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AN AIRPORT COMMUNITY NOISE-IMPACT ASSESSMENT MODEL

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SUMMARY

A computer model has been developed to assess the noise impact of an airport on the community which it serves. Assessments are made using the Fractional Impact Method by which a single number describes the community aircraft-noise environment in terms of exposed population and multiple-event noise level. The model is comprised of three elements: a conventional noise footprint model, a site-specific population distribution model, and a dose-response transfer function. The footprint model provides the noise distribution for a given aircraft operating scenario. This information is combined with a site-specific population distribution obtained from a national census data base to yield the number of residents exposed to a given level of noise. The dose-response relationship relates noise exposure levels to the percentage of individuals who would describe themselves as "highly annoyed" by those levels. This information is used to compute a single-number descriptor of the airport noise environment. In addition to providing a quantitative assessment of the noise environment in the community at large, the model generates a report which lists several demographic variables as a function of noise level which are of interest to community planners and others. These variables include population density, growth rate, average age, average home value, percent homeowners, percent renters, and others. This paper describes the structure and operation of the community response model and presents the results of initial noise impact assessment studies.

N81-23713 #

INTRODUCTION

Airport noise exposure levels have long been determined by means of noise "footprint" models, which are used to define the contours of constant noise level associated with a specified operations scenario, usually described in terms of fleet mix, aircraft schedules, ground tracks, approach and takeoff profiles, and runway use rates. (Refs. 1, 2) Noise footprints provide a graphic description of the area subjected to a given level of noise and are a relatively convenient means for studying how the size and shape of areas exposed to various levels of aircraft noise can be changed by airport operations changes.

While noise footprints are very well suited to describing noise levels in an airport community, certain simplifying assumptions are necessary before one can assess the impact of aircraft noise on the residents of an airport community using only a footprint model. Among these are assumptions about the population distribution under the noise footprint. (Clearly, it makes little difference how noisy it is in unpopulated areas, and noise abatement countermeasures which have their largest influence in such areas will do little to affect the impact of airport noise on the surrounding community, while actions which result in even a relatively small degree of relief in densely populated areas could significantly reduce the overall community noise impact.) Thus, the population distribution is equally important as the noise distribution when the task is to assess the impact of noise on people.

In order to provide a quantified noise impact assessment, the conventional noise footprint approach must be augmented not only with a description of the population distribution, but with some description of how individuals respond to aircraft noise. A "dose-response" transfer function, which expresses a functional relationship between noise level and some measure of human response, serves as this subjective response element of the airport noise-impact assessment model described herein.

This paper describes NASA Langley Research Center's Aircraft-noise Levels and Annoyance Model (ALAMO); a community noise impact assessment model which extends the conventional noise footprint concept to include site-specific population distributions and a relationship between noise level and subjective response (annoyance).

ASSESSMENT METHOD

The ALAMO model makes use of the Fractional Impact Method (FIM) to describe the impact of aircraft noise on an airport community. This approach assumes that the degree of noise impact experienced by residents of an airport community is a monotomically increasing function of the noise level to which they are exposed. (Previous applications of this concept to the problem of aircraft noise impact assessment are described in reference 3.) In a recent analysis of social survey data, Schultz (ref. 4) has found a relationship between the average percentage of subjects who described themselves as "highly annoyed" with their noise environment and the day-night average sound level (L_{dn}) of noise to which they are exposed. This relationship is used in ALAMO to describe the relative impact of different noise exposures on different population groups in the following way: The Schultz transfer function is normalized to unity at an L_{dn} value of 75. This results in a weighting function of the "fraction of impact" which corresponds to a given noise level assuming an impact of 100 percent at an L_{dn} of 75. This weighting function is shown in figure 1. The number of people exposed to a given noise level is multiplied by the corresponding weighting factor. The sum of all the population groups so weighted is called the Level Weighted Population (LWP) and represents a quantitative assessment of noise impact in an airport community.

