A REPORT ON AN INVESTIGATION OF COMMUNITY REACTION TO AIRCRAFT NOISE IN PERTH, WESTERN AUSTRALIA

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1. INTRODUCTION

During the last twenty years community concern has increased over the undesirable effects of noise. Investigations, such as that by the British Government Committee to investigate the problem of noise, (HMSO 1963), have shown that the two main causes of community annoyance to noise have been road traffic noise and aircraft noise.

With the widespread use and acceptance of air travel today, the resultant increase in volumes of air traffic, use of higher performance aircraft, airport orientation and location, and air traffic patterns become critical factors in the lives of people who live in the vicinity of an airport.

Aircraft noise is a special problem, in that aircraft flyover is intermittent in nature. That is, a series of autonomous events, as opposed to road traffic or industrial noises, which are more likely to be continuous in nature, albeit fluctuating in intensity. Associated with the specific problem of aircraft noise also, is the increase in surface traffic and services around the airports with the resultant deterioration of the acoustic environment, with a subsequent increase in community concern for environmental noise pollution.

Little work has been done on the effects of noise from aircraft in the Perth metropolitan area, although the National Acoustics Laboratory study (N.A.L. 1982) of the effects of aircraft noise around the major airports of Australia, including Perth. This study involved conducting of a social survey in various areas identified as being affected by aircraft noise. These areas were related to the NEF (Noise Exposure Forecast) contours. The study also included the measurement of noise in the same areas. Other such studies have been carried out around Heathrow Airport in the United Kingdom (HMSO 1963) and major airports in Europe and the United States, (May, 1980).

The general aim of these studies has been to examine community response to noise and to establish a dose/response relationship which can then be used to predict community response in terms of annoyance and disturbance, to aircraft noise.

The present study was undertaken as a study of community noise levels and related annoyance in the Perth metropolitan area by means of a social survey and extensive sound level measurements. The specific objectives were to:

a) ascertain how widespread and how strong the effect of aircraft noise is in the community in the areas selected;

b) investigate the type of correlation which may exist between measured sound levels, annoyance and air traffic flow;

c) explore the potential of various transportation indicators of annoyance (eg L_{dn}, L_{np}, NEF, L_{eq}) as suitable indicators of the community reaction to aircraft for Perth conditions;

d) compare the results with those from other studies and communities.

Contrasts in standards of living, perception of quality of life and aims in Australian cities and in Perth specifically, may give rise to problems in comparing the results of this present study with other studies. Australian urban society is highly oriented towards suburban living in one-family house surrounded by private gardens and usually at some distance from industrial areas (Spickett & Baker, 1982) and often enjoying an out-of-doors type lifestyle.

One may also speculate that in Perth, being an isolated city, community perception of annoyance due to transportation noise may be quite different to that of other communities. Owing to this isolation, more members of the community probably have a direct contact with the pleasurable conotations of aircraft noise such as, arrivals of relatives or departures on holidays, than in other communities around the world, and hence may have more tolerance of the encroachment of aircraft noise into their lives.

The aims of this study were to be achieved firstly by the carrying out of a social survey, the questionnaires of which were administered by research assistants in September, October and November of 1981. This survey was carried out both within the NEF 25 contour and in an area outside the NEF 25 contour. Secondly, a sound monitoring programme was carried out within this area at several different sites so as to obtain a picture of sound levels in the area and to test for a relationship] between noise levels and community reaction to environmental noise pollution.

2. THE SOCIAL SURVEY DESIGN

2.1 The Study Area

The area investigated in this work covered a large portion of the metropolitan area around the airport. It included the Shires of Bayswater and Bassendean and Cities of Belmont and Canning, as well as parts of the Shires of Kalamunda and Swan, Town of Gosnells and City of Perth.

The area was divided into four approximately equal portions (see Table 1) with a Control area in Ballajura.

