA

NUMBER OF BARRIERS

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE

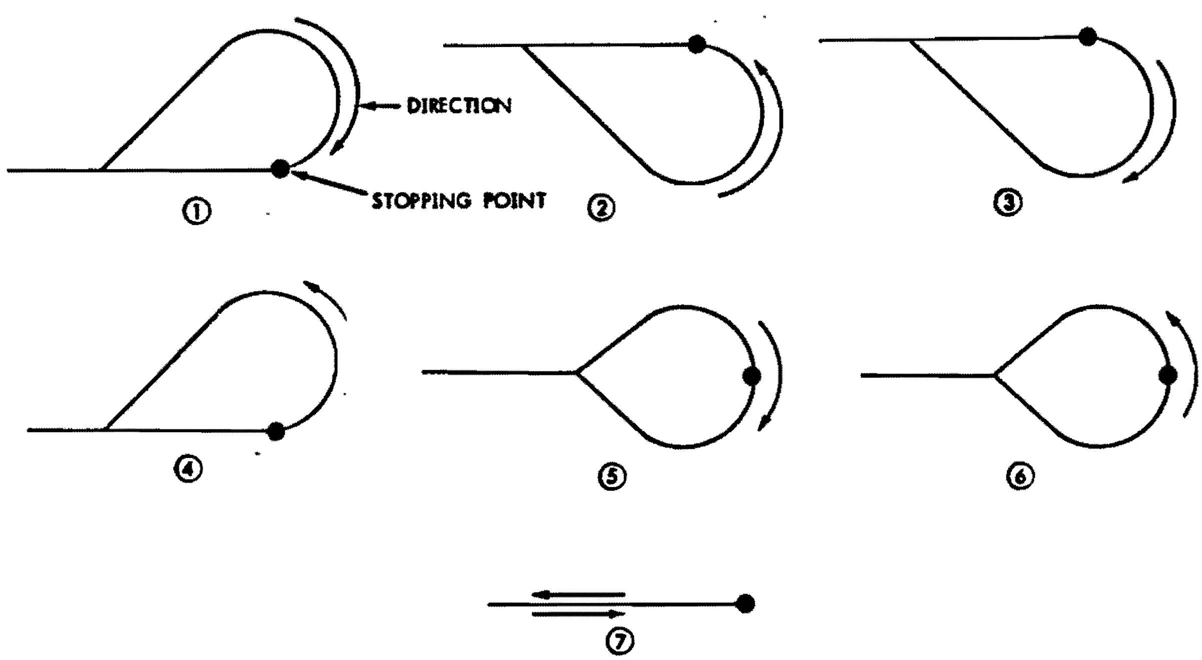
HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME__________
PAGE____ OF____
DATE__________
PROJECT________

FORM 7: DATA INPUT GUIDE

SOURCE TYPE	NO. OF PROG. MODELS	ALLOWABLE GEOMETRY TYPES				IS PROD. RATE COORD. ALLOWED?
		POINT	HAUL	NONHAUL	AREA	
BACKHOE	3	X		X	X	YES
BREAKER	3	X		X	X	NO
BULLDOZER	4	X		X	X	NO
COMPACTOR	3				X	
COMPRESSOR	4	X				
CONCRETE	5	X				
CRANE	4	X				YES
GENERATOR	2	X				
GRADER	1	X		X	X	
LOADER	5	X		X	X	YES
MISCELLAN	4	X				
PAVING	3	X		X	X	
PILE DRIVER	2	X				
PUMP	2					
SCRAPER	4	X				YES
TRUCKS	4	X				YES
USER DEFINED	0	X		X	X	YES

RETURN LOOP TYPES FOR HAUL LINE SOURCES:



APPENDIX E

Field Data Sheets for Example Problems 3 and 4

Example problems 3 and 4 in Section 5 were based on actual field sites during the construction of Interstate 210 in Los Angeles, California. To give the reader a better appreciation of how the sites were modelled, the field data sheets and photographs from the noise measurements made at the sites are presented in this Appendix.

First presented are an overall map of the I-210 project, a more detailed map of the measurement areas and a copy of the photograph log. In the subsequent two sections, the numbers to the right of the photographs indicate the roll number and frame number, for referencing to the photograph log.

The first site, "Cut area, north end of the project", was modelled in example problem 4 in Section 5.3. Site diagram 8-7D shows the modelled area, while the receiver locations are indicated on site diagram 7-30A.

The second site, "Fill area in the vicinity of Terra Bella Avenue", was modelled in example problem 3 in Section 5.3. Site diagram 8-7A shows the specific scenario.

E-2

INDEX OF SHEETS

Sheet No.	
1	Title Sheet
2-5	Typical Cross Sections
6	Standard Plans List
7-42	Plans, Profiles & Earthwork Quantities
43-48	Stage Construction
49-69	City Street Plans
70-112	Contour Grading, Striping, Markers, Fence, Guard Railing, Waterline Crossovers, Erosion Control & Traffic Control System
113-169	Storm Drain Plans & Profiles
170-177	Sewer Plans
178	Mandatory Borrow Site
179	Sewer Quantities
180-198	Drainage Structure List
199-201	Quantity Summaries
202-218	Special Details
219-232	Utility Plans
233-245	Sign Plans
246-291	Electrical Plans
292-297	Retaining Wall
298-326	Sound Walls
327-457	STRUCTURES - SEE LIST BELOW

Sheet No.	
1	Mass Diagram
1-178	Cross Sections

⚠1 SHEETS ADDED FOR ADDENDUM NO. 1

SHEET NO. 33-A
" " 132-A
" " 190-A
" " 191-A

1-210-1(269)7

07	LA	210	R6.6/R12.0	1	457

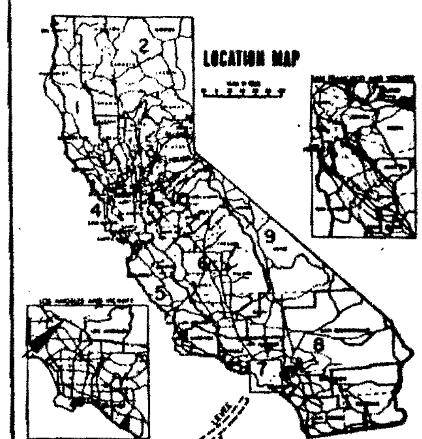
STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF TRANSPORTATION

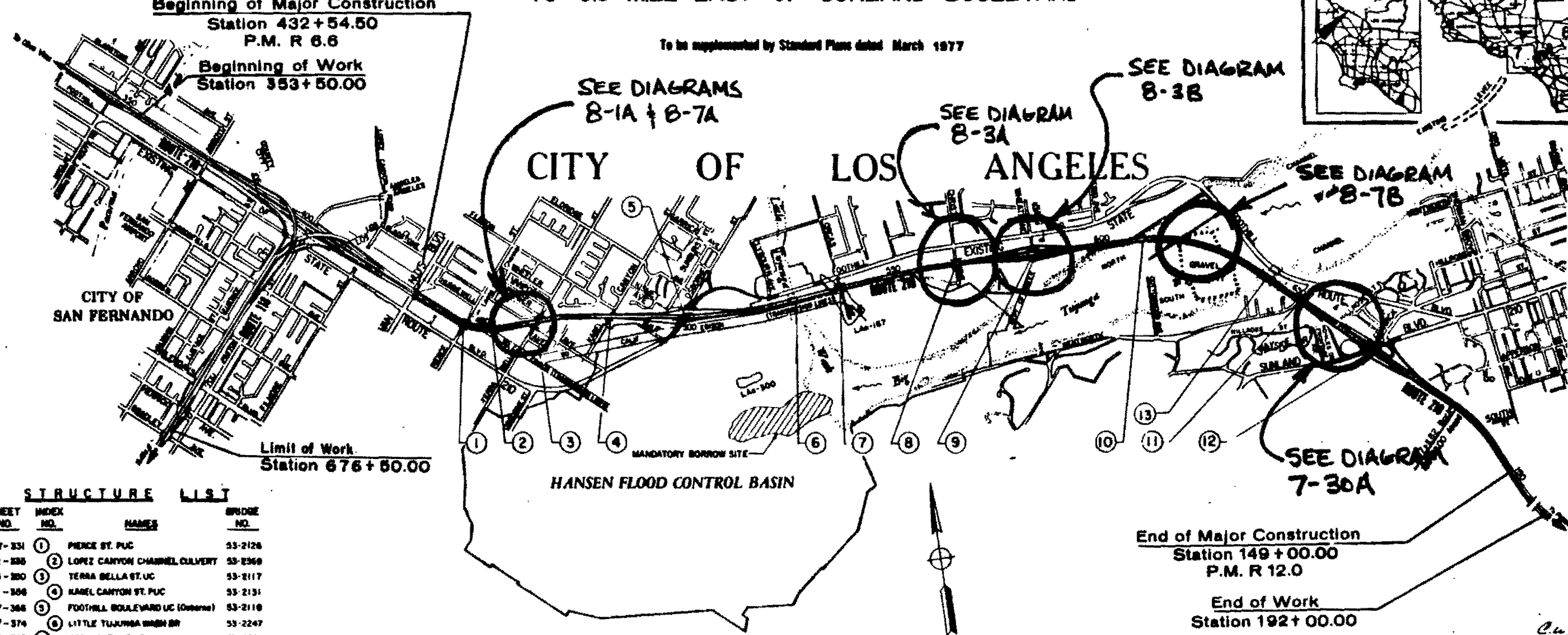
REDUCED PLAN
USE SCALE BELOW
0 1 2 3
3 INCHES ON ORIGINAL PLAN

PROJECT PLANS FOR CONSTRUCTION ON
STATE HIGHWAY

IN LOS ANGELES COUNTY IN LOS ANGELES FROM VAN NUYS BOULEVARD TO 0.9 MILE EAST OF SUNLAND BOULEVARD

To be supplemented by Standard Plans dated March 1977





STRUCTURE LIST

SHEET NO.	INDEX NO.	NAMES	BRIDGE NO.
327-331	1	PIERCE ST. PUC	53-2126
332-335	2	LOPEZ CANYON CHANNEL CULVERT	53-2369
336-350	3	TERRA BELLA ST. UC	53-2117
351-356	4	KAGEL CANYON ST. PUC	53-2131
357-366	5	FOOTHILL BOULEVARD UC (Osborne)	53-2118
367-374	6	LITTLE TUJUNGA WASH BR	53-2247
375-383	7	ORCAS AVENUE UC	53-2230
384-392	8	CHRISTY AVENUE UC	53-2243
393-400	9	WHEATLAND AVE. UC	53-2233
401-420	10	BIG TUJUNGA WASH BR	53-2249
436-444	11	WENTWORTH ST UC	53-2246
445-457	12	SUNLAND BOULEVARD UC	53-2251
421-435	13	SO. BRANCH BIG TUJUNGA WASH BR.	53-2562

The detailed plans are a portion of the route for the State Highway adopted by the California Highway Commission on March 26, 1958 and September 1, 1964 and declared a FREEWAY by resolution of the California Highway Commission on March 26, 1958 and September 1, 1964.

SCALE IN FEET
1000 0 1000 2000 3000

LEGEND
Major Construction

Length of Major Construction 5.4 Miles
Length of Work 7.7 Miles

⚠1 Revised for Addendum No. 1 dated May 10, 1978

Deputy District Director of Transportation
Registered Civil Engineer

Approved March 13, 1978

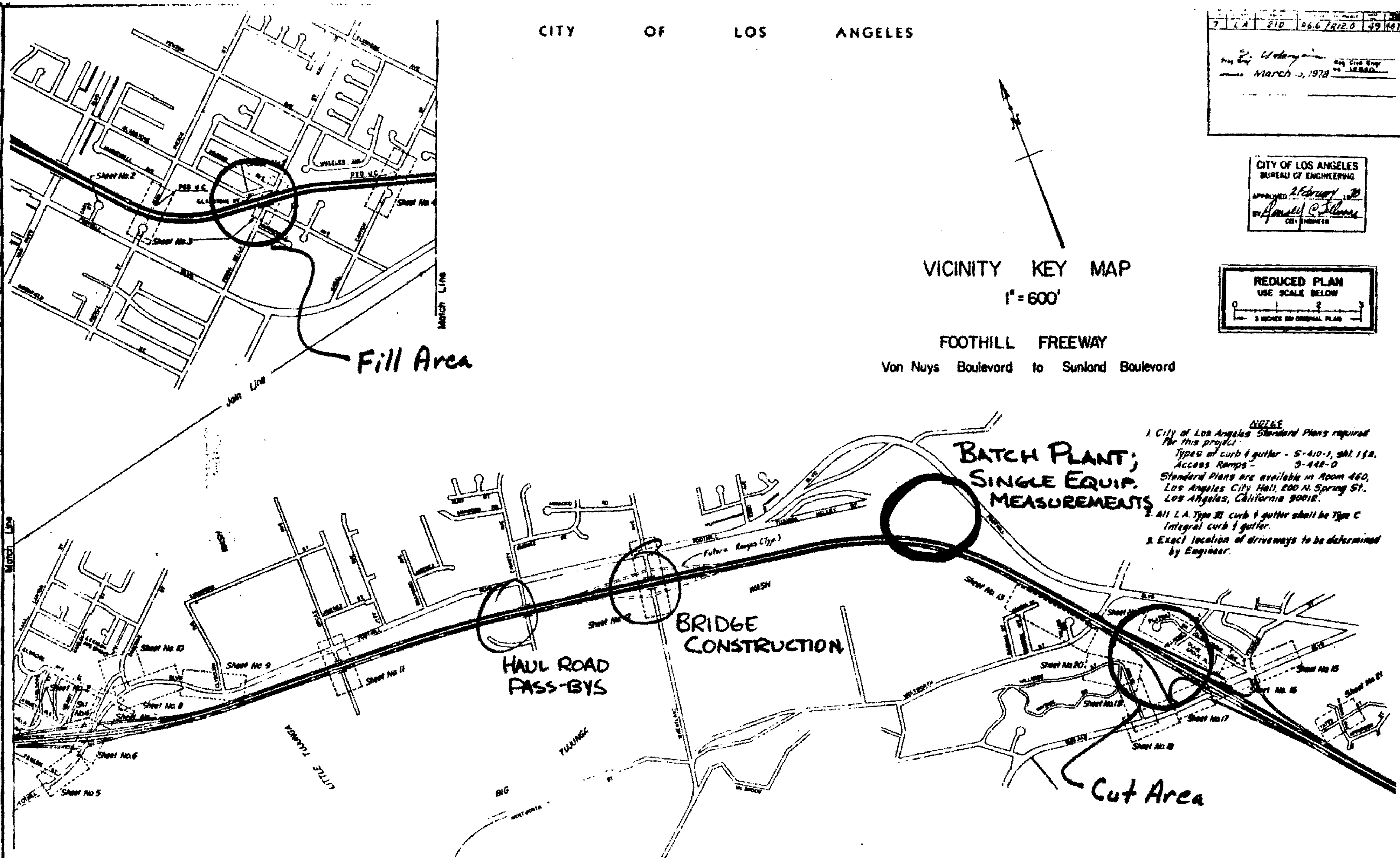
Chief, Office of Office Engineer
Registered Civil Engineer

Contract No. 07-063754

07-209 063754

S Yokoyama 10/77 | N D Kaufman 10/77 | R F Blacker 10/77

CITY OF LOS ANGELES



VICINITY KEY MAP

1" = 600'

FOOTHILL FREEWAY

Von Nuys Boulevard to Sunland Boulevard

March 3, 1978

CITY OF LOS ANGELES
BUREAU OF ENGINEERING
APPROVED 2 February 78
BY [signature]
CITY ENGINEER

REDUCED PLAN
USE SCALE BELOW
0 1 2 3
3 INCHES ON ORIGINAL PLAN

NOTES

1. City of Los Angeles Standard Plans required for this project:
   Types of curb & gutter - S-410-1, sht. 1 & 2.
   Access Ramps - S-442-0
   Standard Plans are available in Room 460, Los Angeles City Hall, 200 N. Spring St., Los Angeles, California 90012.
2. All L.A. Type II curb & gutter shall be Type C Integral curb & gutter.
3. Exact location of driveways to be determined by Engineer.