Working Group 69 of the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) developed the LWP concept used in ALAMO and has recommended LWP as a means for quantifying noise impact in their "Guidelines for Preparing Environmental Impact Statements on Noise" (ref. 5), prepared at the request of the Environmental Protection Agency (EPA). Also described in reference 5 is a second noise impact descriptor called the Noise Impact Index (NII), which is defined as the ratio of LWP to the total impacted population. The NII is a useful measure for comparing the relative impact of one noise environment with another.

MODEL COMPONENTS

The Fractional Impact Method requires that noise and population levels be known throughout the airport community. Since the design philosophy behind the development of the ALAMO model dictated that a modular approach be used which would take advantage of existing impact assessment technology as much as possible, two recently developed "stand-alone" programs were incorporated into ALAMO to provide the necessary noise and population information. Each of these are described briefly in this section.

Noise Distribution

One of the major components of ALAMO is the Integrated Noise Model (INM), a conventional noise footprint model developed by Wyle Laboratories under the sponsorship of the Federal Aviation Administration (FAA) in 1978 to provide the means for fulfilling FAA regulatory requirements for an environmental impact assessment of proposed airport alterations which are federally funded (ref. 6). The INM is comprised of a number of computer programs which predict noise levels either for selected points in the airport community (as identified by the user) or in terms of contours of constant noise level. Noise levels can be expressed using any one of five available noise metrics: Noise Exposure Forecast (NEF), Equivalent Sound Level (L_{eq}), Day-Night Average Sound Level (L_{dn}), Community Noise Equivalent Level (CNEL), and time of exposure above a threshold of A-weighted sound level (TA). The INM data base contains a wide variety of commercial jet transports, including the Concorde SST, as well as a number of general aviation aircraft. Aircraft contained in the INM data base are listed in Table I.

In order to predict noise levels around an airport with INM, the user must describe the runway configuration (number, length, and orientation), the ground tracks associated with each runway, and the profiles associated with each ground track. Furthermore, the number of operations must be specified by operation type (takeoff or landing), time of day (day, evening, or night), aircraft type, and for departing aircraft, the stage length. Convenient defaults are included in the INM to simplify the definition of approach and takeoff profiles. The INM user also specifies the noise metric to be used in the analysis and defines the type of output desired (contour plots of constant noise level or printouts describing the noise level at user specified points on the ground). When contour plots are desired, the user specifies the noise levels to be associated with each contour.

Population Distribution

ALAMO contains a large demographic data base management program developed by CACI, Inc. called SITE II. It is based on US census data which is made commercially available on an as is basis. SITE II is capable of generating a demographic profile report for residents of user-specified closed contours (size and shape essentially arbitrary) located anywhere in the United States. The desired contour is approximated by a polygon formed from up to 150 points whose coordinates are given relative to a reference point, which is defined by its longitude and latitude. For the fractional impact analyses conducted by ALAMO, contours of constant noise level are generated by INM and passed to SITE II, which generates demographic profile reports describing the residents inside each contour. The most important output of SITE II for FIM noise impact assessment is, of course, the number of people residing within each noise contour, however, SITE II outputs a number of other demographic variables which are of interest to noise control planners, including age distribution, distribution of property values, number of households with and without air conditioning, i.e., with windows closed or opened in the summer, percentage of residents who own their own homes, percentage of residents who rent, the number of single-family dwellings, and the number of apartment buildings. Other demographic variables are also available which, while not of direct interest in a noise impact analysis, may nontheless provide some insight into the prevailing attitudes of the impacted population toward the airport. Family income, ethnic origin, occupation, and education level are examples of such variables. Figure 2 is an example of a SITE II demographic profile report which describes the residents inside the L_{dn} 61 contour at Patrick

Henry Field, Newport News, Virginia. Approximately 10 percent of the residents exposed to this noise level would describe themselves as "highly annoyed" according to the dose-response transfer function developed in reference 4.

OPERATION OF MODEL

The operation of the ALAMO assessment model is described in this section. Some of the results of a recent impact assessment exercise involving Patrick Henry Airport in Newport News, Virginia, are used for illustration. Patrick Henry is a small airport serving the Lower Peninsula of Virginia with 26 regularly scheduled commercial jet transport operations (landings and takeoffs of B-727's, B-737's, and BAC-111's) and typically 100 to 200 general aviation operations daily. A detailed description of the ground tracks, profiles, and schedules which comprise the Patrick Henry operating scenario will not be presented here, since it is not our intention to focus on the details of this particular impact assessment, but rather to illustrate the operation of the ALAMO model.