The number of interviews conducted in each area was proportional to the population density, and the questionnaires were administered in a purely random fashion within each zone. The selection of actual sampling sites was based on several considerations. The first was that the sample should be residential. Another was the that only two per cent of the entire survey should be on main roads, as only two per cent of Perth's population reside on main roads.

TABLE 1

AREAS DEFINED BY SURVEY AREAS,

GEOGRAPHICAL DESCRIPTION AND VALID RESPONSES

AREA	VALID RESPONSES	GEOGRAPHICAL DESCRIPTION
1	111	Bayswater, Bassendean, Morley etc
2	28	Swan, Midland etc
3	120	Belmont, Perth Canning
4	41	Kalamunda, Orange Grove etc
Control	21	Ballajura

2.2 The Use of a Social Survey

Community reaction to aircraft noise was investigated by means of a social survey as the method of investigating annoyance and disturbance from aircraft noise. This was determined by several methods.

Firstly, the social survey was used to obtain an indication of the strength and widespread nature of the feelings of annoyance due to aircraft noise are. The overall levels of annoyance in the survey area can then be determined.

Secondly, it was desirable to obtain both qualitative and quantitative indications of the extent of dissatisfaction in the community with aircraft noise. The social survey is a means of measuring the subjective response of residents in the area and quantifying that response.

Thirdly, the social survey can also be used to discover the tangible effects of aircraft noise in the community, effects including health effects, such as sleep disturbance; the extent to which people become accustomed to aircraft noise, and whether aircraft noise might cause people to move away from the vicinity of the airport.

Fourthly, the levels of annoyance and effects found in specific areas could be used to establish whether there is a relationship between levels of annoyance, effects experienced, and the noise levels to which the community is exposed to. An attempt can then be made to use noise dose as a predictor of annoyance experienced in the community as a result of environmental noise pollution.

Lastly, the results of the social survey, both in terms of annoyance levels due to, and effects of, aircraft noise, can be compared with other studies that have been made on the effect of aircraft noise on the community.

Question 3, 4 and 5 - provided a further opportunity to test unprompted reactions to aircraft noise, with a series of questions beginning

'Do you ever complain to yourself about anything in this area?'

In Question 6 - the purpose of the questionnaire was partially revealed. Respondents were asked 'What noises do you notice most around here?', without specifically being asked about aircraft noise. This question was intended to show how prominent the noise source was among various community noises.

Then in Question 7 and 8, all those who had not so far mentioned aircraft or traffic noise were asked if they ever noticed those two specific noises in the neighbourhood. The purpose of this question was to find out how many people reported that they did not notice aircraft noise even when specifically asked. These people could be considered to be those for whom aircraft noise is not a problem. Traffic noise was included in questions up to this point in the interview, because investigations such as that by the British Government Committee to Investigate the Problem of Noise (HMSO 1963) have shown that the two main causes of community annoyance to noise are road traffic noise and aircraft noise; and thus it is desirable to compare the responses to these two types of noise in a survey such as this.

Question 9 - was one of the key questions of the survey. It invited people to rate their annoyance with noise in terms of a semantically labelled 7-point scale. Each score had the following labels:

1 = Not at all
2 = Very little
3 = A small amount
4 = A fair amount
5 = Quite a bit
6 = A lot
7 = A great deal

This scale is particularly useful since it permits a simple grouping of annoyance into defined categories, and provides quantitative scores which can be correlated with sound level measurements. This scale was used in the Spickett and Byrne Study (1979) and similar scales have been used elsewhere (eg McHennell 1966, Langdon 1976, Kajland 1970), and this method of self-rating by respondents on a simple scale has gained much support in both road traffic and aircraft noise investigations (for discussion, see Langdon 1975).