CSP

Project Engineer	Date	Design Engineer	Date	Approval of Recommended by	Date
S. Yokoyama	11/77	W. D. Knutsen	12/77	R. F. Blocker	12/77

STREET PLANS: Sheet 1 of 21 Sheets

E-3

Photo Log – 35 mm

	Frame #	Location	Date	Time	View or Subject
ROLL #1	17	CUT AREA; LOC. C-1	7-30	1130	MIC SETUP
	18	" "	"	"	" "
	19	CUT AREA; LOC. C-1	7-30	1140	CUT PANORAMA
	20	" "	"	"	" "
ROLL #2	1	← DELETED →			
	2	S. OF SUNLAND OVER	7-30	1510	LOOKING NORTH AT CUT AREA
	3	PASS, 20' ABOVE BRIDGE	"	"	" " " " "
	4	← DELETED →			
	5	LOCATION C-1	7-30	1400	CENTRAL LOADING AREA
	6	300 YDS., N. OF C-1; -30'	↓	"	SOUTH TO CUT AREA
	7	150 YDS., N. OF C-1, -10'		"	" " " "
	8	LOCATION C-3	7-31	1000	CENTRAL LOADING AREA
	9	LOCATION C-5	↓	1130	SOUTH LOADING AREA
	10	LOCATION C-6		"	SOUTH LOADING AREA
	11	100' SO. OF C-5		1200	SO. LOADING AREA (LOOKING NORTH)
	12	" " " "			LOOKING NORTH TO C-5
	13	LOCATION F-4	8-1	1100	WEST ALONG FENCE
	14	" "	"	"	SOUTH AT FILL AREA
	15	MIC. LOCATION	"	"	EAST AT FILL AREA
	16	LOCATION F-5	"	1130	SOUTH AT FILL AREA
	17	TERRA BELLA & PRAGER	"	1520	SOUTHWEST AT FILL AREA

Photo Log - 35 mm

	Frame #	Location	Date	Time	View or Subject
	18	TERRA BELLA & PRAGER	8-1	1520	WEST AT FILL AREA
	19	EAST OF TERRA BELLA	8-7	0900	SITE F-6 @ BOUNDARY FENCE
	20	" " " "	↓	"	" " , LOOKING N.W.
	21	BRIDGE CONSTR. SITE	↓	1100	GENERATOR
	22	CONCRETE BATCH PLANT	↓	1130	NORTH OF PLANT, BEHIND 100 FT. MICPHONE POSITION
	23	" " "	↓	1145	SOUTH OF PLANT, BEHIND 100 FT. MICPHONE POSITION
	24	CUT AREA	↓	1300	LOADING OPERATION
ROLL #3	1 THRU 5	NEXT TO BATCH PLANT	8-9	1300	CAT 930 LOADER; SINGLE EQUIP. MEAS.
	6 THRU 8	" " " "	↓	1400	GARDNER-DENVER COMPRESSOR
	9 THRU 15	FILL AREA (TERRA BELLA)	↓	1730	CAT 834 TRACTOR; SINGLE EQUIP. MEAS.
	16 THRU 19	FILL AREA (TERRA BELLA)	8-14	1200	SITE AREA FROM 100' MIC. POSITION
	20	" " "	8-15	1250	FILL SITE FROM MIC.
	21	CENTER CUT AREA	↓	1300	SITE C-1
	22 THRU 24	CUT AREA C-1	↓	1330	CUT AREA; WEST/NORTH/SOUTH

Measurement Site Data

Highway: I-210 Date: July/August, 1979

Site Location: Cut area; north end of project

Type of Measurements:

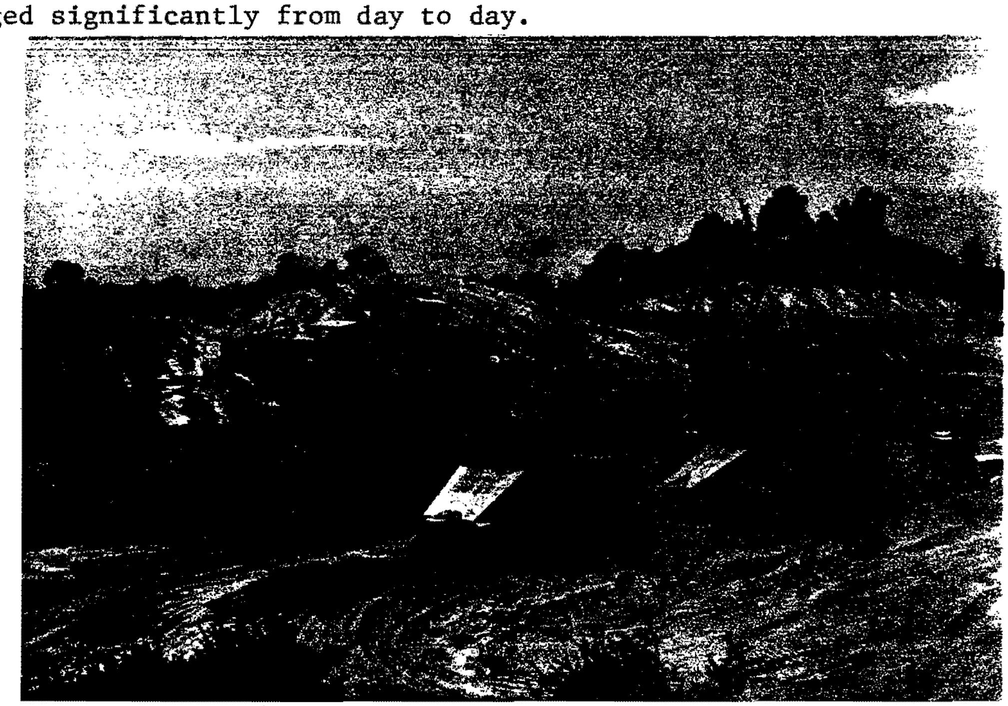
Site Boundary
Activity
Movies

Soil/Terrain Conditions: Area where haul trucks operate: hard, bank earth; area around Cl, C5, C6; hard, bank earth C4 located on top of pile of boulders. Area around C2, C3; loose soil, uneven terrain.

Machinery Description:

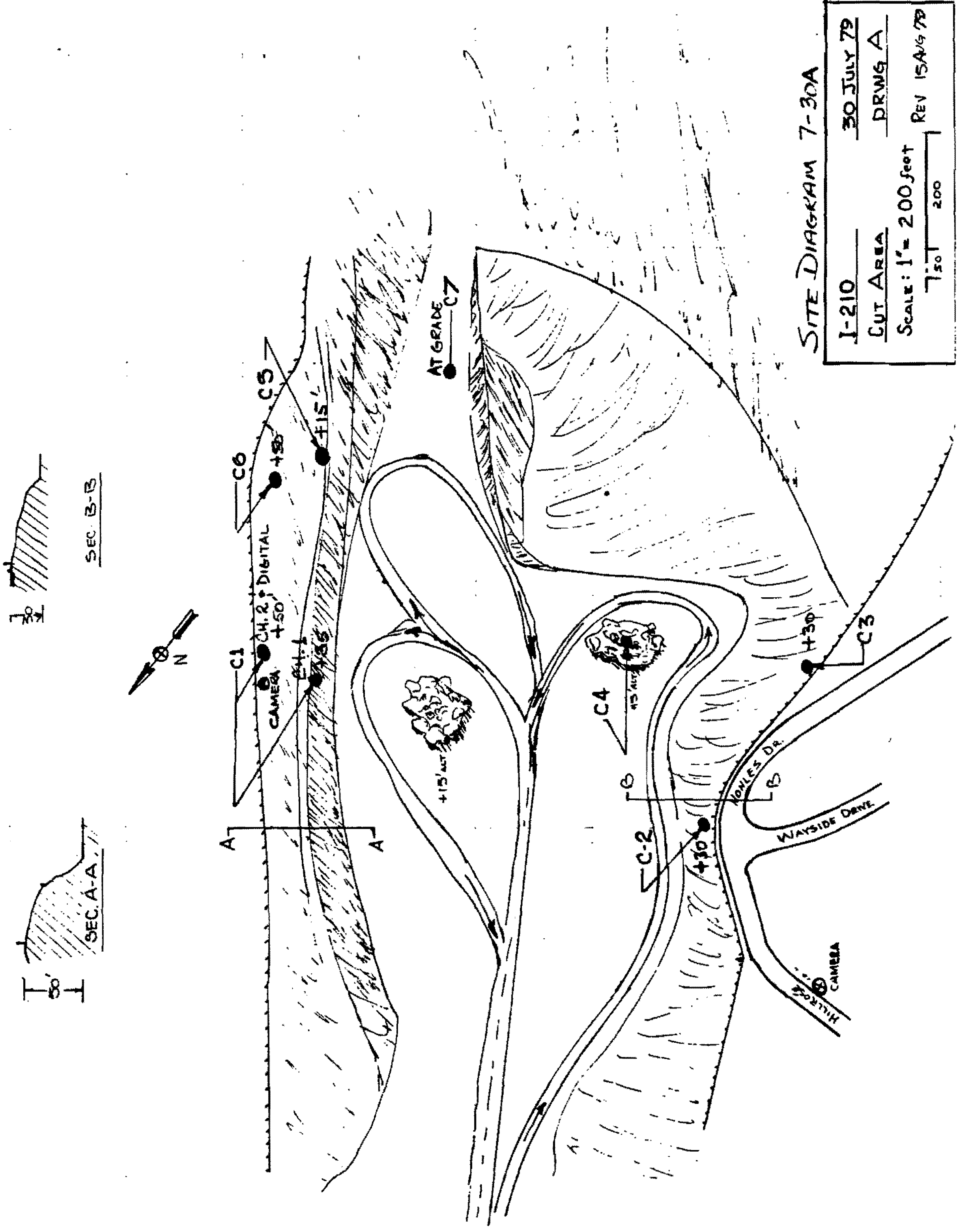
Fiat-Allis 31 track dozer (#2506)
Fiat-Allis 41 track dozer (#2508)
Cat D9G track dozer (#2246)
Cat. D9G track dozer (#2231)
2 Cat. 992 wheeled front end loader; 10 yd. scoop
Peterbilt tractor w/dual exhaut; double belly dump 20 yd. semitrailers.

Miscellaneous Information: Several sketches of area made; cut area terrain changed significantly from day to day.



2-24

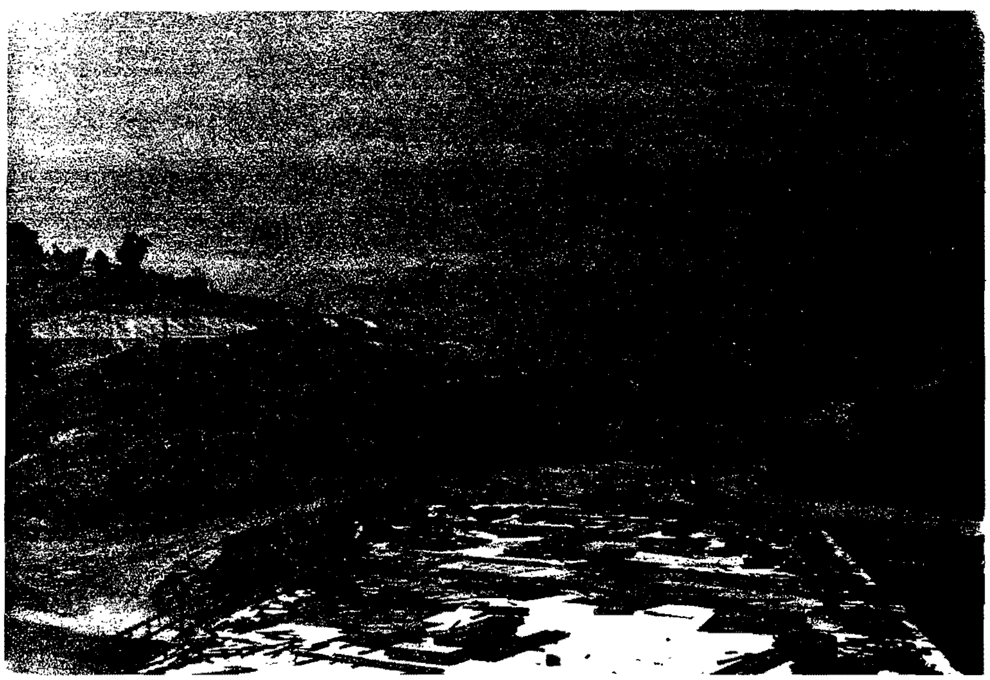
SITE DIAGRAM 7-30A



1-19

1-20

2-2



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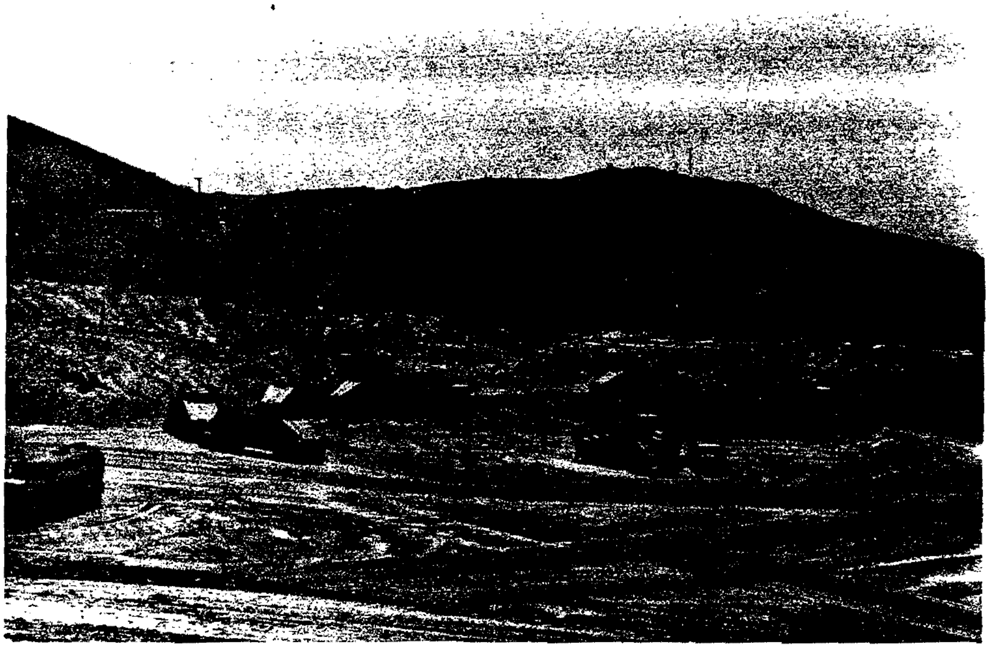

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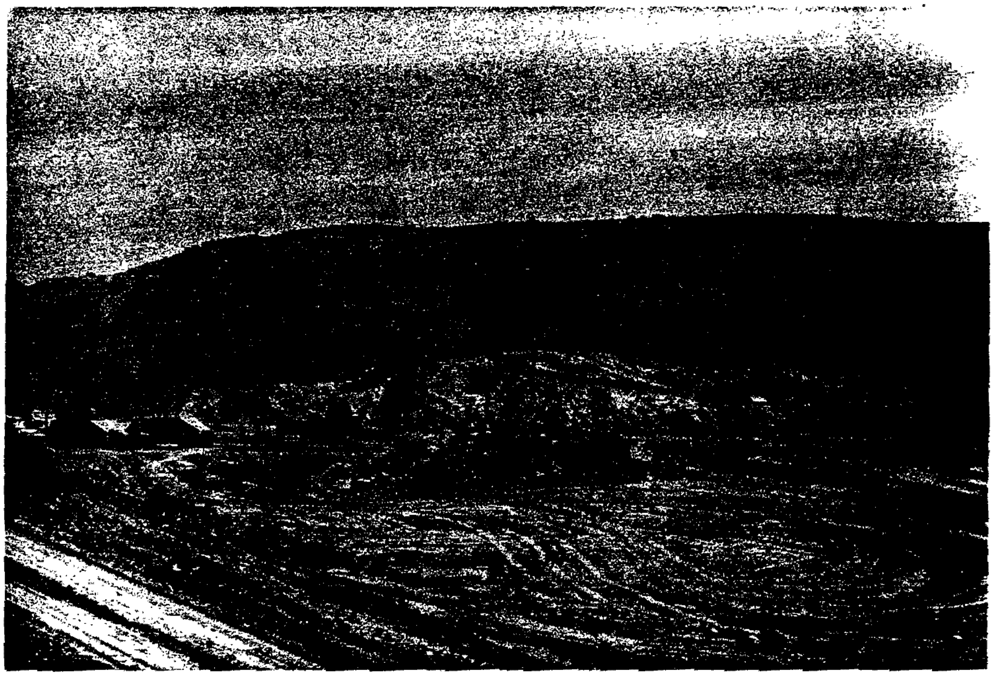
2-6