The user initiates an ALAMO impact assessment by describing the airport operations in an INM-compatible format. (Reference 1 contains detailed formatting information.) ALAMO passes this information to INM, which generates L_{dn} noise contours from L_{dn} 35 to L_{dn} 90, in 5 dB increments. These contours generally divide the community into concentric bands around the airport, with the residents of each band exposed to a different noise level. ALAMO further subdivides the airport community by superimposing an octant "compass rose" over the INM-generated noise footprint, dividing each band around the airport into eight sections. Thus, the entire airport community is subdivided into regions, each of which is identified by a unique combination of noise level and direction from the airport. It thus becomes possible to describe the impact of airport noise on those residents exposed to levels between 65 L_{dn} and 70 L_{dn} who live to the north-northwest of the airport, for example. Figure 3 is an example of a noise footprint with an octant "compass rose" superimposed. This footprint describes noise levels in the community around Patrick Henry Airport. (Only four L_{dn} contours are included in this figure to reduce clutter.)

ALAMO performs a FIM impact assessment on the community as a whole and on each of the eight octants separately. This results in an overall community impact assessment and an impact assessment as a function of direction from the airport, which helps to identify those neighborhoods which experience the greatest noise impact in a given airport community.

The first step which ALAMO takes in performing these analyses is to determine which regions (bounded by adjacent L_{dn} contours and two adjacent lines from the compass rose) are "impacted." In its current configuration, ALAMO declares a region "impacted" if the airport noise increases the total day-night average noise level by at least one decibel. Thus, the airport noise is compared with an estimate of what the noise level would be in the absence of the airport, based on the following empirical relationship between ambient noise level and population density, due to Galloway (ref. 7).

$$L_{dn} = 10 \log \rho + 22$$

The quantity ρ is the population density expressed on a per-square-mile basis. Those regions for which the levels of airport noise are far enough below the estimated ambient noise level to have no impact on the region by the above criterion are excluded from further analysis.

For each region which ALAMO defines as impacted by airport noise, the fractional impact is computed by multiplying the population of that region by a level-dependent weighting factor, as described in an earlier section. The Level Weighted Population (LWP) is computed (for the community as a whole and for each octant separately) by summing these fractional impacts. Finally, the Noise Impact Index (NII) is computed for each octant and for the entire community by dividing the LWP values by the corresponding (unweighted) population figures.

ALAMO generates an impact summary report for each analysis which lists the Level Weighted Population and the Noise Impact Index for each octant and for the entire community, as well as the number of people residing in impacted regions and the number and percentage of impacted persons who would describe themselves as "highly annoyed" by airport noise according to the transfer function of reference 4. Also included in the summary report is a quantity called the equivalent noise level. This represents the uniform L_{dn} level which would result in the corresponding LWP/NII values listed in the summary report and is provided simply to give the user a better intuitive "feel" for the degree of noise impact than the LWP/NII numbers tend to provide.

Figure 4 is an example of an impact summary report for Patrick Henry Airport. This report indicates that 32,684 people reside near enough to the airport to be impacted according to the criterion described above. Of these, 3,245 are exposed to levels high enough to be "highly annoyed" by the aircraft noise. This represents 9.9 percent of the total impacted population and corresponds to an equivalent uniform noise level of L_{dn} 60. Most of the residents predicted to be highly annoyed with aircraft noise live to the west-southwest of the airport (over 60 percent). Here there is an equivalent uniform noise level of L_{dn} 64, with 14.8 percent of the impacted residents of this octant expected to describe themselves as highly annoyed. No adverse effect is predicted for residents living to the south-southwest, south-southeast, east-southeast, and north-northwest of the airport.

In addition to this impact summary report, a report is generated which list various demographic variables as a function of noise level (fig. 5). This report reveals several interesting features of the airport community surrounding Patrick Henry International Airport.