A 10-point annoyance scale was used in the National Acoustic Laboratory's aircraft noise social survey. This was then combined with other scaled measurements for reaction, such as disturbance rating and complaint disposition to give aircraft noise a psychological scaling of subjective rating which, it is claimed, gives an accurate assessment of the overall subjective reaction to aircraft noise. However, it has been found (Hede and Bullen 1980) that annoyance reaction correlated significantly with NEF although affectedness measure provided a stronger correlation. The scale that was used in this study, however, provides a simple categorising of annoyance and permits comparison with previous studies.

In Question 10 - respondents were asked 'Have you ever made an official complaint about the noise here?' The aim of this question was to discover how many people had gone so far as to make a personal complaint, verbally or in writing, to their MP, council or other authority. If they had not complained, respondents were asked the reason why not, in order to determine whether the reason was a lack of desire to complain, or some other reason, such as pessimism about the outcome of complaint, or ignorance of appropriate avenues of complaint.

The aim of Question 11 was to obtain information on the times of day at which respondents, in their opinion, were most exposed to aircraft noise. Respondents were asked 'when do you notice the most noise around here?' and nine time periods were suggested. Respondents were asked to indicate whether they found the noise 'not noticeable', 'noticeable' or 'very noticeable' in each time period.

Questions 12 to 20 - examined various tangible effects of noise on people's lives. The questions covered aspects such as sleep disturbance, having to close windows because of noise, interference with television or radio listening, interference with conversation and consideration of moving away because of noise. The answers to these questions not only help to communicate the effects of noise in readily understandable, everyday terms, but also provide a means of validating the 7-point annoyance scale.

Questions 21 to 24 - provided demographic data on the sample composition, in terms of sex, age, length of residence in the present dwelling and whether the person worked.

Questions 25 to 27 - obtained data on the type of dwelling, while Question 28 was reserved for additional comment.

A further question was asked as to whether the interviewer would permit a noise monitoring device to be installed on their property for a period of 24 hours.

2.4 The Conduct of the Survey

The social survey was carried out by 6 research assistants during September, October and November of 1981. Interviews were conducted mainly during the day although some were carried out in the evening. The assistants carried a letter of identification, but it was seldom used. In nearly all cases they simply introduced themselves as research assistants conducting an environmental survey. Residents tended to consent or refuse outright without requesting or desiring a letter of identification.

No specific homes were selected in advance for the interviews and no advance warning of the survey was given to residents. The sample was essentially random in nature, and 321 valid responses were received.

The survey results were analysed by computer. The programme used was the Statistical Package for Social Sciences, which has been devised to permit rapid statistical analysis of social survey data (Nie 1975). The programme produces absolute frequencies of all variables, and cross tabulations of selected variables. This one can, for example, cross tabulate scores on the annoyance scale with sex to see the relative pro-proportion of males and females at each annoyance score, or one can cross-tabulate selected areas with 'sleep disturbance', to see what proportion of people in each area are awoken at night by aircraft noise. The programme also provides simple frequency distributions as well as correlation of variables, regression and scatter diagrams.

3. THE SOCIAL PROFILE

The purpose of this study was to investigate the effects of aircraft noise on residents of the Perth Metropolitan area. Therefore, in order to validate the results of the study, there is a need to establish that the population sampled are representative of the total population exposed to aircraft noise. It was partly towards this end that some personal details were obtained during the course of an interview.

Tables 3 and 4 show the age and sex distribution of the population sample and the population of Western Australia and Australia. The Perth metropolitan area population is not dissimilar to that of Western Australia. From Table 3 it can be seen that the sample population is not truly representative in sex of the Western Australian population. While 49 per cent of WA's population is female, approximately 73 per cent of our sample population is female. This feature is present probably because more women tend to spend more time in the home than men and there is a tendency also for the women of the house to answer the door.

From Table 4 it can be seen that the age distribution of the sample population is similar to the age distribution for Western Australia, with the sample population having slightly higher numbers in the 45-65 age brackets.

This over representation could well be due to older people, particularly those in retirement, spending more time about the house, and to younger people being more likely to be at a place of employment during the daytime, which was the time when most interviews were carried out.