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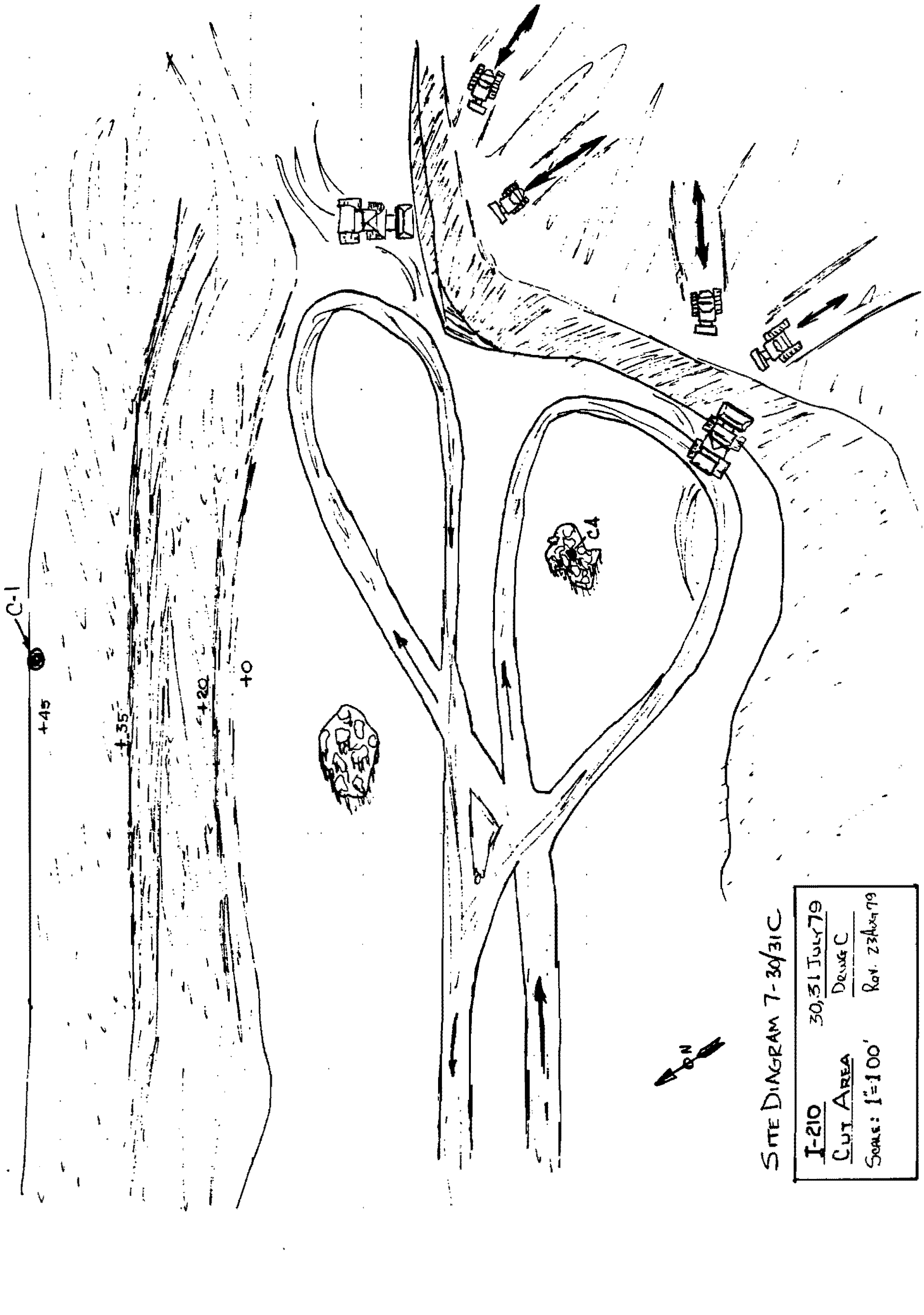
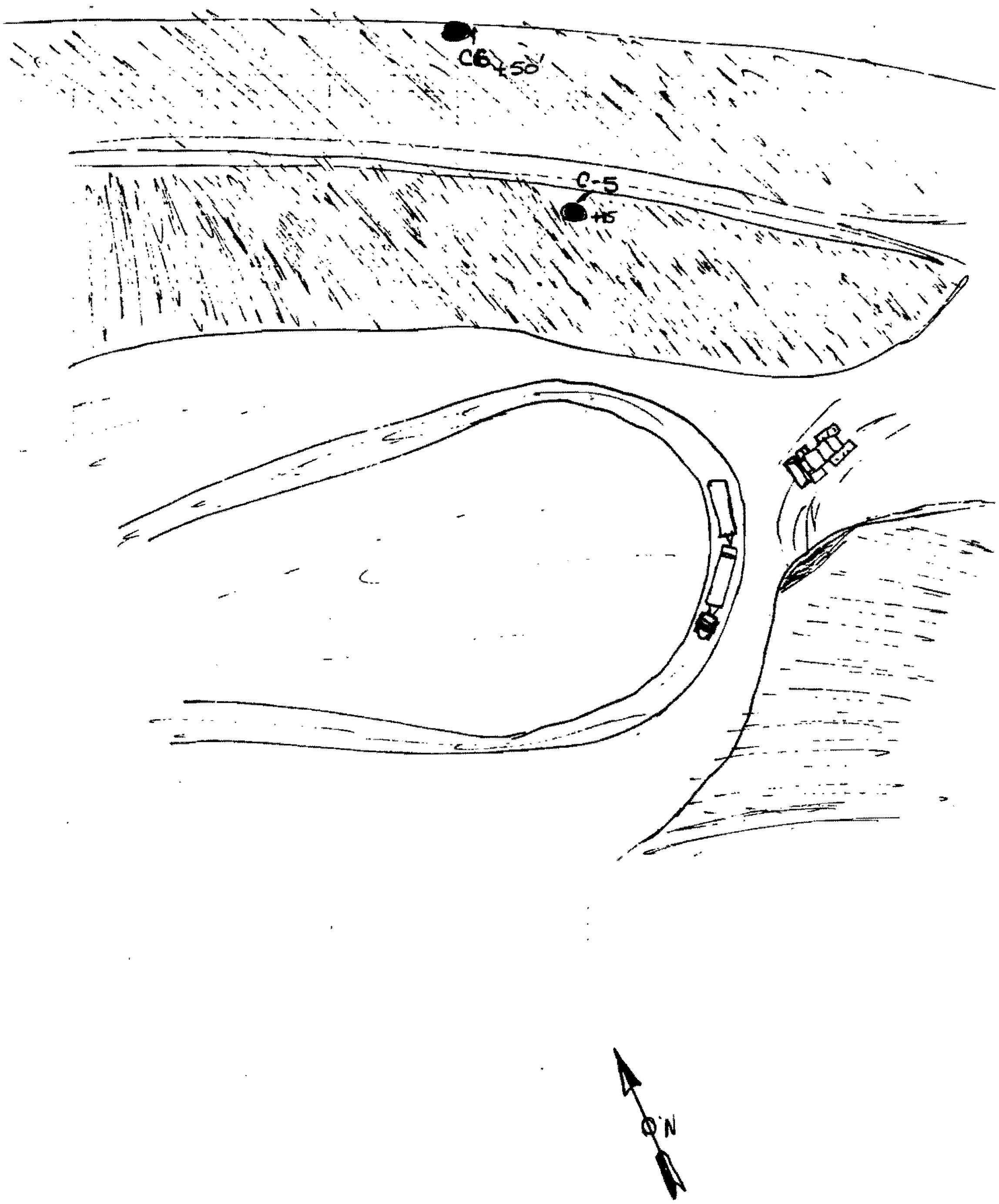
2-8