First, there are no residents exposed to levels in excess of L_{dn} 75. (Contours of L_{dn} 50 and lower required more points to define than INM could accommodate. For such a case, ALAMO prints the message "No Contour Found"). The population density is significantly greater where the noise levels are relatively high than where they are relatively low. The average ages of adults in the higher noise-level areas is somewhat greater than in the lower noise-level areas and the percentage of residents 65 years old and older also appears to increase somewhat with noise level. Average family income increases with increasing noise level while average home values apparently decrease slightly. (The average family income in the L_{dn} 70-75 band is 24 percent higher than in the L_{dn} 55-60 band while home values in the L_{dn} 70-75 band are about 4 percent lower than in the L_{dn} 55-60 band.)

These results present a profile of the airport community which may be of interest to individuals or groups concerned with the impact of airport noise. Considerable care and judgment must be exercised, however, before one draws conclusions from the demographic data reported by ALAMO for a given airport community. For example, while both family income and home values vary with noise level in the Patrick Henry Airport community, there is no justification for concluding that these variations are due exclusively to noise level differences. Obviously, many other factors influence the demographic variables addressed by ALAMO. With this caveat in mind, ALAMO can be used to provide information about an airport community and the impact of aircraft noise on that community which, heretofore, has not been readily available.

IMPLICATIONS OF MODELING EFFORT

The ALAMO model is capable of performing a FIM impact assessment for any airport in the United States. The user must describe the runways, ground tracks, profiles, fleet mix, and flight schedules which comprise the airport operating scenario as well as the longitude and latitude of some point on the airport property to act as a reference point for the SITE II demographic program. Note that the airport description does not have to correspond to the existing operating scenario but can just as well describe a hypothetical case. For example, the noise impact of extending an existing runway or adding an additional runway can easily be compared with the impact associated with existing operations. Similarly, the effects of adding or eliminating a particular aircraft type from the fleet mix can be readily assessed as can the benefits to be achieved by imposing a nighttime curfew. Different combinations of ground tracks and approach/takeoff profiles can also be assessed in terms of their noise impact. Various land-use scenarios can be studied in order to determine, for example, if the reduction in noise impact which would be achieved if the airport purchased certain adjacent tracks of land would justify the cost of such a purchase. Of course, it has been possible to study hypothetical operation's scenarios such as these for as long as noise footprint models have existed. The feature which distinguishes previously available analyses from the kind of analysis possible with a model such as ALAMO is the fact that the people who are impacted can now be included explicitly in the analysis. The availability of census data-base management programs such as the SITE II program used in ALAMO, coupled with recent advances in the quantification of human responses to noise makes it feasible to extend the conventional footprint assessment technology to account not only for source and path characteristics, but for the characteristics of the receiver as well. As an important byproduct, the demographic composition of the airport community can be readily obtained as a function of noise level.

Extending the conventional noise footprint concept to account for the distribution of people in an airport community results in additional benefits besides an improved assessment methodology. It provides the framework for identifying flightpaths which can minimize noise impact by indicating which areas in an airport community are the least densely populated. Work currently in progress at Langley Research Center is focused on the problem of optimizing airport operations with respect to noise impact. The ALAMO impact assessment model described in this paper plays a central role in this noise effects research by providing the means for comparing various noise-minimal operating scenarios with each other and with standard (nonoptimized) airport operations to quantify the reductions in impact which can be achieved.

The potential exists for further extending the airport noise impact modeling concepts described in this paper. A dynamic representation of population and noise distributions, which includes a stochastic treatment of such nondeterministic variables as aircraft ground track and takeoff profile, may soon be within the state of the art. Such a model could provide for an improved impact assessment by accounting for the effects of changes in activity and setting which are naturally associated with a dynamic population.

A single-event-oriented, dynamic representation of airport operations would also permit a more sophisticated treatment of time-of-day effects than is currently available through such metrics as L_{dn}, for example. Additional subjective response research is needed, however, before the influence of such factors as activity, setting, and time of day can be adequately incorporated into a general assessment model.