Question 23 was designed to establish whether or not respondents did spend more time at home during the day. It asked 'Do you do shift work?' This question failed to really indicate the times of day respondents were usually in their homes, because it was not established whether a respondent worked at all.

The fact that there is an over representation of older people, females and possibly people not in the work force in our sample may not in itself be an undesirable feature of the results, if the sample is representative of those most exposed to a noise dose.

Another feature of the results is the number of people who have lived in the area for over ten years - 40 per cent. This result could have perhaps been made more meaningful by including 20 years and 30 years in the length of residency categories. Where people who have lived in the area for a long time could well have become used to the noise levels as they increased over the years, and the over representation of such people in the sample may lead to a biasing of results. Those people living in the area for a short time may not be used to the noise and thus may have given different responses to the interview. These people are under represented in the population sample, as can be seen in Table 5.

It is reasonable to expect that the design and construction material of a dwelling will have an effect on its acoustic shielding properties. It was with this in mind that basic data on dwelling types was obtained during the course of the interview. (Tables 6, 7 & 8).

TABLE 3

SEX DISTRIBUTION

	Total Survey - Control		W.A.	Australia
	No.	%	%	%
Male	79	26.3	51	50
Female	220	73.3	49	50
Not specified	1	0.3		

TABLE 4

AGE DISTRIBUTION

	Total Survey - Control		W.A.	Australia
Age	No	%	%	%
16-24 years	43	14.3	23	21.5
25-34 years	71	23.7	23	21.5
35-44 years	50	16.7	16	16
45-54 years	51	17.0	15	12
55-66 years	46	15.3	11	12
65 years	39	13.0	11.5	12.5

TABLE 5

LENGTH OF RESIDENCY

	Total Survey - Control	
Length	No	%
1-6 months	23	7.7
6-12 months	28	9.3
1-4 years	59	19.7
4-10 years	69	23.0
10 years	120	40.0
Unspecified	1	0.3

TABLE 6

TYPE OF HOUSE

Type	Total Survey No.	Total Survey %	Total Survey - Control No.	Total Survey - Control %
High Set House	33	10.3	29	9.7
Low Set House	277	86.3	261	87.0
2 Storey	4	1.2	3	1.0
Units	2	0.6	2	0.7
Other	5	1.5	5	1.6

TABLE 7

HOUSE CONSTRUCTION

Construction Material	Total Survey No.	Total Survey %	Total Survey - Control No.	Total Survey - Control %
Wood	15	4.7	15	5.0
Brick	274	85.45	253	84.3
Fibrolite	19	5.9	19	6.3
Plasterboard	12	3.7	12	4.0
Unspecified	1	0.3	1	0.3

TABLE 8

ROOF MATERIAL

Material	Total Survey No.	Total Survey %	Total Survey - Control No.	Total Survey - Control %
Iron	29	9.0	27	9.0
Fibrolite	12	3.7	11	3.7
Tile	279	86.7	261	87.0
Unspecified	1	0.3	1	0.3

It can be seen from the results that the majority of houses were free standing, single storey brick and tile houses, and low set. Ten per cent of the houses were high set and there were small numbers of wood, and fibrolite houses. From these results, it could be said that the dwelling type sample was sufficiently homogenous for this variable to be safety neglected in considering variations in noise annoyance. The predominance of brick construction is also consistent with the dwelling type distribution in the Perth metropolitan area.

4. RESULTS OF THE SOCIAL SURVEY

4.1 Unprompted Responses

Question 2 included a list of various environmental factors, and respondents were asked to rate each factor according to what the respondent personally felt about that factor. Results revealed that nearly 20 per cent of respondents in the total Survey Area (minus the Control Area), which from now on shall be referred to as the survey area, rated the level of noise in the area as fairly bad to very bad. Nearly 25 per cent rated both 'frequency of aircraft flyover' and 'amount of traffic' as fairly bad to very bad. This corresponds well with the results of a study, not yet published which found that, in Perth, traffic noise and aircraft noise rated equally as the feature most wanted improved in he neighbourhood (Tables 9, 10 and 11).