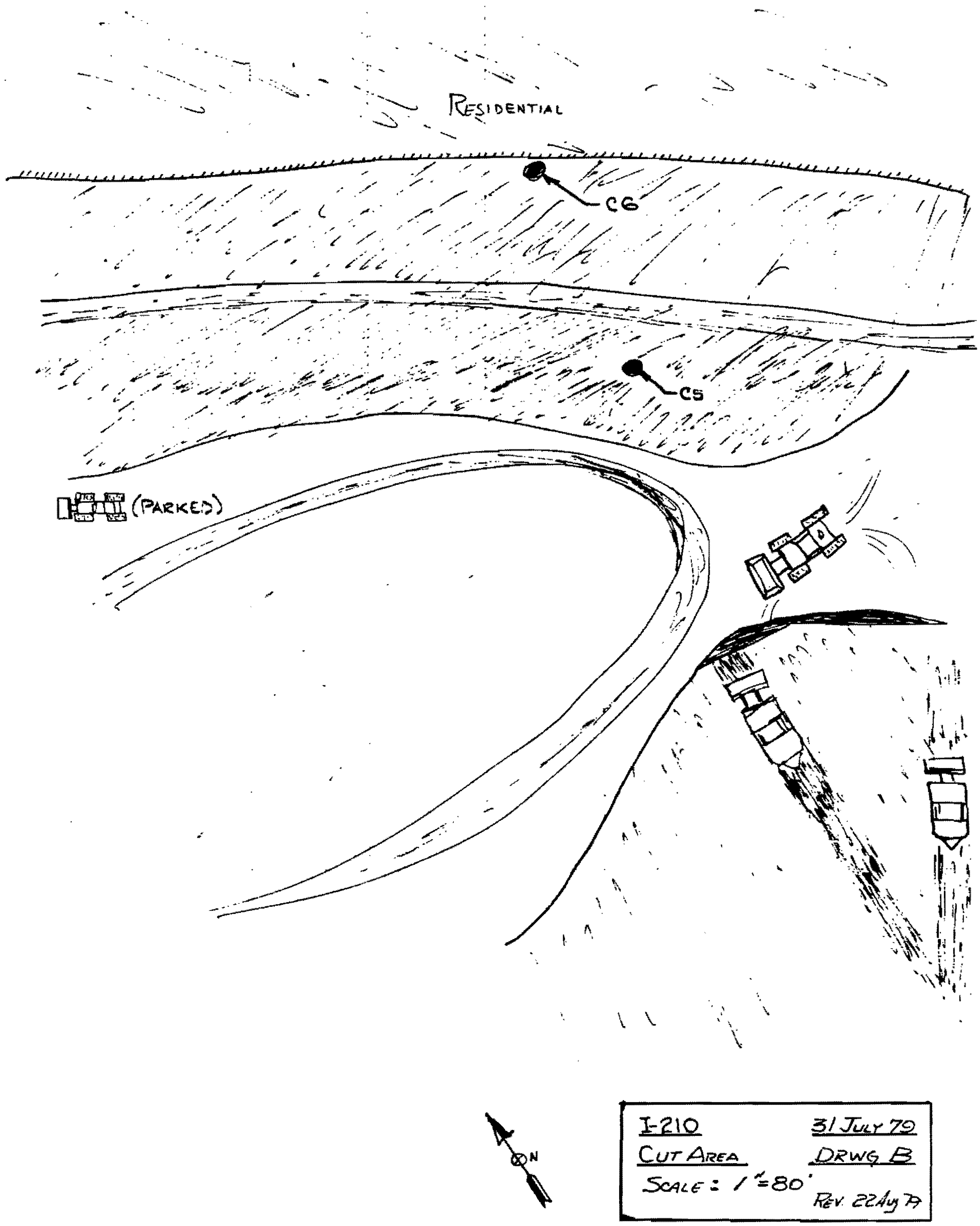


SITE DIAGRAM 7-30/31C
I-210
CUT AREA
SCALE: 1"=100'
30,31 JULY 79
DRWG C
REV. 23AUG79
C-1
+45
+35
+20
+0
CA
N

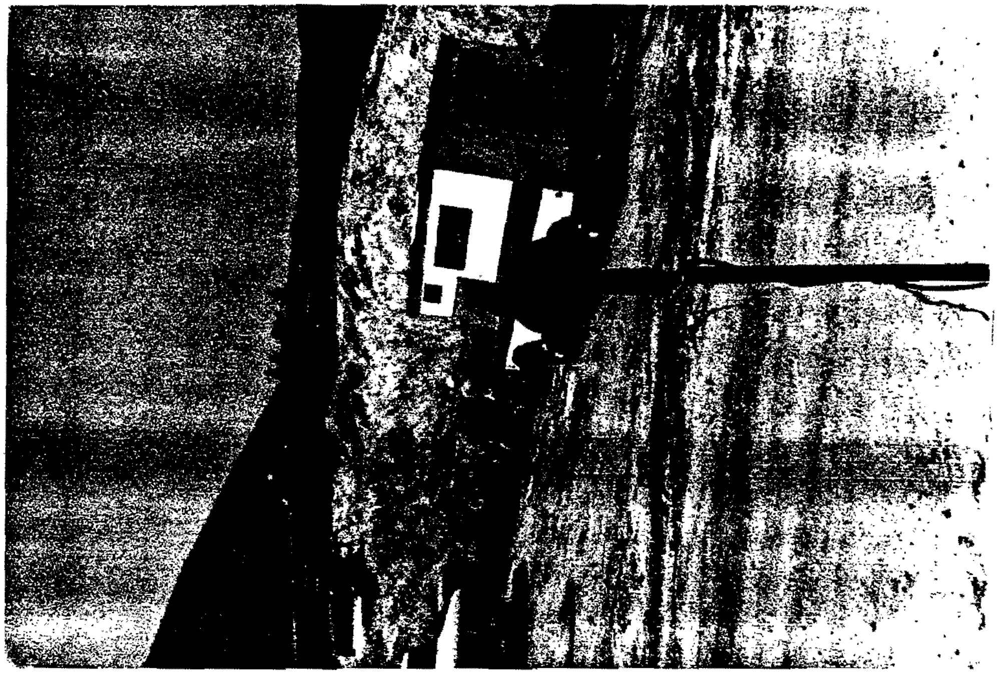


I-210	30 July 79
CUT AREA	DRWG F
SCALE: 1" = 80'	REV. 22 AUG 79

SITE DIAGRAM 7-30F

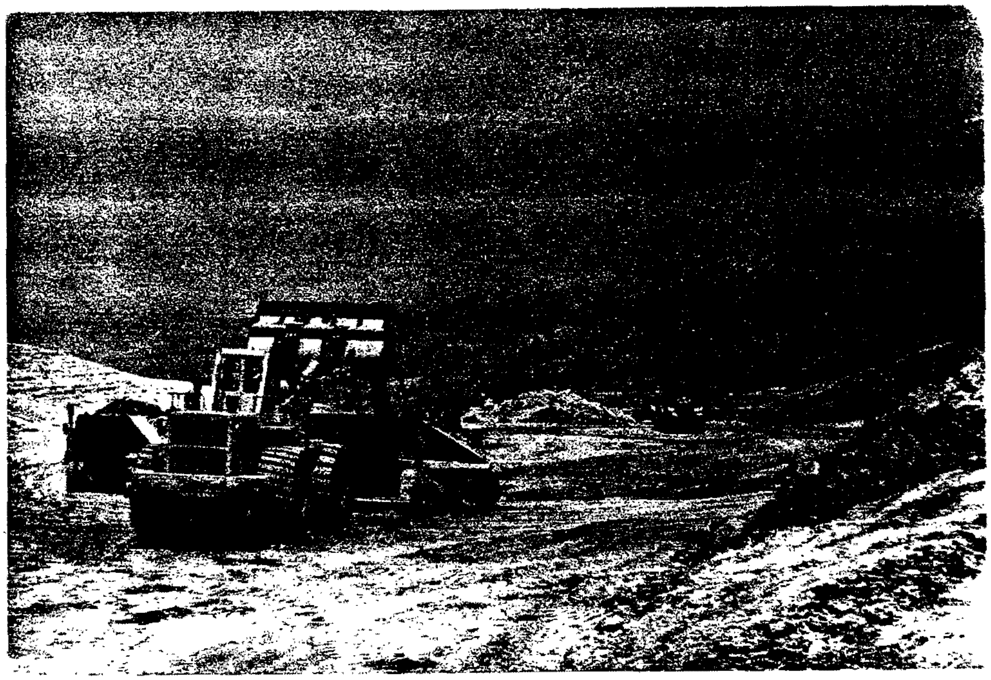


SITE DIAGRAM 7-31B



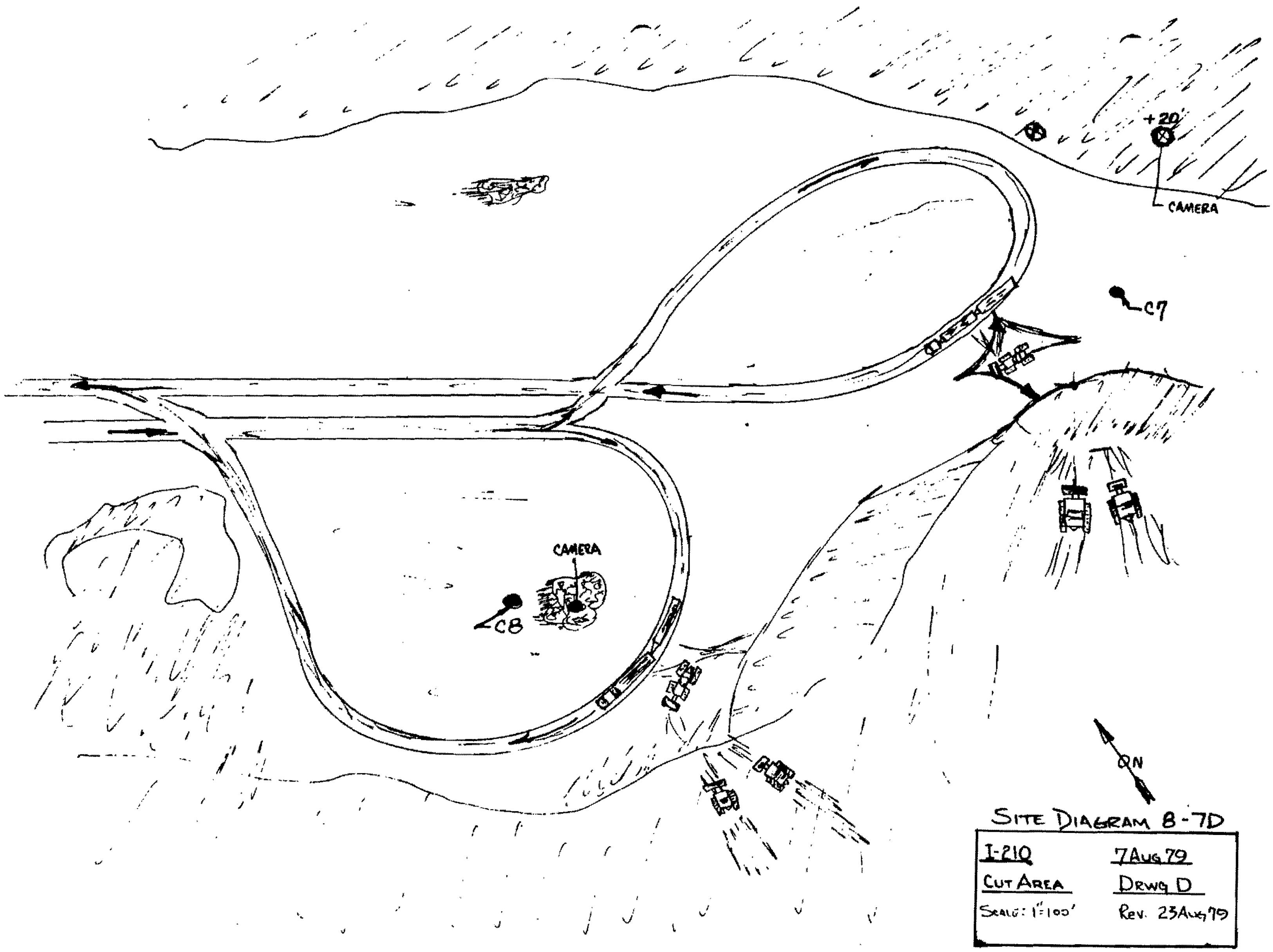
2-10

2-9



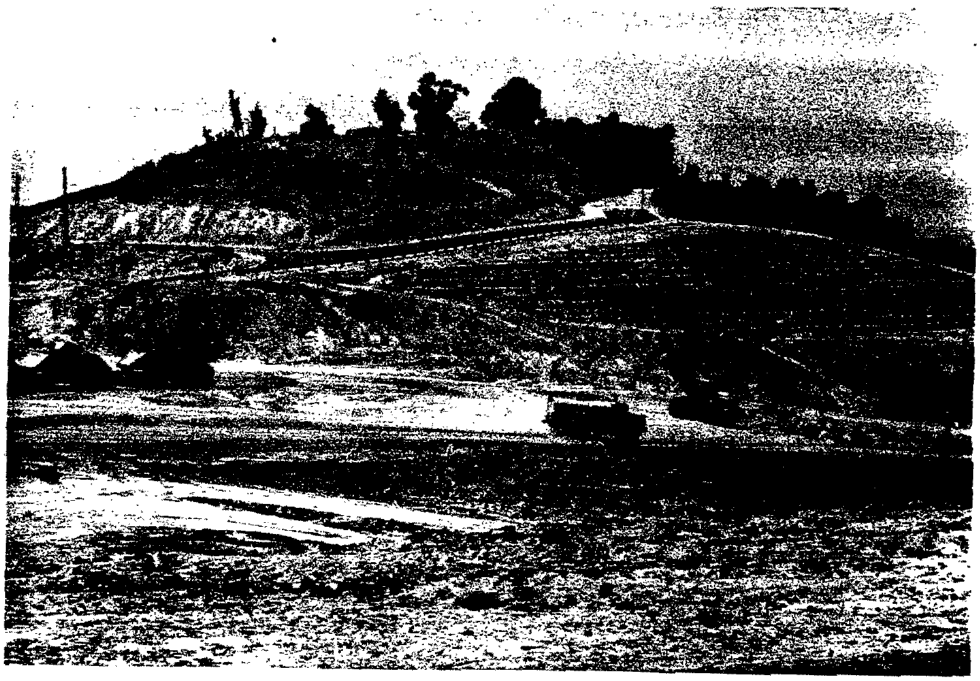
2-11

2-12


+20'
CAMERA
C7
CAMERA
C8
N
SITE DIAGRAM 8-7D
I-210
7 AUG 79
CUT AREA
DRWG D
SCALE: 1"=100'
REV. 23 AUG 79

3-21

3-22



3-23

3-24

DATA LOG SUMMARY

HIGHWAY: I-210 DATE: JULY/AUG. 1979

SITE LOCATION: CUT AREA

Sample	Location	Date	Time	Dur.	Site Diag.	Comments	Reduced
45-1	C-1	7-30	1147	15	7-30A 7-30/31C	W/MOVIES; CH. 1 & 2 SEPERATED BY 100'	✓
2	C-5	7-30	1455	15	7-30A 7-30F	—	✓
3	C-3	7-31	0940	15	7-30A	—	✓
4	C-5/C-6	7-31	1130	15	7-30A 7-31B	CH. 1 & 2 SEPERATED BY 100'	✓
5	C-4	7-31	—	20	7-30A 7-30/31C	W/MOVIES	✓
15	C-7	8-7	1308	6	7-30A 8-7D	W/ MOVIES; LOADING OPERATION SOUTH OF CUT AREA: N. OF SUNLAND BRIDGE	✓
16	C-8	8-7	1339	6	8-7D	W/MOVIES; LOADING OPERATION; CENTER OF CUT AREA	✓
210-1-1	C-1	7-30		2:53	7-30A 7-30/31C	SITE BOUNDARY	✓
-1-2	C-2	7-31		2:45	7-30A	SITE BOUNDARY	✓
-1-3	C-3	7-31		—	7-30A	SAMPLE NOT GOOD	
210-2-1	C-1	7-31		1:45	7-30A 7-30/31C	SITE BOUNDARY	✓
210-5-2	C-1	8-9		1:00	7-30A	SITE BOUNDARY	✓
210-7-2	C-1	8-15		12:00	7-30A	SITE BOUNDARY	✓

ACTIVITY NOISE MEASUREMENTS

HIGHWAY: I-210 DATE: JULY/AUGUST 1979

SITE LOCATION: CUT AREA

Sample	Location	Date	Dur.	L_{eq}	L_{99}	L_{90}	L_{50}	L_{10}	L_1
45-1; CH 1	C-1	7-30	13	77	64	72	78	81	84
45-1; CH 2	C-1	7-30	14	74	61	72	76	86	87
45-2	C-5	7-30	14	79.1	70	73	77	84	86
45-3	C-3	7-31	15	76.8	73	74	77	79	80
45-4; CH 1	C-5	7-31	20	79.1	71	74	79	81	84
45-4 CH 2	C-6	7-31	20	69.9	65	67	69	71	73
45-5	C-4	7-31	16	75.2	71	73	75	77	80
45-15	C-7	8-7	6	75.4	69	72	75	77	78
45-16	C-8	8-7	5	75.6	71	72	75	78	82

SITE BOUNDARY/COMMUNITY NOISE MEASUREMENTS

HIGHWAY: I-210 DATE: JULY/AUG 79

SITE LOCATION: CUT AREA

Sample	Location	Date	Dur.	L_{eq}
210-1-1	C-1	7/30	02:53	68
-1-2	C-2	7/31	02:45	61.63
-1-3	C-3	7/31	N/G	
210-2-1	C-1	7/31	01:45	66.67
210-5-2	C-1	8/9	01:00	69.4
210-7-2	C-1	8/15	12:00	55.65

Measurement Site Data

Highway: I-210 Date: July/August, 1979

Site Location: Fill area; in the vicinity of Terra Bella Avenue, 2 seperate locations.

Type of Measurements:

Site Boundary
Activity
Movies

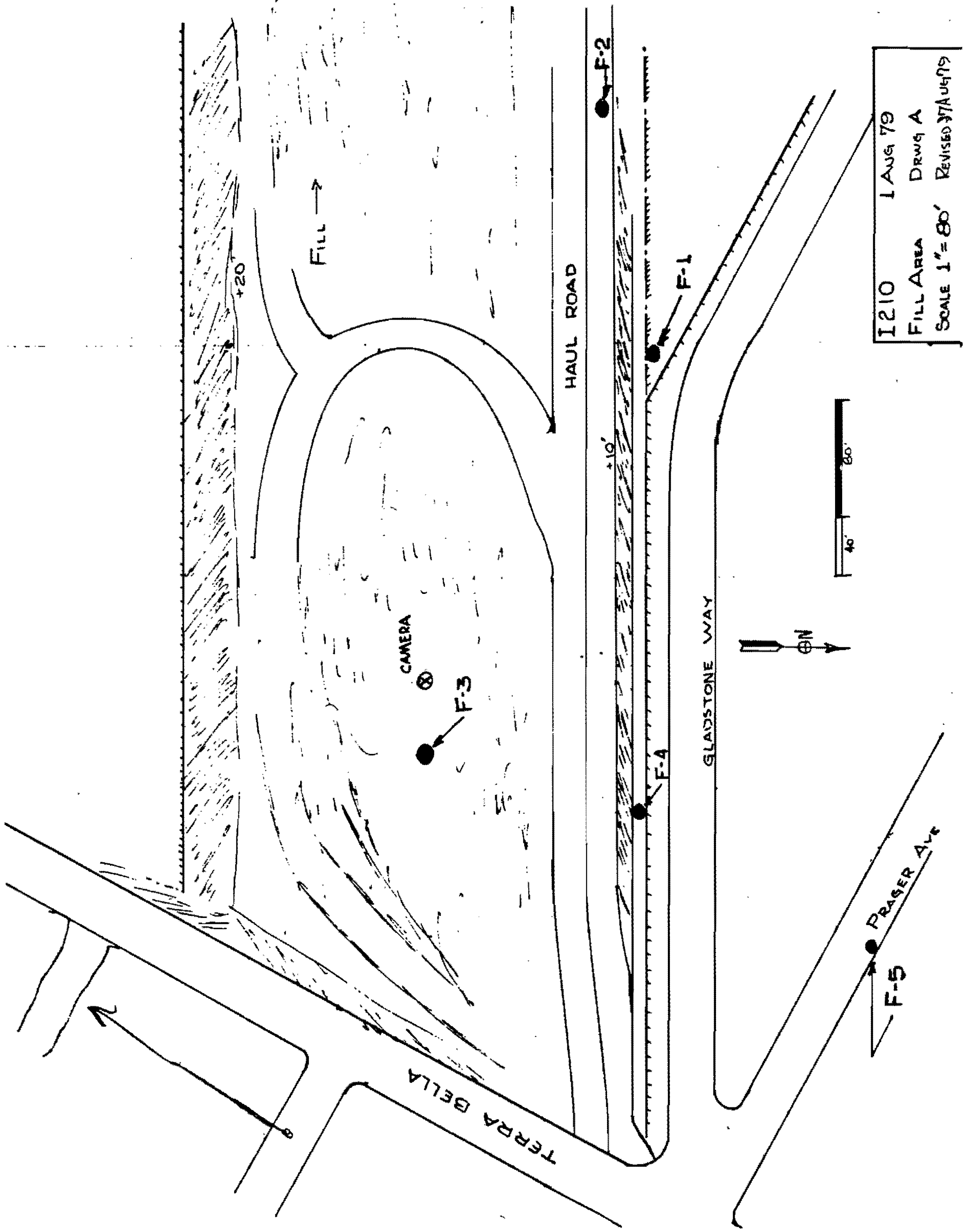
Soil/Terrain Conditions: Area where truck dump soil is loosely compacted earth; small windrows are seperated by approximately 12' run parallel along dumping area.

Machinery Description:

Cat. 834 wheeled tractor
Peterbilt tractor truck with dual exhaust; double belly dump
 20 yd. trailers
Cat. Water truck (occasional passbys)
Cat. 16 grader