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TABLE I.- AIRCRAFT INCLUDED IN INM DATA BASE

Aircraft Number	Aircraft Name
1	2E NBTF DC-9-32
2	DC-9-15
3	BAC-111
4	737/100-200
5	3E NBTF 727-200
6	727-100
7	4E NBTF 707-320B/C
8	707-120B
9	720B
10	DC-8-55
11	DC-8-61/63
12	Convair-990
13	4E NTJ 707-120/320
14	720
15	DC-8-30
16	Convair-880
17	VC-10
18	STOL F-28-2000
19	SST CONCORDE
20	2 Engine Wide Body
21	3E MRWB DC-10-10
22	3 Eng. WB L-1011
23	3E LRWB DC-10-30
24	3E LRWB Stretch
25	4 Eng. WB 747-200
26	747-100
27	747 Stretch
28	DC9 w/SAM Engines
29	737 w/SAM Engines
30	727 w/SAM Engines
31	707 w/SAM Engines
32	DC8 w/SAM Engines
36	727 Adv. w/SAM Engines
37	727 Adv. w/RFN Engines
38	2ETFGA SABRELINER
39	2ETP TWIN OTTER
40	2EP CESSNA 310

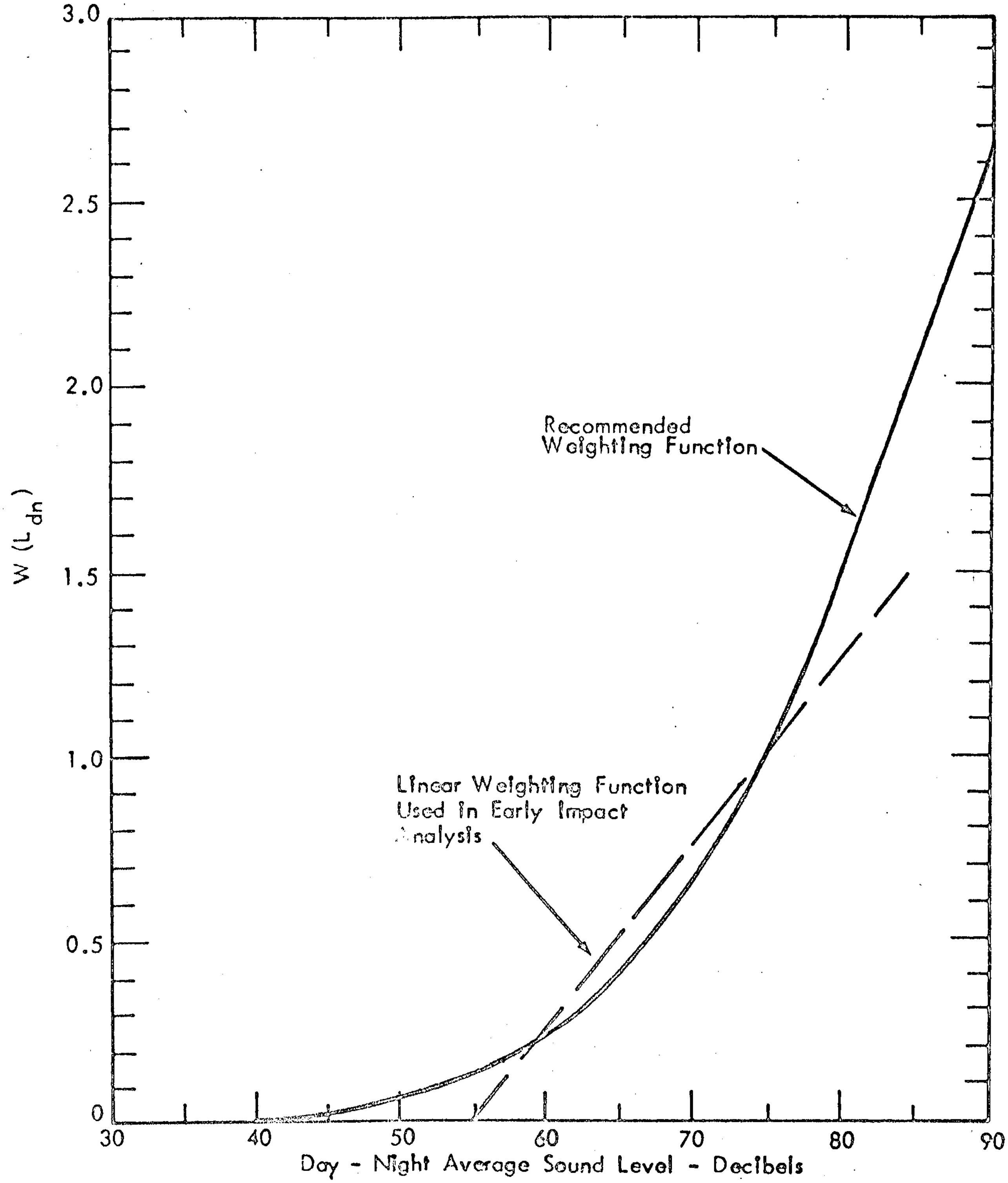

Figure 1.- Sound level weighting function for Fractional Impact Analysis

DEMOGRAPHIC PROFILE REPORT

NOISE IMPACT ANALYSIS
PATRICK HENRY FIELD
10% HIGHLY ANNOYED

	DEG	MIN	SEC
LATITUDE	37	7	52
LONGITUDE	76	20	29

69 POINT POLYGON

WEIGHTING PCT 100

	LATEST	CHANGE FROM 70
1977 POPULATION	8432	3069
1977 HOUSEHOLDS	2688	1093
1977 PER CAP INCOME	$ 5310	$ 2659
ANNUAL COMPOUND GROWTH	6.7	

1970 CENSUS DATA

POPULATION

TOTAL	5363	100.0
WHITE	5323	99.3
NEGRO	0	0.0
OTHER	40	.7
SPAN	25	.5

AGE AND SEX

	MALE		FEMALE		TOTAL
0-5	292	11.0	278	10.3	10.6
6-13	463	17.4	475	17.6	17.5
14-17	250	9.4	212	7.8	8.6