By breaking these results down into areas, it can be seen which noise is of most concern in which neighbourhood. It can be seen from Table 9 that the areas with the greatest number of people rating the 'level of noise' as 'fairly bad' to 'very bad' are Areas 2 and 3. However, 43.6 per cent of respondents in Area 2 rated 'frequency of aircraft flyover' 'fairly bad' to 'very bad' and only 15 per cent of respondent in the same area rated 'amount of traffic' in a similar way. Areas 3 and 4 both seemed to equally rate 'frequency of aircraft flyover' and 'amount of traffic'.

4.2 Complaints and the Noticing of Noise

Questions 3, 4 and 5 were designed to obtain unprompted responses to aircraft noise and/or noise in general. From Table 12, it can be seen that 127 people in the survey area complained to themselves about something. Of the respondents, 5.3 per cent complained to themselves about noise while 9.7 per cent and 4.3 per cent complained about roadway activity and aircraft activity respectively (Table 13). Those respondents who said they complained about noise were then asked to specify which noise they complained about, 8 people specified traffic noise. It can now be seen from Table 14 that up to this point in the interview, where no prompting about noise has yet occurred, 62 people have said they complain to themselves about noise, 21 of these specifically complained about aircraft noise.

Question 6 asked respondents, who had not already mentioned aircraft or traffic noise, what noises they most notice in the area. In response to this question, 95 people mentioned aircraft noise, and 177 mentioned traffic noise. Questions 7 and 8 indicated that 23 per cent of respondents did not notice aircraft noise when specifically asked and nearly 26 per cent did not notice traffic noise. (Table 14)

In summary it can be said that a total of 272 people mentioned or noticed traffic noise and a total of 185 people mentioned or noticed aircraft noise. Both these figures are significant portions of the sample population.

Table 15, 16, 17 and 18 indicate in what areas which noise is of most concern to residents. It can be seen that nearly 11 per cent of respondents in Area 2 complained about aircraft noise while Areas 2, 3 and 4 more specifically complained about traffic noise (Table 13). The question as to what noises the respondents noticed most in the area showed Areas 3 and 4 to have a significant portion of the population noticing aircraft noise. The control area is consistently low in its response to either noise, although, significantly the response to traffic noise is higher than to aircraft noise.

TABLE 9

LEVEL OF NOISE IN THE AREA

Rating	Total Survey - Control		Area 1	Area 2	Area 3	Area 4	Control
	No.	%	%	%	%	%	%
Very good	57	19.0	20.7	21.4	14.2	26.8	66.7
Fairly good	92	30.7	35.1	35.7	26.7	26.8	9.5
Average	92	30.7	31.5	17.9	34.3	26.8	14.3
Fairly bad	42	13.7	10.8	14.3	15.0	17.1	9.5
Very bad	18	6.8	1.8	10.7	10.0	2.4	
			22.6	25	25	19.5	9.5

TABLE 10

AIRCRAFT FLYOVER

Rating	Total Survey - Control		Area 1	Area 2	Area 3	Area 4	Control
	No.	%	%	%	%	%	%
Very good	35	11.7	19.8		7.5	9.8	28.6
Fairly good	53	17.7	27.0	7.1	15.0	7.3	33.3
Average	130	43.3	37.8	35.7	46.7	53.7	33.3
Fairly bad	56	18.7	9.9	42.9	19.2	24.4	4.8
Very bad	18	6.0	2.7	10.9	8.3	4.9	
		24.7	11.7	43.6	27.5	29.3	4.8

TABLE 11

AMOUNT OF TRAFFIC

Rating	Total Survey -Control		Area 1	Area 2	Area 3	Area 4	Control
	No.	%	%	%	%	%	%
Very good	36	12.0	14.4	14.3	10.0	9.8	28.6
Fairly good	66	22.0	24.3	17.9	17.5	31.7	38.1
Average	123	41.0	45.9	42.9	40.8	26.8	23.8
Fairly bad	43	14.3	8.1	7.1	20.0	19.5	9.5
Very bad	31	10.3	7.2	17.9	10.8	12.2	
Don't Know	1	0.3		0.8			
		24.6	15.3	15.0	30.8	31.7	9.5

TABLE 12

DO YOU COMPLAIN?