Miscellaneous Information: None

SITE DIAGRAM 8-1A



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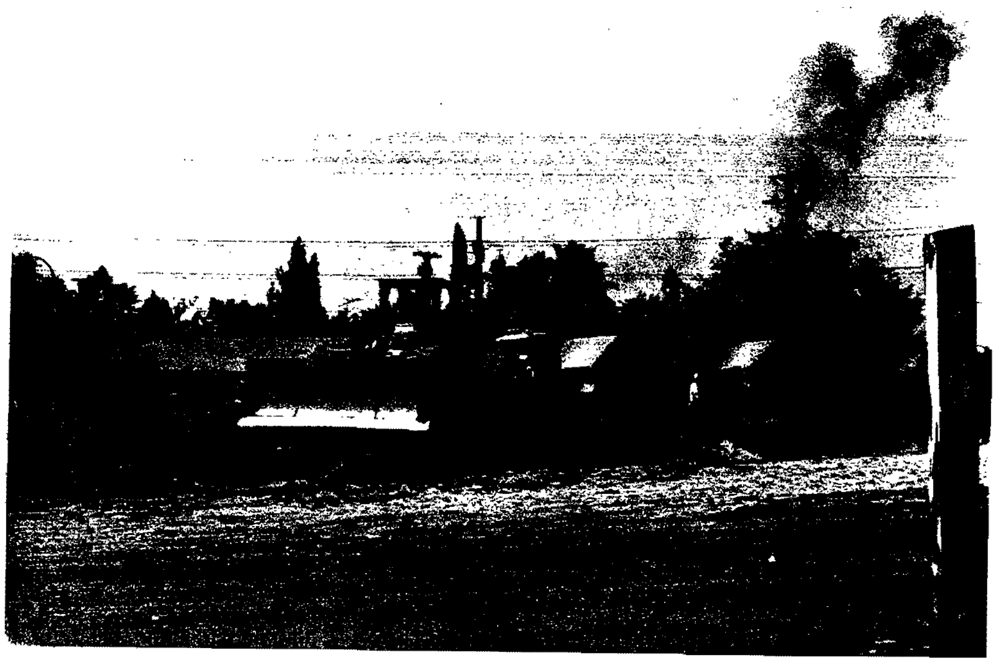
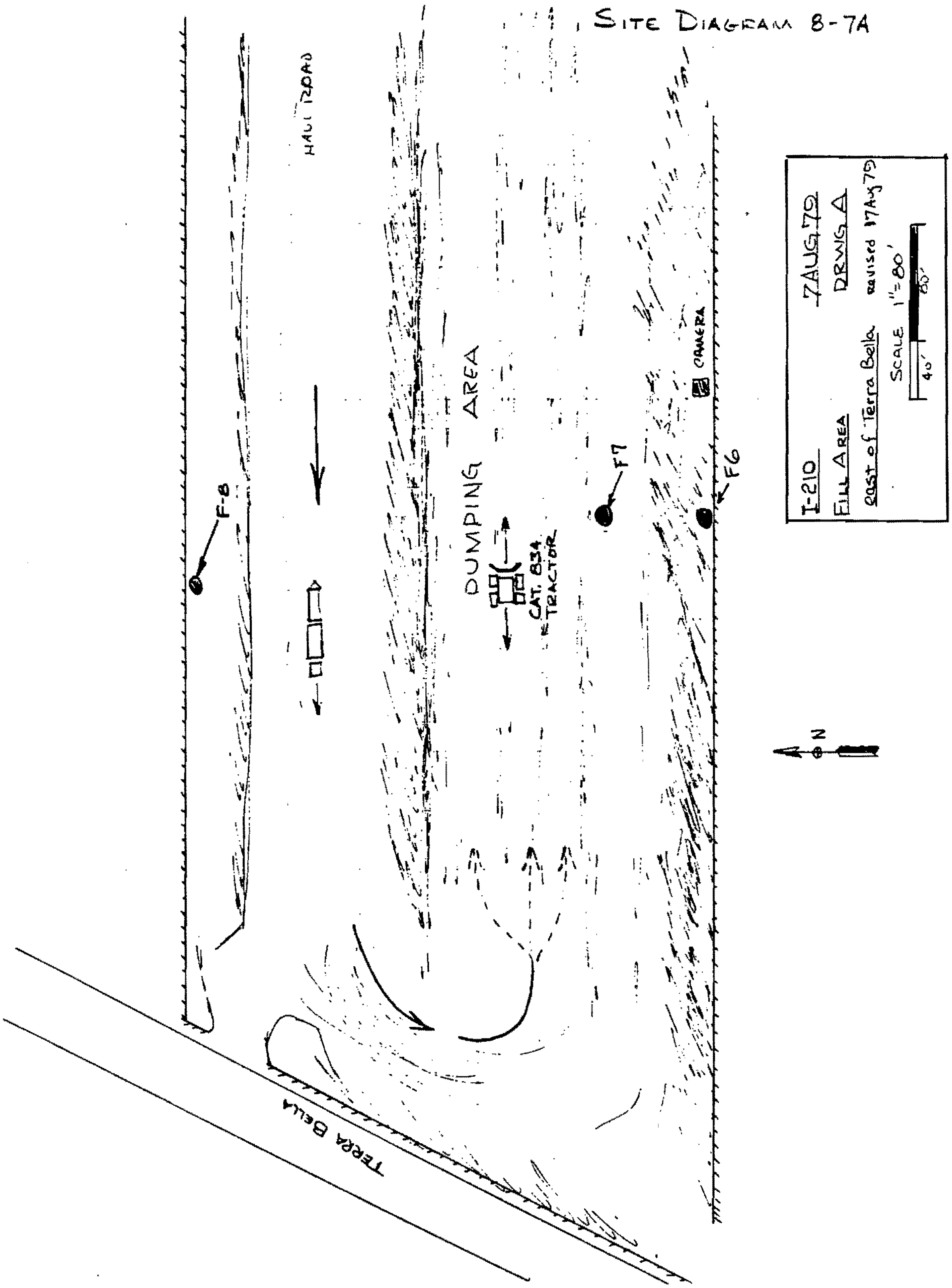


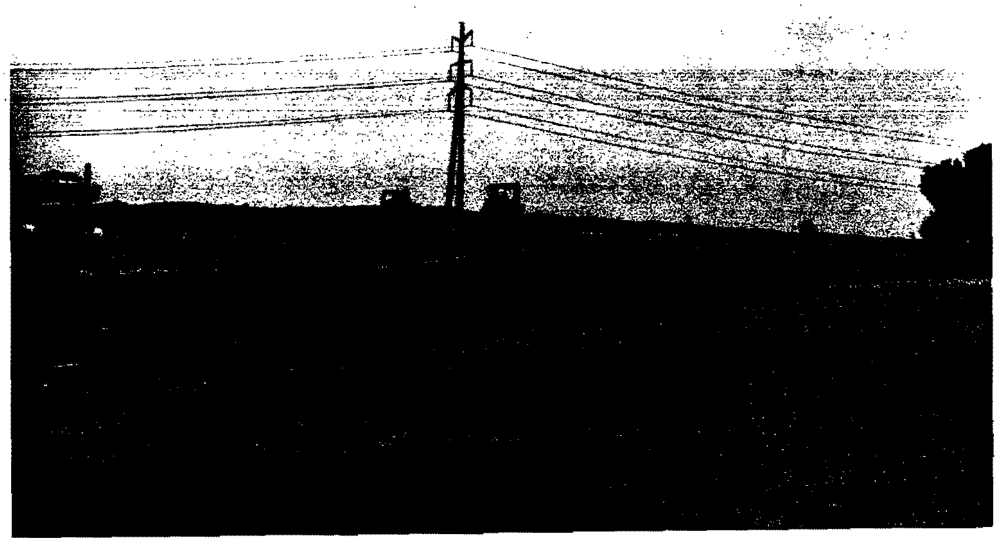
2-14

2-15

2-16


SITE DIAGRAM 8-7A
HAUL ROAD
DUMPING AREA
CAT. 834 TRACTOR
CAMERA
F-8
F7
F6
TERRA BELLA
I-210
FILL AREA
east of Terra Bella
7AUG79
DRWG A
revised 17Aug79
SCALE 1"=80'
40'
80'
N

2-17



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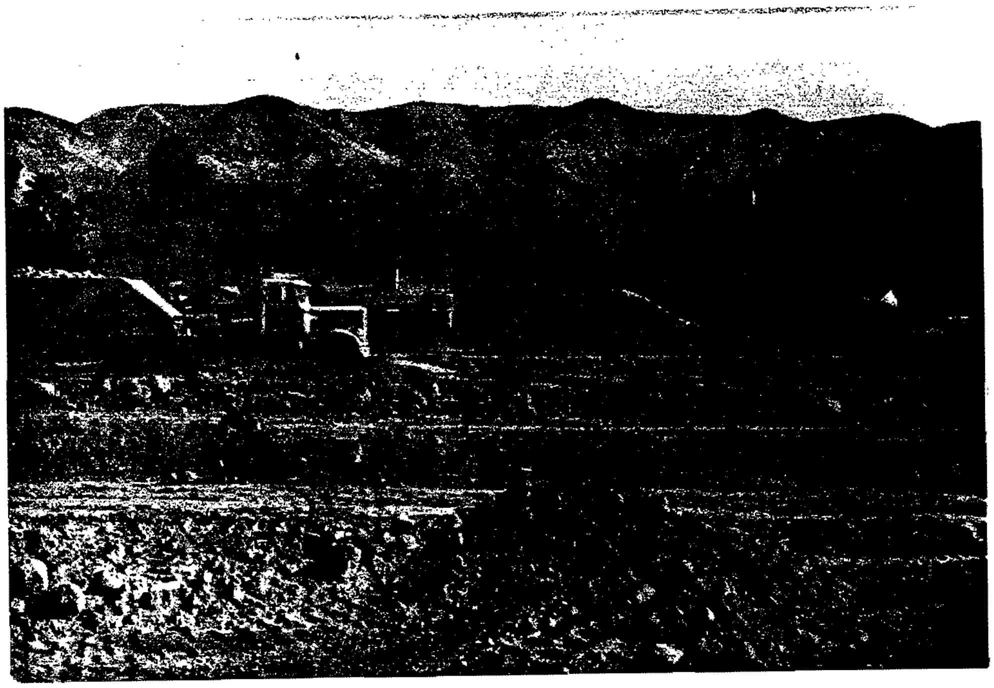
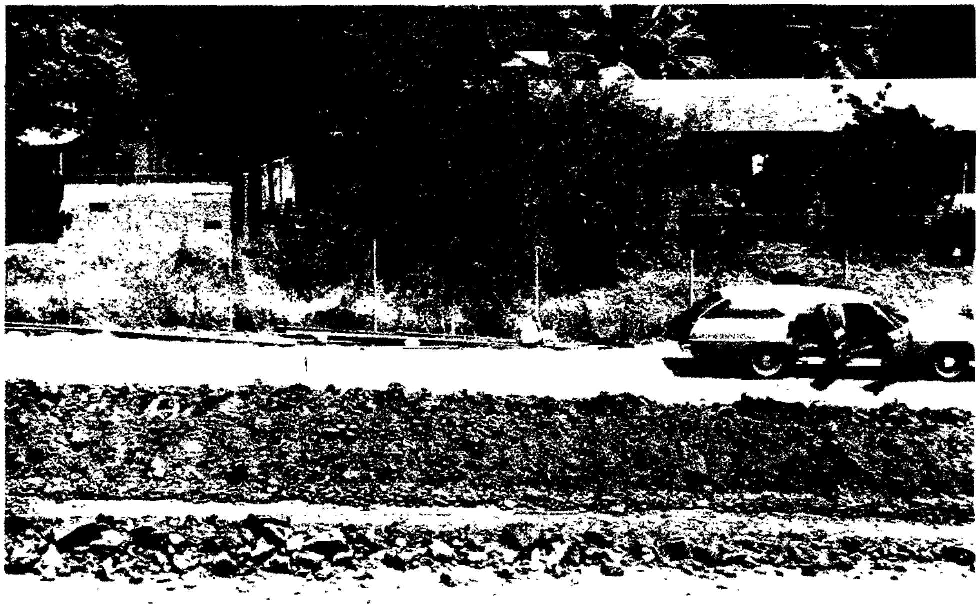


2-19

2-20



3-16

3-20

3-17

3-18

DATA LOG SUMMARY

HIGHWAY: I-210

DATE: July/August 1979

SITE LOCATION: Fill Area

Sample	Location	Date	Time	Dur.	Site Diag.	Comments	Reduced
45-6	F-2	8-1	1015	15	8-1A		✓
7	F-3	8-1	1045	15	8-1A		✓
8	F-4	8-1	1105	15	8-1A		✓
9	F-4	8-1	1510	15	8-1A		✓
10	F-6	8-7	0923	12	8-7A	w/Movies	✓
210-1-4	F-5	8-1		2:15		Community Measurement	✓
210-2-2	F-1	8-1		—		No Good	
-2-4	F-5	8-3		0:35		Community Measurement	✓
210-3-1	F-1	8-3		6:08		Site Boundary	✓
210-5-1	F-6	8-7		1:00		Site Boundary	✓
210-6-1	F-8	8-14		20:00		Area Adjacent to Fill Operation	✓
210-7-1	F-8	8-14		24:00		" " " " "	✓

ACTIVITY NOISE MEASUREMENTS

HIGHWAY: I-210

DATE: July/August 1979

SITE LOCATION: Fill Area

Sample	Location	Date	Dur.	L_{eq}	L_{99}	L_{90}	L_{50}	L_{10}	L_1
45-6	F-7	8-1	9	76.8	70	72	76	80	82
-7	F-3	8-1	12	82.9	67	75	81	86	89
-8	F-4	8-1	15	80.8	67	71	77	84	91
-9	F-4	8-1	—	—	UNUSABLE	—	—	—	—
-10	F-6	8-7	8	72.4	58	60	70	77	80

SITE BOUNDARY/COMMUNITY NOISE MEASUREMENTS

HIGHWAY: I-210

DATE: July/Aug 79

SITE LOCATION: Fill Area

Sample	Location	Date	Dur.	L_{eq}
210-1-4	F-5	8-1	02:15	63.9
210-2-2	F-1	8-1	— N/G	—
2-4	F-5	8-3	00:35	44.9
210-3-1	F-1	8-3	06:08	72.1
210-5-1	F-6	8-7	01:00	69.4
210-6-1	F-8	8-14	20:00	54.9
210-7-1	F-8	8-14	24:00	56.9

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

This report presents the results of model validation work at three sites for HICNOM, a highway construction noise prediction computer program prepared under contract for the Federal Highway Administration (1,2). The purpose of this work was to add to the data base on model validation previously done on the program (1,2,3). It was beyond the scope of this study to perform a full validation of the program.

The procedure used in this study included several steps. First, three actual highway construction sites were selected that exhibited activities testing the range of program options. Then, field measurements of the noise levels at each site were taken, along with detailed notes on the consruction operations. The measurements were each one half-hour in duration and were made with a Metrosonics dB-306 Metrologger, which samples four times per record and computes the equivalent sound level (L_{eq}).

The sites were then modelled using the computer program and the resulting predicted noise levels were compared to the measured levels.

The three sites were all on Interstate 440, currently under construction in Nashville, Tennessee. Figure 1 locates the sites on the project. Site A is discussed in Section 2.0. It consisted of a bulldozer keeping clear a fill section along which scrapers were hauling and then pushing the scrapers through the area during their haul.

Site B, discussed in Section 3.0, consisted of a fill embankment being created by a bulldozer spreading material being hauled and dumpted by a series of trucks. A pile driver operated in the distance, shielded by the fill embankment.

Site C is discussed in Section 4.0. It consisted of a major cut operation that involved two bulldozers, two loaders, haul trucks, and four compressor/ rock drill pairs.

Section 5.0 summarizes the results.

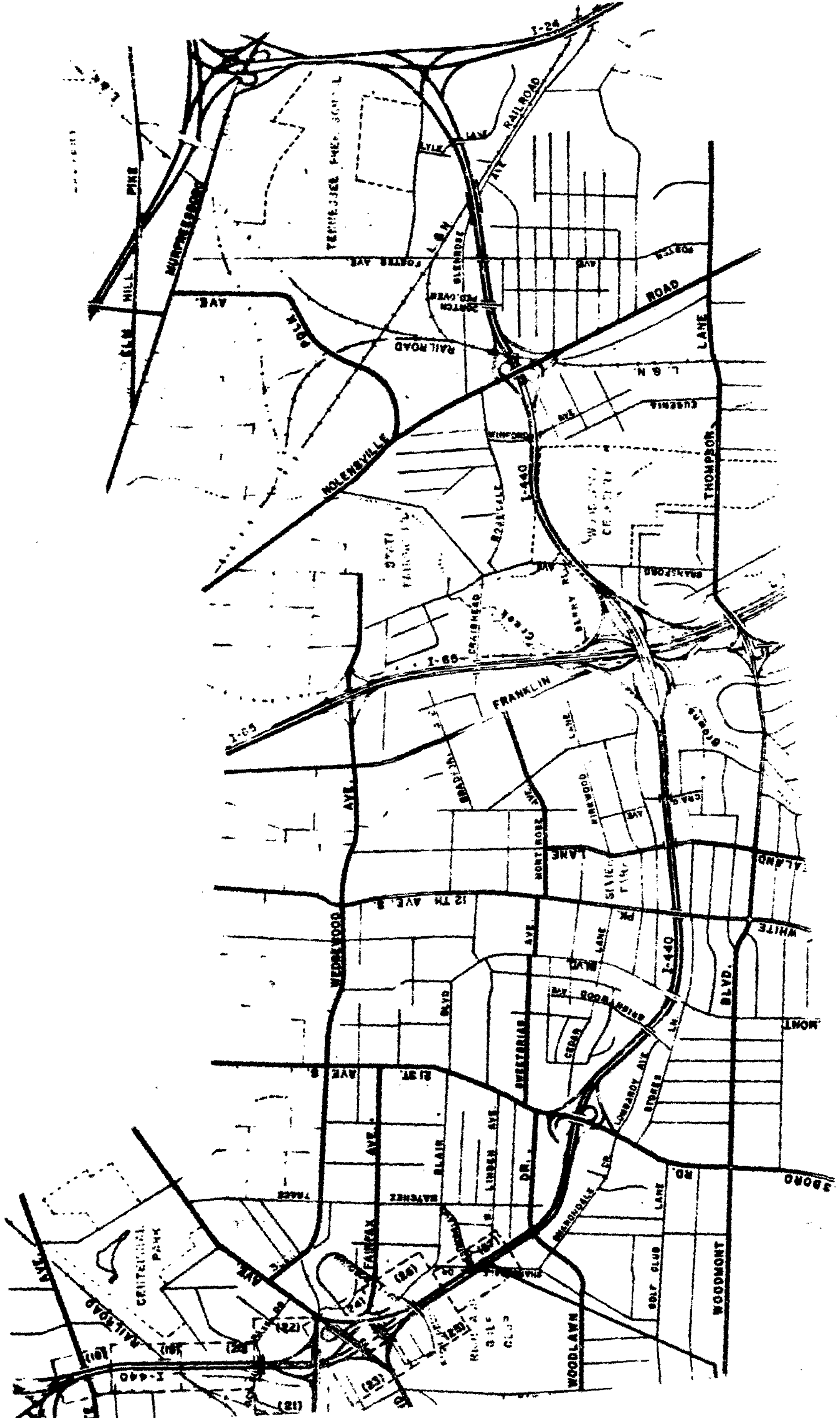


Figure 1. Site Location Map

2.0 SITE A: BULLDOZER AND SCRAPERS

Site A was located near Station 189 of Project No. 7 of the I-440 construction just east of Sharondale Drive, as shown in Figure 2. The measurement point was just behind the Blair House Apartments, near the right-of-way line. At this site, a Komatsu D85E bulldozer was moving back and forth along a freshly placed fill area, trying to keep the area passable as a haul road for Caterpillar 621B scrapers. When the scrapers reached this point in their haul, they bogged down in the soft earth and then had to be pushed about 200 feet by the dozer until they cleared the soft area. After dropping their loads about a quarter-mile beyond this site, the scrapers passed back through the site.