18-20	104	3.9	108	4.0	4.0
21-29	331	12.4	339	12.5	12.5
30-39	370	13.9	379	14.0	14.0
40-49	316	11.9	317	11.7	11.8
50-64	368	13.8	368	13.6	13.7
65 +	166	6.2	228	8.4	7.3
TOTAL	2660		2704		
MEDIAN(AGE)	27.0		28.4		27.7

FAMILY INCOME (000)

$0-5	246	17.3
$5-7	130	9.1
$7-10	367	25.8
$10-15	430	30.2
$15-25	230	16.2
$25-50	19	1.3
$50 +	0	0.0
TOTAL	1422	

AVERAGE $10210
MEDIAN $ 9738

HOME VALUE (000)

$0-10	192	15.2
$10-15	322	25.5
$15-20	336	26.6
$20-25	229	18.1
$25-35	137	10.8
$35-50	42	3.3
$50 +	7	.6
TOTAL	1265	

AVERAGE $17847
MEDIAN $16756
OWNER 82.7

OCCUPATION

MGR/PROF	549	29.5
SALES	99	5.3
CLERICAL	324	17.4
CRAFT	387	20.8
OPERTIVS	222	11.9
LABORER	108	5.8
FARM	10	.5
SERVICE	158	8.5
PRIVATE	7	.4

RENT

$0-100	167	63.0
$100-150	77	29.1
$150-200	16	6.0
$200-250	5	1.9
$250 +	0	0.0
TOTAL	265	

AVERAGE $ 82
MEDIAN $ 79
RENTER 17.3

EDUCATION ADULTS > 25

0-8	770	26.5
9-11	795	27.3
12	845	29.1
13-15	262	9.0
16 +	236	8.1

AUTOMOBILES

NONE	151	9.4
ONE	741	46.0
TWO	642	39.8
THREE+	78	4.8

HOUSEHOLD PARAMETERS

FAM POP	5150	96.0
INDIVIDS	213	4.0
GRP QTRS	0	0.0
TOT POP	5363	

UNITS IN STRUCTURE

1	1538	95.6
2	17	1.1
3-4	2	.1
5-9	28	1.7
10-49	0	0.0
50 +	0	0.0

HOUSEHOLDS WITH:

TV	1422	89.2
WASHER	1215	76.2
DRYER	581	36.4
DISHWSH	199	12.5
AIRCOND	595	37.3
FREEZER	519	32.5

NO OF HH'S	1595
NO OF FAM'S	1416
AVG HH SIZE	3.4

Figure 2.- Demographic profile of residents within L_{dn} 61 at PHF.