Answer	Total Survey - Control		Area 1	Area 2	Area 3	Area 4	Control
	No.	%	%	%	%	%	%
Yes	127	42.3	40.5	50.0	41.7	43.9	14.3
No	169	56.3					
Don't Know	4	1.3					

TABLE 13

SPECIFIC COMPLAINT

Complaint	Total Survey - Control		Area 1	Area 2	Area 3	Area 4	Control
	No.	%	%	%	%	%	%
Noise	16	5.3	2.7	7.1	5.8	9.8	4.8
Road Activity	29	9.7	9.0	3.6	10.0	14.6	-
Aircraft Activity	13	4.3		10.7	6.7	4.9	-
Other	71	23.7	28.8	28.6	20.8	14.6	14.8
None	171	57.0	59.5	50.0	56.7	56.1	81.0

TABLE 14 COMPLAINT AND NOTICING NOISE (SUMMARY)

	Total Survey Control No.	%
SPECIFIC COMPLAINT		
Roadway Activity	29	9.7
Aircraft Activity	13	4.3
Other	71	23.7
No Complaint	171	57.0
Noise	16	5.3
SPECIFIC NOISE		
Aircraft	8	2.6
Traffic	12	4.0

(i.e. total of 21 people (6.9%) mentioned aircraft noise before noise was disclosed as survey subject).

	Total Survey Control No.	%
NOISE NOTICED (Unprompted)		
Aircraft	95	31.7
Traffic	177	59.0

(i.e. an additional 95 people mentioned aircraft noise before aircraft noise was disclosed as survey subject).

		Total Survey Control No.	%
NOISE NOTICED (Prompted)			
Aircraft	NO	69	23.0
	YES	133	44.3
Traffic	NO	77	25.7
	YES	54	18.0

Noise identified as a significant component of the questionnaire.

TABLE 16

WHAT NOISES DO YOU NOTICE MOST AROUND HERE? (Q 6)
(Unprompted)

	AREA		TRAFFIC	AIRCRAFT
1st Mentioned	Total - Control	No.	141	63
		%	47.0	21.0
	1		53.2%	12.6%
	2		42.9%	35.7%
	3		44.2%	21.7%
	4		41.5%	31.7%
	Control		23.8%	9.5%
2nd Mentioned	Total - Control	No.	36	32
		%	12.0	10.7
	1		5.4%	2.7%
	2		10.7%	10.7%
	3		13.3%	20.0%
	4		26.8%	4.9%
	Control		4.8%	9.5%

TABLE 17

AIRCRAFT NOISE (PROMPTED)

	Total Survey - Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
No	69	23.0					
Yes	133	44.3	50.5	42.9	37.5	48.8	9.5
	98	32.7					

TABLE 18

TRAFFIC NOISE NOTICED (PROMPTED)

	Total Survey - Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
No	77	25.7					
Yes	54	18.0	14.4	21.4	17.5	26.8	9.5
	169	56.3					

TABLE 19

ANNOYANCE FROM NOISE

Rating	Total Survey - Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
Not at all	65	21.6	27.9	7.9	17.5	19.5	47.6
Very little	118	39.3	36.9	28.6	40.0	51.2	33.3
Small amount	59	19.7	18.8	28.6	19.2	17.1	14.3
Fair amount	31	10.3	9.9	7.1	11.7	9.8	4.8
Quite a bit	15	5.0	5.4	7.1	5.8		
Great deal	12	4.0	0.9	10.7	5.8	2.4	