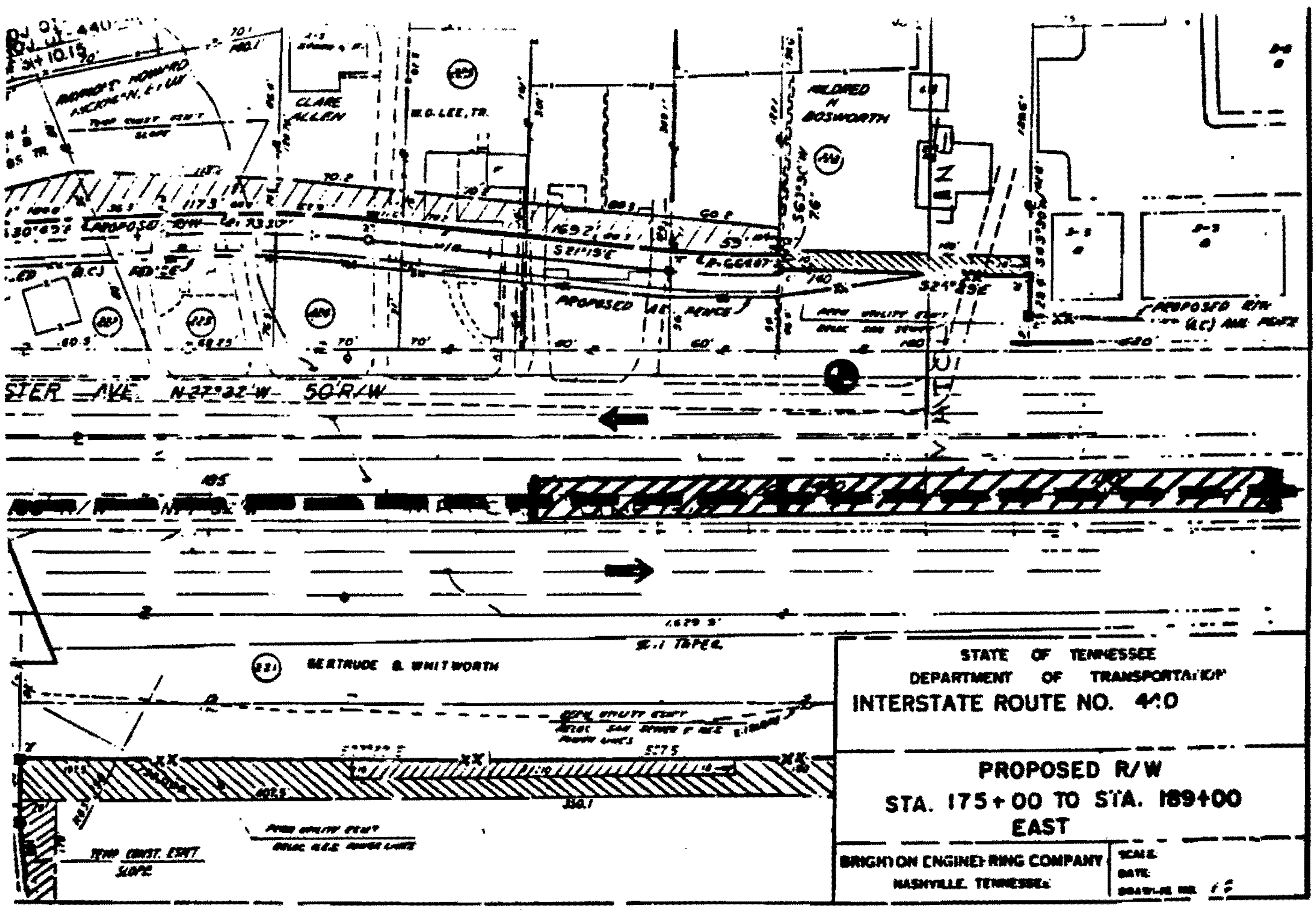
Four operations had to be defined for the modeling:

1. bulldozer assisting scrapers;
2. bulldozer working on fill above;
3. unloaded scrapers returning through site;
4. loaded scrapers approaching site, stopping, being pushed by dozer, and leaving site.

Each of these operations was modelled as a separate "source". They are represented by BULLDOZER 1, BULLDOZER 2, SCRAPER 2 and SCRAPER 1, respectively in Figures 3-6.

Figure 3 shows a sketch of the site as modelled for the program. BULLDOZERS 1 and 2 were both represented as area sources, while SCRAPERS 1 and 2 were modelled as "haul" line sources. The receiver was located about 40 feet from the apartments and 55 feet from the edge of the bulldozer areas.

Figure 4 presents the worksheets used to prepare the data prior to entering it into the computer. Note that an excess attenuation of 1.5 dB/distance doubling was assigned to the receiver because of the presence of the soft earth and a fair amount of underbrush and small trees. The first SCRAPER



○ RECEIVER

▨ BULLDOZER AREAS

▬ SCRAPER HAUL LINES

Figure 2. Site A Plan View

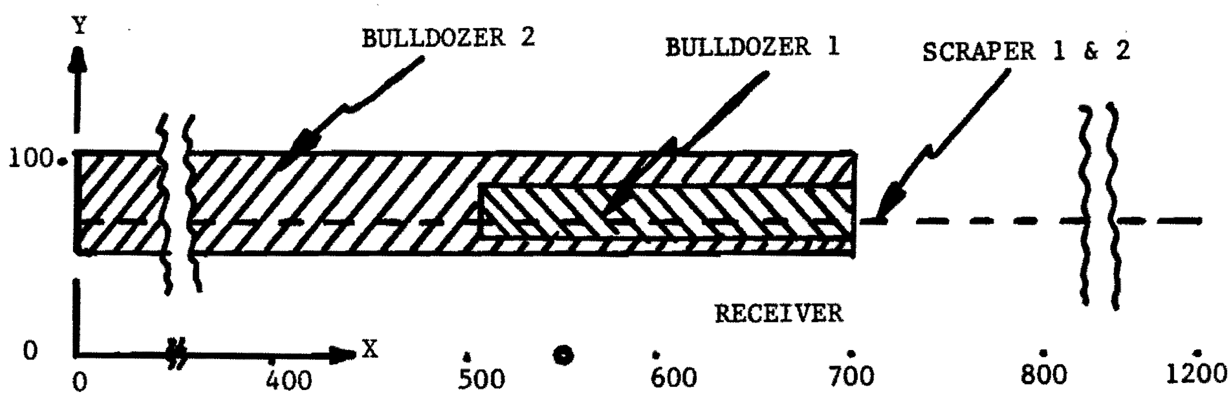


Figure 3. Site A Model Sketch

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME WB
PAGE 1 OF 5
DATE 12/10/82
PROJECT 440 A

FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
440 A BEHIND BLAIR HOUSE

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	40 FT From BLAIR	550	0	0	1.5
2					

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE
PREDICTION PROGRAM

NAME
PAGE 2 OF 5
DATE
PROJECT 440 A

FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
SCRAPER	CAT 621B	4	4	2

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 8 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	1200	70	0	15
2	0	70	12	
-				

VEHICLES PER HOUR	RETURN LOOP	
	TYPE(5)	RADIUS(6)
2	0	0

(5) SEE FORM 7; IF 0, ENTER POINT NUMBERS (SEE TO THE RIGHT)
(6) ENTER ANY VALUE IF TYPE IS 0 OR 7.

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)
0	

(7) ENTER 0 IF NON-STOP
(8) ENTER 0 TO HAVE PROGRAM COMPUTE AVERAGE SPEED (ONLY IF (7) IS NON-ZERO); ENTER ANY VALUE IF (7) IS 0.

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	REFERENCE SPEED	SLOPE	CRITICAL SPEED	CAPACITY	ACOUSTIC HEIGHT	FREQUENCY

Figure 4. Site A Worksheets (Page 1 of 2)

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE PREDICTION PROGRAM

NAME ______
PAGE 3 OF 5
DATE ______
PROJECT 440A

FORM 3: "HAUL" LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
SCRAPER	CAT 621B	4	4	4

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 8 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	0	70	12	20
2	580	70	3	3
3	700	70	3	15
4	1200	70	0	

VEHICLES PER HOUR	RETURN LOOP TYPE(5)	RETURN LOOP RADIUS(6)
6	0	0

POINT NUMBERS STOPPING(7)	POINT NUMBERS DECELERATION(8)
2	0

HICNOM
FHWA HIGHWAY CONSTRUCTION NOISE PREDICTION PROGRAM

NAME ______
PAGE 4 OF 5
DATE ______
PROJECT 440A

FORM 5: AREA SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
BULLDOZER	KOMATSU 85E	2	3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES
3.8	2	1

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
510	75	3	30	1
700	75	3	30	2
				3

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	GEOMETRY TYPE
BULLDOZER	KOMATSU 85E	2	3

HOURS WORKED(3)	NO. OF PTS. ON C/L(4)	NUMBER OF VEHICLES
4.2	2	1

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS FROM LAST AREA SOURCE

POINT COORDINATES

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	WIDTH AT THIS POINT	DO NOT ENTER
0	80	12	50	1
700	80	3	50	2
				3

Figure 4. Site A Worksheets (Page 2 of 2)

source (unloaded scrapers) was assigned model number 4 and was described by two endpoints representing the ends of the modelled site. Only one scraper passed by during the half hour measurement, which factored to an hourly volume of two scrapers. A loop type of zero indicates that these scrapers did not turn around in the modelled area. A stopping point of zero indicated that they did not stop in the modelled area.

The second SCRAPER source (loaded scrapers) was modelled by four points (entering site; stopping point; end of dozer push; leaving site). Speeds on the resulting three sections were estimated at 20, 3 and 15 mph. Three scrapers passed in this direction during the half hour, factoring to an hourly volume of 6. A loop type of zero was again used, and the stopping point was indicated as point 2.

The dozer was modelled as two sources: BULLDOZER 1 pushed the scrapers; BULLDOZER 2 worked the fill when no scrapers were present. Both sources were represented by a model number of 2 because the observed field noise levels corresponded most closely to that model number. Based on field observations, the dozer worked in the BULLDOZER 1 mode for about 47% of the time and in the BULLDOZER 2 mode for 53%. These percents factored to daily work durations of 3.2 and 4.8 hours (based on an 8-hour day). Both areas were defined by two endpoints, with area widths of 30 feet for BULLDOZER 1 and 50 feet for BULLDOZER 2. Figure 5 presents the input data file created by the program after the information on the worksheets was entered into the program.

The results of the program are shown in Figure 6. The total 8-hour L_{eq} at the receiver was 70.3 dBA. The major contributions were from the dozer, with the larger contribution during the push operations (BULLDOZER 1: 68.2 dBA).

The measured L_{eq} at this site was 73 dBA, which is 2.7 dBA higher than the predicted value. Part of the difference can be explained by the choice of

```
440A BEHIND BLAIR HOUSE
  1  RECEIVERS
     X          Y          Z      EX. ATT.(DB/DD)    DESCRIPTION
     550.0       0.0        0.0           1.50      40 FT FROM BLAIR
  0  POINT SOURCES
  2  LINE SOURCES
  2    POINTS                 FREQ.:  500              SCRAPER 1        CAT 621B
     X          Y          Z      LEQ(REF) VEH. DENS.
   1200.0      70.0        6.0       81.0 0.0000252
      0.0      70.0       18.0        0.0 0.0000000
  4    POINTS                 FREQ.:  500              SCRAPER 2        CAT 621B
     X          Y          Z      LEQ(REF) VEH. DENS.
      0.0      70.0       18.0       81.0 0.0000746
     560.0     70.0        9.0       81.0 0.0004105
     700.0     70.0        9.0       81.0 0.0000756
   1200.0      70.0        6.0        0.0 0.0000000
  2  AREA SOURCES
  2    POINTS                 FREQ.:  500              BULLDOZER   1   KOMATSU D85E
     X          Y          Z      LEQ(REF)   WIDTH
     510.0     75.0        9.0       74.8       30.0
     700.0     75.0        9.0        0.0       30.0
  2    POINTS                 FREQ.:  500              BULLDOZER   2   KOMATSU D85E
     X          Y          Z      LEQ(REF)   WIDTH
      0.0      80.0       18.0       75.2       50.0
     700.0     80.0        9.0        0.0       50.0
  0  BARRIERS
```

Figure 5. Site A Input Data File

```
440A EEHIND BLAIR HCUSE

RECEIVER NUMBER          LEQ          DESCRIPTION


        1                70.3      40 FT FROM BLAIR


COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER:  1

INDEX    INTENSITY     LEVEL      SOURCE           DESCRIPTION

  101    0.224348E+06  53.5    SCRAPER 1        CAT 621B
  102    0.444339E+06  56.5    SCRAPER 2        CAT 621B
  202    0.948045E+06  59.8    SCRAPER 2        CAT 621B
  302    0.481527E+05  46.8    SCRAPER 2        CAT 621B
10101    0.658647E+07  68.2    BULLDOZER    1   KOMATSU D85E
10102    0.244028E+07  63.9    BULLDOZER    2   KOMATSU D85E

KEY TC INDEX:
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALAGOUS TO LINE SOURCE VARIABLES.
```

Figure 6. Site A Results File

model number for the dozer. Model Number 2 has a reference emission level of 80 dBA at 50 feet. Field observations showed the Komatsu dozer to have a level closer to 81 dBA at the same distance. Thus, if the BULLDOZER levels were each adjusted upward 1 dBA, the total level at the site would be about 71.3 dBA, or only 1.7 dBA below the measurement.

3.0 SITE B: TRUCK HAUL ROAD

Site B was located near Station 360 of Project No. 5 of the I-440 Construction Project just east of the I-65 interchange, as shown in Figure 7. The microphone was located in the side driveway of the Proctor residence on West Iris Drive. The project right of way line was just behind this residence's backyard, where a tall fill for the S-E Ramp between I-65 and I-440 was being constructed.

At this site, Caterpillar 796 trucks were hauling material from the east along the future ramp, passing about 240 feet from the microphone. They dumped their loads approximately 220 feet beyond this passby point, and then returned to the east along the future ramp. A Caterpillar D8 dozer was spreading this material after it was dumped by the trucks. Off in the distance, shielded by the fill embankment, a pile driver was working near a railroad overpass for the N-E Ramp from I-65 to I-440.

This site was modeled with 3 sources: the "haul" line source of TRUCKS, the "non haul" line source of BULLDOZER, and the "point" source of PILE DRIVER. Figure 8 shows a sketch of the site as modeled for the program.

Figure 9 presents the coding worksheets used for the site. For site B, an excess attenuation value of 0 was used for this receiver because of the elevated fill. The trucks were represented by model number 1, and defined by a line of 2 points. An average speed of 20 mph was used between the 2 points. Eleven trucks entered the site during the half-hour measurement, which corresponded to an hourly volume of 22 trucks per hour. A loop type of 7 was used because the trucks simply performed a 3-point turn at the end of their haul before dumping their loads.

The Caterpillar D8 bulldozer was assigned a model number of 2. It worked along the "non haul" line for about half the measurement period, which factored to a work duration of 4.0 hours (per 8 hour day). Two points were used to describe this line.