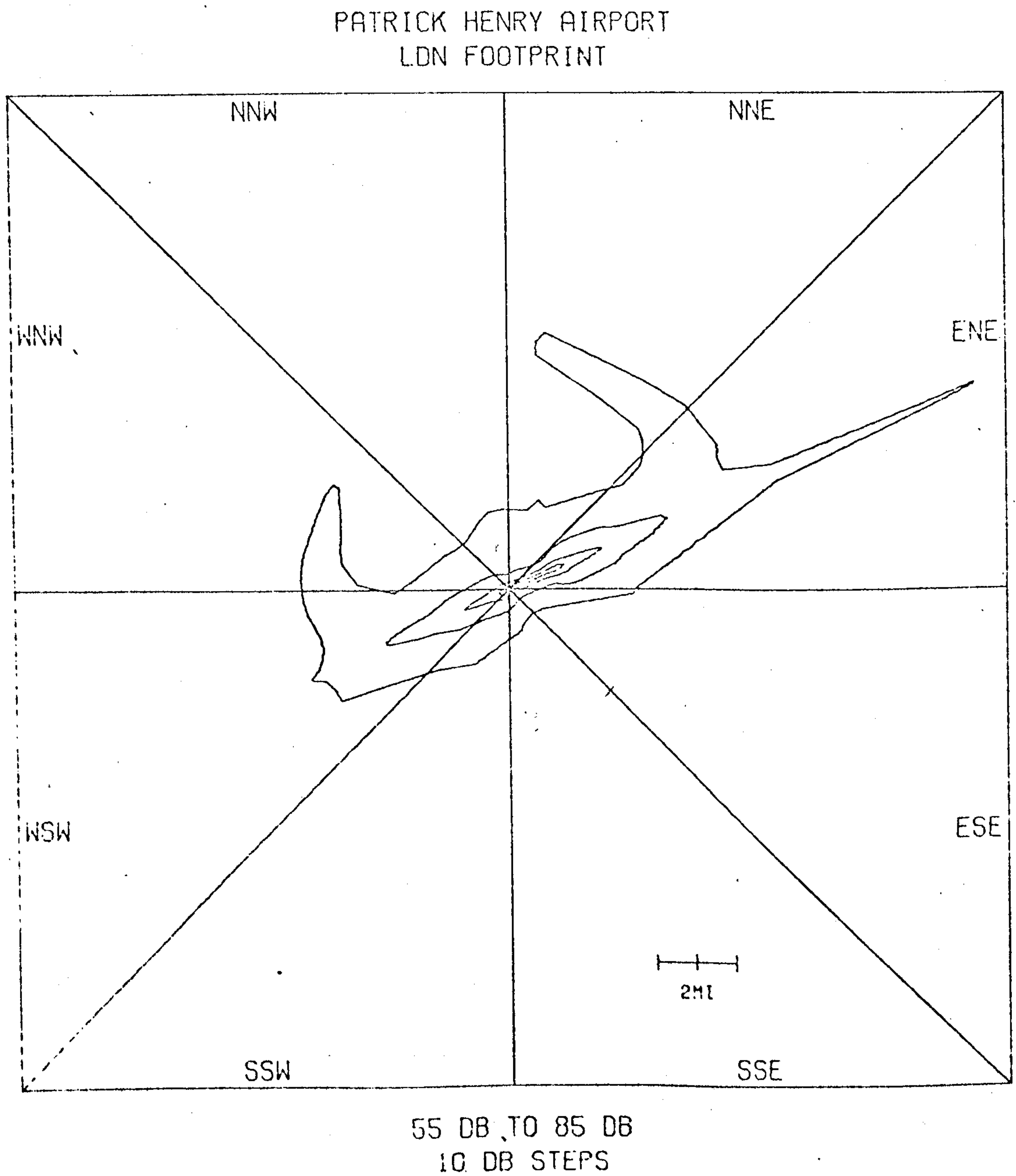

Figure 3.- Footprint of L_{dn} contours for PHF.