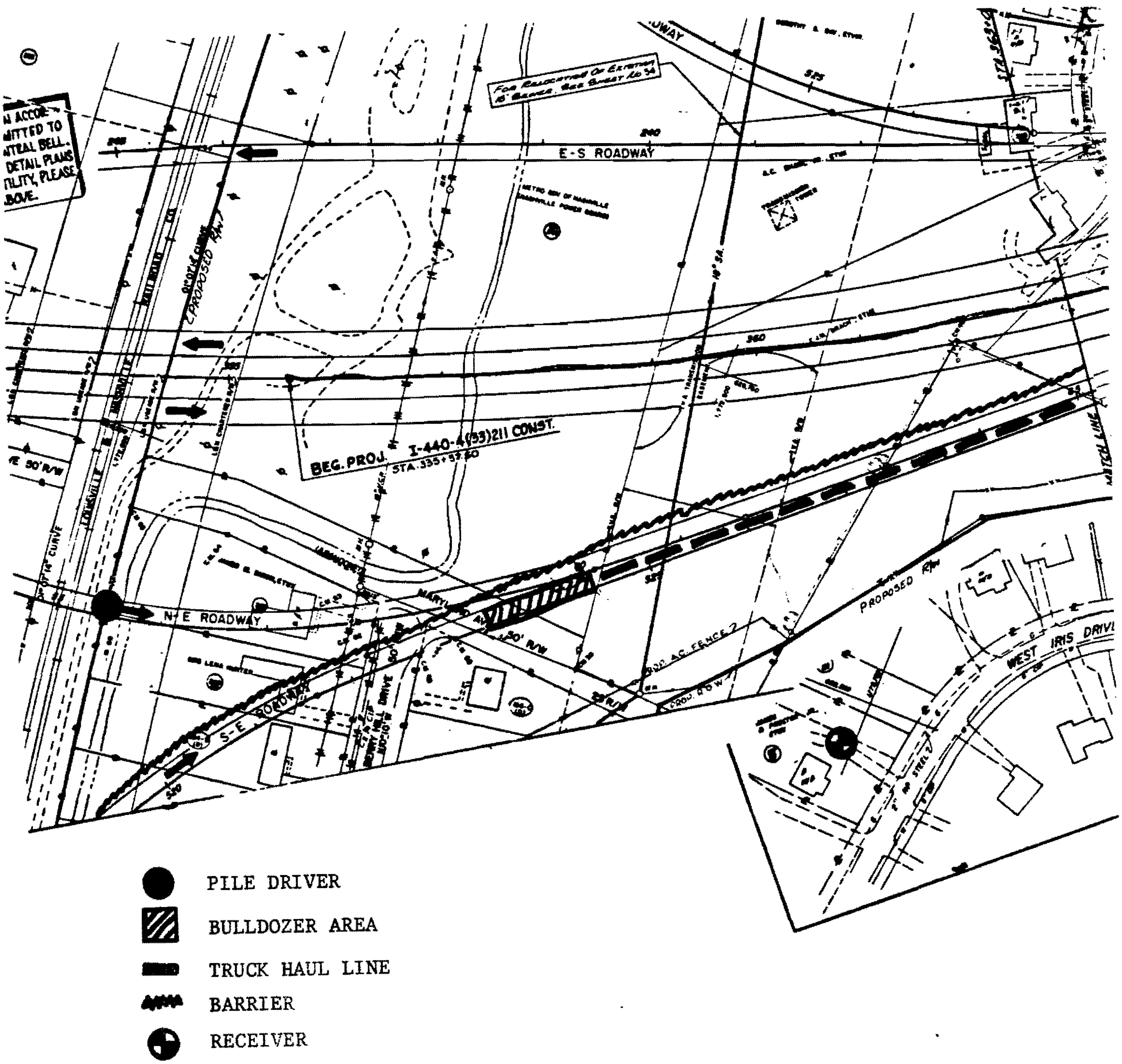


Figure 7. Site B Plan View

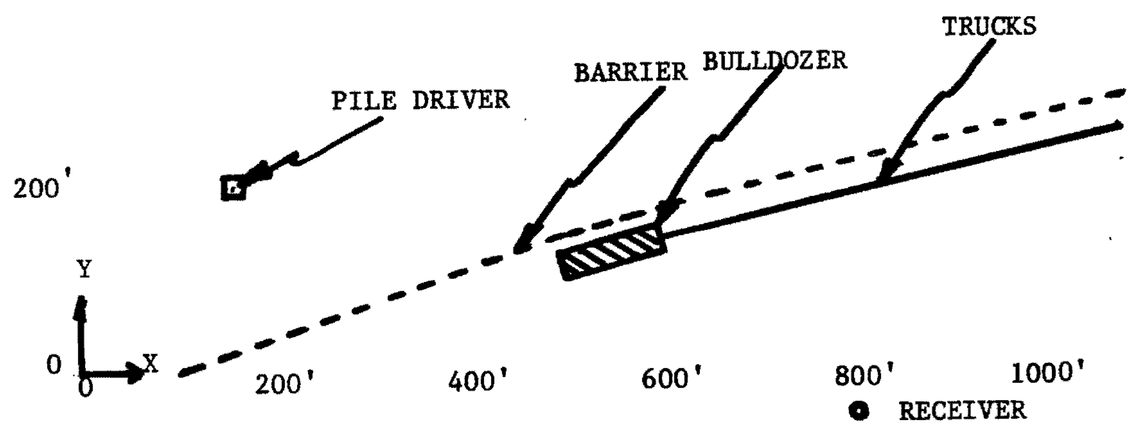


Figure 8. Site B Model Sketch

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FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
440B - TRUCK HAUL/DUMP, I-65 S-E RAMP; WEST IRIS DR.

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	PROCTOR RESID.	813	-58	0	0
•					

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FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	CAT 796	1	8	2

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	1074	220	25	20
2	592	138	25	

VEHICLES PER HOUR	RETURN LOOP TYPE(5)	RETURN LOOP RADIUS(6)
22	7	0

(5) SEE FORM 7; IF 0, ENTER POINT NUMBERS (SEE TO THE RIGHT)
(6) ENTER ANY VALUE IF TYPE IS 0 OR 7.

POINT NUMBERS STOPPING(7)	POINT NUMBERS DECELERATION(8)

(7) ENTER 0 IF NON-STOP
(8) ENTER 0 TO HAVE PROGRAM COMPUTE AVERAGE SPEED (ONLY IF (7) IS NON-ZERO); ENTER ANY VALUE IF (7) IS 0.

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	REFERENCE SPEED	SLOPE	CRITICAL SPEED	CAPACITY	ACOUSTIC HEIGHT	FREQUENCY

Figure 9. Site B Worksheets (Page 1 of 2)

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	CAT D-8	2	2	4.0	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
496	110	25	1
592	138	25	2

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS

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FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
PILE DRIVER	NE RAMP/RR TRACK	1	1	3.2	152	193	25

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FORM 6: BARRIER DATA

NUMBER OF BARRIERS
1

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)
SE RAMP EDGE	4

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
96	0	25
496	138	25
592	165	25
1074	248	25

Figure 9. Site B Worksheets (Page 2 of 2)

The pile driver working in the distance was assigned a model number of 1 ("nominal" data from the literature). The duration of this operation during the measurement period was factored to a value of 3.2 hours for an 8-hour day.

A barrier was defined for this site to account for the shielding of the pile driver noise by the S-E Ramp fill. Because this barrier did not shield the noise from the bulldozer or trucks, it was modelled as behind these sources. The barrier was represented by four points to account for the horizontal curve in the ramp. Figure 10 presents the input data file created by the program after the information on the worksheets was entered into the program.

The results of the computer run are shown in Figure 11. The total 8-hour L_{eq} at the receiver was 64.3 dBA. The largest contribution was from the pile driver, 62.4 dBA. The second major source was the bulldozer with a level of 58.8 dBA.

The measured L_{eq} at this site was 67 dBA, which is 2.7 dBA higher than the predicted value. Field observations of the pile driver levels showed a maximum level of 66 dBA, so it appears that the pile driver contribution in the model is reasonable. The contribution for the trucks in the model seem low, although this could be attributed to the relatively small number of trucks when averaged over an hourly L_{eq} value. No emission level data on the trucks could be gathered because of the lack of access to the top of the fill.

```
440B - TRUCK HAUL/DUMP, I-05 S-E RAMP; WEST IRIS DR.
  1  RECEIVERS
     X           Y           Z      EX. ATT.(DB/DD)    DESCRIPTION
     813.0       -58.0        0.0         0.00      PROCTOR RESID.
  1  POINT SOURCES
     X           Y           Z       LEQ(REF)   FREQ.    SOURCE          DESCRIPTION
     152.0       193.0        45.0        67.3  1500  PILE DRIVER 1   NE RAMP/RR TRACK
  2  LINE SOURCES
  2    POINTS                 FREQ.:  500             BULLDOZER   1   CAT D8
     X           Y           Z      LEQ(REF) VEH. DENS.
     496.0       110.0        31.0        75.0 0.0100000
     592.0       138.0        31.0         0.0 0.0000000
  3    POINTS                 FREQ.:  500             TRUCKS  1       CAT 796
     X           Y           Z      LEQ(REF) VEH. DENS.
    1074.0       220.0        31.0        68.5 0.0002816
     592.0       138.0        31.0        76.0 0.0002816
    1074.0       220.0        31.0         0.0 0.0000000
  0  AREA SOURCES
  1  BARRIERS
  4  POINTS     DESCRIPTION: SE RAMP EDGE
     X           Y           Z
      96.0         0.0        25.0
     496.0       138.0        25.0
     592.0       165.0        25.0
    1074.0       248.0        25.0
```

Figure 10. Site B Input Data File

440E - TRUCK HAUL/DUMP, I-65 S-E RAMP; WEST IRIS DR.

RECEIVER NUMBER	LEQ	DESCRIPTION
1	64.3	PROCTOR RESID.

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 1

INDEX	INTENSITY	LEVEL	SOURCE	DESCRIPTION
1	0.172117E+07	62.4	PILE DRIVER 1	NE RAMP/RR TRACK
101	0.753136E+06	58.8	BULLDOZER 1	CAT D8
102	0.346089E+05	45.4	TRUCKS 1	CAT 796
202	0.194620E+06	52.9	TRUCKS 1	CAT 796

```
KEY TO INDEX:
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                    AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALAGOUS TO LINE SOURCE VARIABLES.
```

Figure 11. Site B Results File

4.0 SITE C: I-440 CUT SECTION

Site C was located in the northeast quadrant of the I-440/Nolensville Road interchange. A wide area of earth and rock was being excavated from this site and hauled to Site B, discussed in Section 3.0. Figure 12 shows a plan view of this site.

There was a great deal of activity at this site. Nearest to the microphone, which was located at the end of a dead end street at the right of way fence, was a major earth excavating operation. Two Caterpillar D8 dozers were pushing material down from a railroad embankment into the cut section. A Caterpillar 9888 wheeled loader and Caterpillar 983 tracked loader were operating opposite one another filling Caterpillar 796 trucks. The trucks then hauled this material away from the site.

About 500 feet away, four compressor/rock drill units were working in a rock section. All four compressors were made by Gardner-Denver (750/dfm). Two of these compressors were newer models that appeared to have been built to meet U.S. Environmental Protection Agency standards. The other two were noisy older models.

As shown in Figure 13, this site was modeled with 10 point sources, two "non haul" line sources, and one "haul" line source. In addition, an earth mound fairly close to the microphone shielded the noise from the bulldozers along part of their line; the mound was thus modelled as a barrier.

The four rock drills were modelled as source type BREAKER, model number 1. Based on observations of their operations, values for their workday duration were computed as 1.9 hours, 1.2 hours, 4 hours and 2.1 hours. The two older noisy compressors were assigned model numbers of 1, while the two newer ones were assigned model numbers of 4. All four compressors operated during the entire measurement period, so the workday duration for them was 8 hours.