AIRPORT: PATRICK HENRY AIRPORT
COMMUNITY: NEWPORT NEWS, VIRGINIA

	E N E	N N E	W N W	W S W	TOTAL
IMPACTED POPULATION	3608	3145	12665	13266	32684
LEVEL WEIGHTED POP	583	508	2366	5338	8795
NOISE IMPACT INDEX	.162	.162	.187	.402	.269
EQUIVALENT NOISE LEVEL	56	56	57	64	60
PERCENT HIGHLY ANNOYED	6.0	6.0	6.9	14.8	9.9
POP HIGHLY ANNOYED	215	187	873	1969	3245

Figure 4.- ALAMO noise impact summary for PHF.

AIRPORT: PATRICK HENRY AIRPORT
COMMUNITY: NEWPORT NEWS, VIRGINIA

DEMOGRAPHIC VARIABLES 1970 OR AS NOTED	NOISE DUE TO AIRPORT, LDN 45 - 50	50 - 55	55 - 60	60 - 65	65 - 70	70 - 75	75 - 80
SELF-NOISE, LDN(1)(2)	N	N	45	44	48	47	0
IMPACTED POP(1)(3)	O	O	21638	4260	4587	2199	0
AREA, SQ KM			55.12	16.67	6.55	3.65	.85
TOT POP / SQ KM	C	C	392	255	700	602	0
AVG GROWTH RATE, APR	O	O	-1.0	3.2	3.3	3.3	0.0
PCT FAMILY POPULATION	N	N	62.8	97.8	97.6	97.5	0.0
AVG AGE, ADULTS > 17	T	T	29	36	37	37	0
PCT AGE 65+	O	O	1.5	1.7	2.3	2.4	0.0
PCT 16+ YRS ED(4)	U	U	13.8	18.5	15.7	15.7	0.0
PCT MGR/PROF	R	R	34.0	36.6	37.0	36.8	0.0
AVG FAMILY INCOME			11067	12917	13712	13760	0
PCT SINGLE FAM DWL	F	F	63.8	87.9	92.3	92.0	0.0
PCT HOME OWNERS	O	O	78.2	88.6	89.6	89.5	0.0
AVG HOME VALUE	U	U	24069	23757	23029	23034	0
PCT HH WITH A/C	N	N	53.9	83.3	79.1	79.0	0.0
PCT HH WITH TV	D	D	95.2	96.3	97.3	97.1	0.0

(1) BASED ON 1977 POPULATION DATA
(2) BASED ON POPULATION, AFTER GALLOWAY
(3) POPULATION EXPOSED TO LEVELS RAISING TOTAL EXPOSURE > 1 D
(4) ADULTS 25 YEARS OLD OR OLDER

Figure 5.- ALAMO demographic profile report for PHF.

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16. Abstract

A computer model has been developed to assess the noise impact of an airport on the community which it serves. Assessments are made using the Fractional Impact Method by which a single number describes the community aircraft-noise environment in terms of exposed population and multiple-event noise level. The model is comprised of three elements: a conventional noise footprint model, a site-specific population distribution model, and a dose-response transfer function. The footprint model provides the noise distribution for a given aircraft operating scenario. This information is combined with a site-specific population distribution obtained from a national census data base to yield the number of residents exposed to a given level of noise. The dose-response relationship relates noise exposure levels to the percentage of individuals who would describe themselves as "highly annoyed" by those levels. This information is used to compute a single-number descriptor of the airport noise environment. In addition to providing a quantitative assessment of the noise environment in the community at large, the model generates a report which lists several demographic variables as a function of noise level which are of interest to community planners and others. These variables include population density, growth rate, average age, average home value, percent homeowners, percent renters, and others. This paper describes the structure and operation of the community response model and presents the results of initial noise impact assessment studies.

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