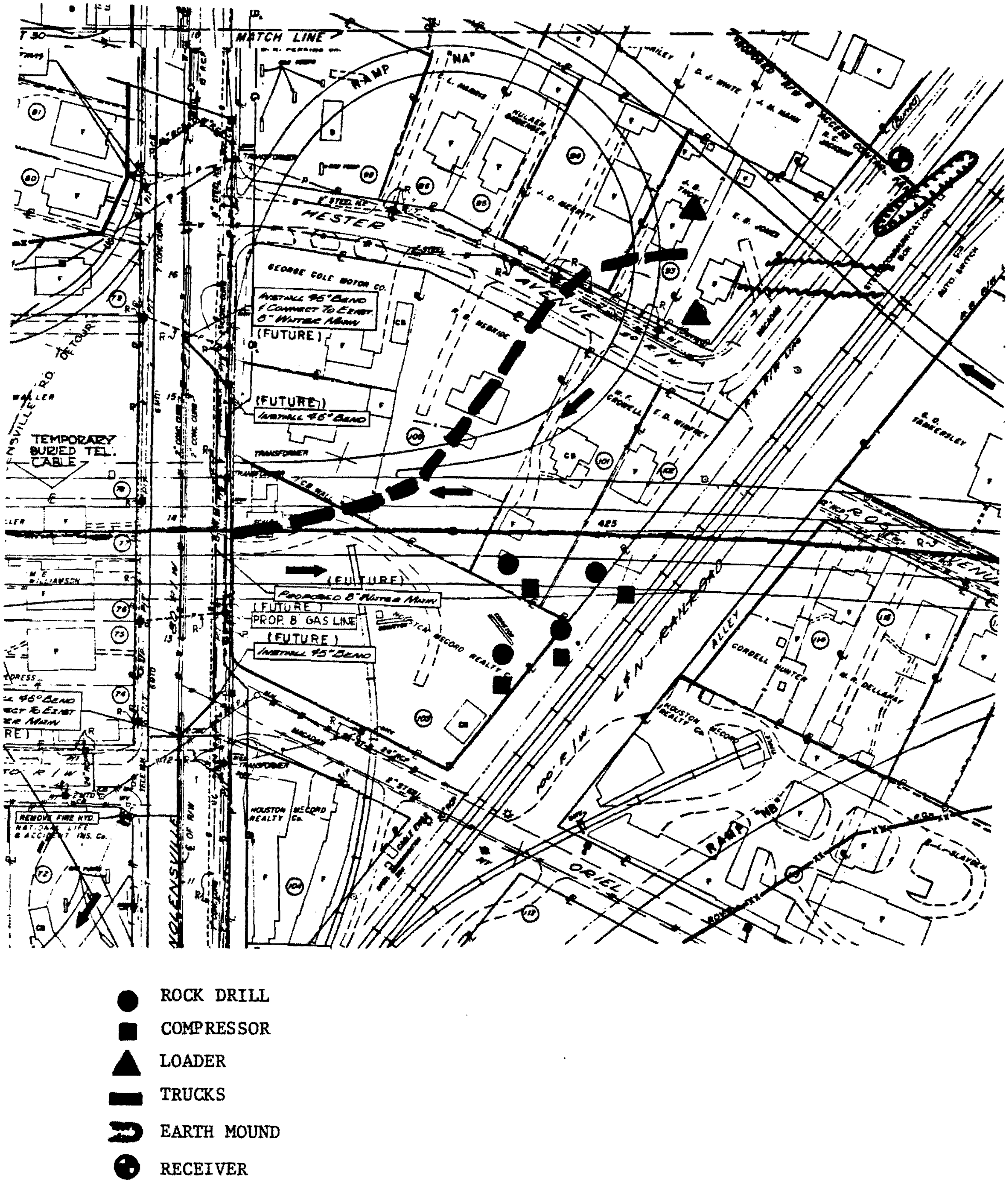

Figure 12. Site C Plan View

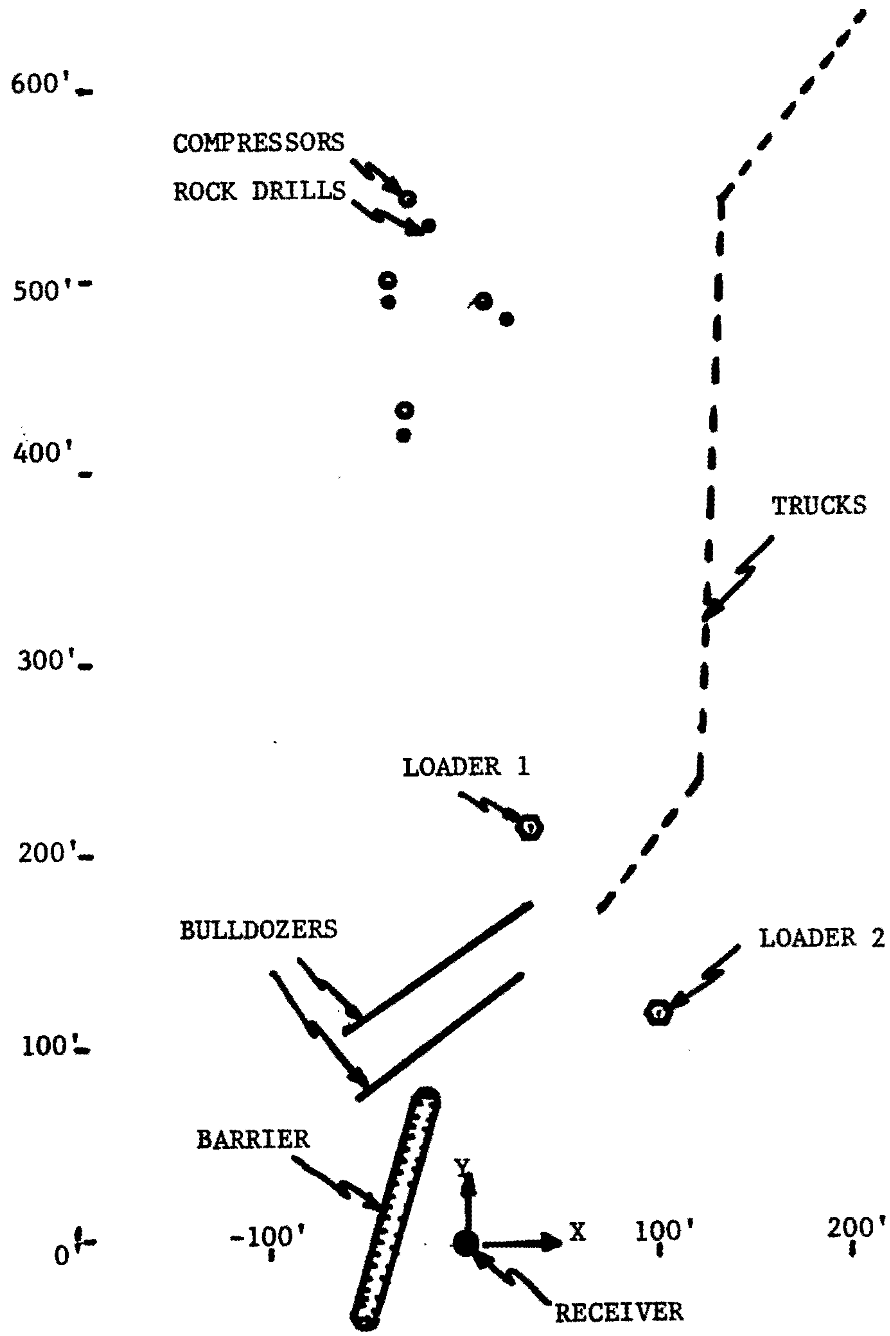

Figure 13. Site C. Model Sketch

The two loaders were also modelled as point sources because they operated over a fairly small area. Both were assigned model numbers of 5. The wheeled loader (Caterpillar 9888) was computed to have a work duration of 5.9 hours, while the tracked loader (Caterpillar 983) was assigned a work hour duration of 4.8 hours.

Both bulldozers were Caterpillar D8 models, and were therefore assigned model numbers of 2. The percents of time that the two bulldozers were in operation during the measurement period were facted to "hours worked" of 4.8 and 5.6, respectively. Both were modelled as "non haul" line sources, where each line consisted of two endpoints.

The trucks that were being loaded by the loaders were Caterpillar 796 models, and were thus assigned a model number of 1. The trucks entered the site through a temporary underpass approximately 700 feet from where they were being loaded. Their travel path was described by three straight line segments (four points). When they reached the loading area, they made a 3-point turn and backed under the loader buckets; this manuever is described by a loop type of 7. Segment speeds of 20, 15 and 5 miles per hour were assigned to the three segments as the trucks approached the loading point. Ten trucks entered the site during the 30 minute measurement period, which factored to an hourly volume of 20 trucks per hour. Figure 14 shows the coding worksheets for the site, and Figure 15 shows the formatted input file.

The prediction results for this site are shown in Figure 16. The total predicted 8-hour L_{eq} at the receiver was 76.5 dBA. Examining the component contributions shows that many of the sources were major contributors to the total level at the receiver. While none of the contributions exceeded 70 dBA, seven of them were between 65 and 70 dBA. The two loudest components were the distant older compressors. The tracked loader (LOADER 2) was the third highest contributor (67.9 dBA). BREAKER 3, which ran continuously during the measurement period, LOADER 1, and the two bulldozers also had significant contributions. The least noisy components were the two newer quiet compressors (COMPRESSORS 3 and 4) and the trucks on the haul road. The small contribution from the compressors was due to their low emission level, while the small contribution from the trucks was due to their relatively low volume during the period.

The measured L_{eq} at the site for a 30 minute period was 80 dBA. Thus, the model predicted 3.5 dBA lower than the measurement. As with most measured/predicted differences, the reason could likely be the emission levels for the equipment. Because this was a large complex site with many sources of noise, it would be virtually impossible to make emission level measurements without interfering with contract operations.

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FORM 1 - TITLE AND RECEIVER DATA

PROBLEM TITLE (ENTER AS ONE LINE)
440C: INTERCHANGE AT NOLENSVILLE RD.

NUMBER OF RECEIVERS (MAXIMUM OF 10)
1

DO NOT ENTER	DESCRIPTION (MAX. 16 CHARACTERS)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	EXCESS GROUND ATTEN. (DB/DD)
1	END RD. @ ROW	0	0	0	0
2					

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FORM 2 - POINT SOURCE DATA

POINT SOURCES (MAXIMUM OF 10)

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS NUMBER(3)	X-COORDINATE	Y-COORDINATE	Z-COORDINATE
BREAKER	ROCK DRILL (15)	1	1	1.2	22	478	0
COMPRESSOR	GARD:DEN. OLD		1	8	12	488	0
BREAKER	ROCK DRILL (16)	1	1	1.9	-22	533	0
COMPRESSOR	GARD.-DEN. OLD		1	8	-32	543	
BREAKER	ROCK DRILL (17)	1	1	4	-43	489	0
COMPRESSOR	GARD:DEN. NEW		1	8	-43	499	0
BREAKER	ROCK DRILL (18)	1	1	2.1	-33	424	0
COMPRESSOR	GARD.-DEN. NEW		1	8	-33	434	
LOADER	CAT 9888	5	1	4.8	100	120	0
LOADER	CAT 983	5	1	5.9	35	217	0

Figure 14. Site C Worksheets (Page 1 of 3)

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FORM 3: 'HAUL' LINE SOURCEDATA

SOURCE TYPE (1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NO.(2)	HOURS WORKED(3)	NO. OF PTS. IN LINE(4)
TRUCKS	CAT 796	1	5	4

NOTES: (1),(2),(3): SEE FORM 2 FOR EXPLANATION; (4) ENTER 0 TO REUSE POINTS FROM LAST HAUL SOURCE

POINT COORDINATES (MAX. = 20; MAX. = 6 IF RETURN LOOP TYPE IS 0)

DO NOT CODE	X-COORDINATE	Y-COORDINATE	Z-COORDINATE	SEGMENT SPEED
1	207	641	6	20
2	130	544	0	15
3	120	239	0	5
4	65	174	0	

VEHICLES PER HOUR	RETURN LOOP	
	TYPE(5)	RADIUS(6)
20	7	0

(5) SEE FORM 7; IF 6, ENTER POINT NUMBERS (SEE TO THE RIGHT)
(6) ENTER ANY VALUE IF TYPE IS 6 OR 7.

POINT NUMBERS	
STOPPING(7)	DECELERATION(8)

(7) ENTER 0 IF NON-STOP
(8) ENTER 0 TO HAVE PROGRAM COMPUTE AVERAGE SPEED (ONLY IF (7) IS NON-ZERO); ENTER ANY VALUE IF (7) IS 0.

IF SOURCE TYPE IS 'USER DEFINED' OR MODEL NUMBER IS 0, ALSO ENTER:

MAXIMUM LEVEL	REFERENCE SPEED	SLOPE	CRITICAL SPEED	CAPACITY	ACOUSTIC HEIGHT	FREQUENCY

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	CAT D8	2	2	5.6	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-65	109	0	1
33	174	0	2

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS

Figure 14. Site C Worksheets (Page 2 of 3)

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FORM 4 - 'NONHAUL' LINE SOURCE DATA

SOURCE TYPE(1)	DESCRIPTION (MAX. 16 CHAR.)	MODEL NUMBER(2)	GEOMETRY TYPE	HOURS WORKED(3)	NUMBERS OF POINTS IN LINE(4)
BULLDOZER	CAT D8	2	2	4.8	2

POINT COORDINATES (MAX. = 20)

X-COORDINATE	Y-COORDINATE	Z-COORDINATE	DO NOT ENTER
-54	76	0	1
33	141	0	2
			•

NOTES:
(1),(2),(3): SEE FORM 2 FOR EXPLANATION
(4) ENTER 0 TO REUSE POINTS

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FORM 8: BARRIER DATA

NUMBER OF BARRIERS
1

MAXIMUM IS 3

DESCRIPTION (MAX. 16 CHAR.)	NUMBER OF POINTS (MAX. 5)
EARTH MOUND	2

X-COORDINATE	Y-COORDINATE	Z-COORDINATE
-50	-30	12
-20	75	12

Figure 14. Site C Worksheets (Page 3 of 3)

```
440C: INTERCHANGE AT NOLENSVILLE ROAD
  1  RECEIVERS
     X          Y            Z      EX. ATT.(DB/CC)    DESCRIPTION
       0.0        0.0        0.0           0.00      END RD. @ ROW
 10  POINT SOURCES
     X          Y            Z        LEQ(REF)  FREQ.    SOURCE           DESCRIPTION
      22.0      478.0        2.0         62.8  1500  BREAKER 1          ROCKDRILL (15)
      12.0      468.0        4.0         89.3  1000  COMPRESSOR   1     GARD.-DEN. OLD
     -22.0      533.0        2.0         80.8  1500  BREAKER 2          ROCKDRILL (16)
     -32.0      543.0        4.0         89.3  1000  COMPRESSOR   2     GARD.-DEN. OLD
     -43.0      489.0        2.0         86.0  1500  BREAKER 3          ROCKDRILL (17)
     -43.0      499.0        4.0         65.0  1000  COMPRESSOR   3     GARD.-DEN. NEW
     -33.0      424.0        2.0         83.2  1500  BREAKER 4          ROCKDRILL (18)
     -33.0      434.0        4.0         65.0  1000  COMPRESSOR   4     GARD.-DEN. NEW
      35.0      217.0        6.0         78.7   500  LOADER  1          CAT 988B
     100.0      120.0        6.0         77.8   500  LOADER  2          CAT 983
  3  LINE SOURCES
  5    POINTS              FREQ.:  500             TRUCKS  1            CAT 796
     X          Y            Z      LEQ(REF) VEH. DENS.
     207.0      641.0        6.0         76.0 0.0003779
     130.0      544.0        6.0         76.0 0.0005039
     120.0      239.0        6.0         63.1 0.0004761
      65.0      174.0        6.0         76.0 0.0004761
     120.0      239.0        6.0          0.0 0.0000000
  2    POINTS              FREQ.:  500             BULLDOZER    1     CAT D8
     X          Y            Z      LEQ(REF) VEH. DENS.
     -54.0       76.0        6.0         75.8 0.0092061
      33.0      141.0        6.0          0.0 0.0000000
  2    POINTS              FREQ.:  500             BULLDOZER    2     CAT D8
     X          Y            Z      LEQ(REF) VEH. DENS.
     -65.0      109.0        6.0         76.5 0.0085036
      33.0      174.0        6.0          0.0 0.0000000
  0  AREA SOURCES
  1  BARRIERS
  2  POINTS      DESCRIPTION: EARTH MOUND
     X          Y            Z
     -50.0      -30.0       12.0
     -20.0       75.0       12.0
```

Figure 15. Site C Input Data File

440C: INTERCHANGE AT NOLENSVILLE ROAD

RECEIVER NUMBER	LEQ	DESCRIPTION
1	76.5	END RD. @ ROW

COMPONENT CONTRIBUTIONS FOR RECEIVER NUMBER: 1

INDEX	INTENSITY	LEVEL	SOURCE		DESCRIPTION
1	0.208049E+07	63.2	BREAKER 1		ROCKDRILL (15)
2	0.892972E+07	69.5	COMPRESSOR	1	GARD.-DEN. OLD
3	0.105620E+07	60.2	BREAKER 2		ROCKDRILL (16)
4	0.719175E+07	68.6	COMPRESSOR	2	GARD.-DEN. OLD
5	0.413026E+07	66.2	BREAKER 3		ROCKDRILL (17)
6	0.315156E+05	45.0	COMPRESSOR	3	GARD.-DEN. NEW
7	0.288792E+07	64.6	BREAKER 4		ROCKDRILL (18)
8	0.417308E+05	46.2	COMPRESSOR	4	GARD.-DEN. NEW
9	0.383590E+07	65.8	LOADER 1		CAT 9888
10	0.617377E+07	67.9	LOADER 2		CAT 983
101	0.123759E+05	40.9	TRUCKS 1		CAT 796
201	0.103229E+06	50.1	TRUCKS 1		CAT 796
301	0.417364E+04	36.2	TRUCKS 1		CAT 796
401	0.813795E+05	49.1	TRUCKS 1		CAT 796
102	0.476946E+07	66.8	BULLDOZER	1	CAT D8
103	0.346001E+07	65.4	BULLDOZER	2	CAT D8

KEY TO INDEX:

```
    X - POINT SOURCE, WHERE X OR XX IS INPUT SEQUENCE # OF POINT SOURCES.
   XX
  YXX - LINE SOURCE, WHERE XX IS INPUT SEQUENCE # OF LINE SOURCES
 YYXX                      AND Y OR YY IS SEQUENCE # OF POINTS FOR THE XXTH LINE.
1YYXX - AREA SOURCE, WHERE XX AND YY ARE ANALAGOUS TO LINE SOURCE VARIABLES.
```

Figure 16. Site C Results File

5.0 SUMMARY AND CONCLUSIONS

Measurements and predictions of highway construction noise were made and compared at three construction sites for Interstate 440 in Nashville, Tennessee. The results are summarized below:

Site	Measured L_{eq} (dBA)	Predicted L_{eq} (dBA)	Measured-Predicted (dBA)
A	73	70.7	2.7
B	67	64.3	2.7
C	80	76.5	3.5

In all three sites, the measured values were higher than the predicted values. There are two probable and one other possible reason for these differences. The two probable reasons are:

- a higher emission level for the major noise contributors than was modelled;
- a lower value for the adjustment made to this emission level to obtain the work cycle equivalent sound level than was modelled.

The other possible reason could be a difference in the excess attenuation propagation rate from the sources to the receiver. However for two of the sites, a conservatively high value of zero decibels excess attenuation per distance doubling was used.

It is very difficult when collecting data from targets of opportunity, as these sites were, to make emission level measurements. Emission level data was obtained for the bulldozer at Site A because of the closeness of the operation to the right of way, and because the bulldozer was often the only piece of equipment on the site. As noted in Section 2.0, the predicted value for Site A could be adjusted upwards 1 dBA based on the emission level measurements, which would only put the predictions 1.7 below the measurement. However, at the other sites, emission levels could not be measured without access onto the site in order to get close enough to the equipment. Even then, the equipment in question would have to be tested when the other sources of noise were not running. As an alternative, the equipment to be tested could be removed from the site where its noise level could be isolated. In either case special cooperation from the contractor or state highway agency would be needed.

Determining the adjustment to the maximum level for the work cycle would be a bit easier than measuring the emission level, but is still difficult. This determination would be done by observing the average time to complete a work cycle and the levels associated with each phase of the cycle. However, when observations are being made at a site such as Site C, where there are 13 different noise sources, it is difficult enough to keep track of overall percent of time in operation for each source without having to make work cycle observations.

Despite the differences in the measurements and the predictions, the model performed fairly well. Given the above mentioned possible reasons for differences, it was encouraging that a site as complex as Site C could be modeled to be within 3.5 dBA of a measured value.

In conclusion, this data makes a positive contribution to the model validation data base for the HICNOM highway construction noise prediction model. Further validation is still warranted, especially in the areas of source emission levels and work cycle L_{eq} adjustments.

For studies during project planning and design, the model seems to be a valid analysis tool, accurate to the degree that the input data assumptions are accurate. Those assumptions can be considerable: what equipment will be on the site and in what quantity; where will the equipment be located; how long will it operate; etc. This study does, however, support the conclusion that if these parameters are known, the model produces good predictions. Thus, for example, if abatement measures are being analyzed while a project is under construction, realistic answers will be obtained, especially if the engineer is able to obtain specific emission level data for the equipment under study.

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