4.3 Annoyance from Noise

An attempt was made to quantify the degree of annoyance from aircraft noise by use of the 7-point annoyance scale described earlier. Area 2 again came to the force with 10.7 per cent of respondents saying they were annoyed a great deal and a total of 24.9 per cent being annoyed a fair amount to a great deal by aircraft noise. Area 3 also showed a high portion (23.3 per cent) of the population being annoyed a fair amount to a great deal, whereas 16.2 per cent of the population in Area 1 were annoyed a fair amount to a great deal. (Table 19).

Spickett and Baker (1982) used a 10-point scale for the rating of annoyance, however a rating of 7 or greater on their scale can be considered roughly equivalent to this study's fair amount to a great deal. Their study showed 16.3 per cent of the total survey compared with 19.3 per cent in this study to be significantly annoyed, as defined above. This result is to be expected as the Spickett and Baker study was undertaken wholly outside the NEF 25 contour while this study took place both within and outside the NEF 25 contour.

Another comparison with the aforementioned study is worth making. The areas in that study showing the highest percentage of respondents rating annoyance as 7 or greater were located in this study's Area 3, which also showed a high percentage of the population being annoyed significantly. This comparison tends to lend validity to the two studies' results of both surveys.

It is worth noting that no respondent rated their annoyance as 'a lot'. This result may indicate that when people are annoyed to a high degree they are prepared to selected the top end of the scale, passing over 'a lot' in favour of 'a great deal'.

4.4 Consistency of Response

Although both the masked questions and the annoyance scale reveal a significant degree of displeasure with road traffic noise, it is interesting to compare the replies to these questions to determine whether people have been consistent in their response when the purpose of the survey became apparent. Tables 20, 21 and 22 show cross-tabulations of scores on the annoyance scale with the 'level of noise', and 'frequency of aircraft flyover' (Question 2), and a cross-tabulation of 'level of noise' and specific complaint.

Table 20 shows that 50 per cent of those who said they complained to themselves about noise rated the 'level of noise' as fairly bad to very bad and only one respondent complaining about noise rated the 'level of noise' as fairly good to very good. A similar trend is observed in those who complained specifically about roadway activity or aircraft activity.

Table 21 shows that while 45.6 per cent of respondents rating 'level of noise' as fairly bad to very bad gave low annoyance scores, only 8 per cent of those rating 'level of noise' as fairly good to very good recorded high annoyance scores. Table 22 shows a similar result for 'aircraft flyover' and annoyance from noise. The fact that a large number of people recorded low annoyance scores although they rated 'level of noise' or 'aircraft flyover' as fairly bad to very bad is not necessarily an inconsistent result. This result may merely reflect the different dimensions involved in rating from very good to very bad and 'annoyance'; that is a person may regard a certain noise level as fairly bad or very bad without being annoyed to a considerable degree.

TABLE 20

CROSS TABULATION OF LEVEL OF NOISE AND SPECIFIC COMPLAINT

Level of Noise Rating	Noise	Specific Road-way Activity	Complaint Air-craft Activity	Other
Very good	1	1	1	10
Fairly good	0	3	2	26
Average	7	10	5	24
Fairly bad	5	9	4	8
Very bad	3	6	1	3

TABLE 21

CROSS TABULATION OF LEVEL OF NOISE AND ANNOYANCE FROM NOISE

	Annoyance From Noise					
Level of Noise Rating	Not At All	Very Little	A Small Amount	A Fair Amount	Quite A Bit	A Great Deal
Very good	22	19	12	1	1	1
Fairly good	18	49	16	8	0	1
Average	17	37	21	11	4	0
Fairly bad	2	10	10	10	6	1
Very bad	1	3	0	1	4	9

TABLE 22

CROSS TABULATION OF AIRCRAFT FLYOVER AND ANNOYANCE FROM NOISE

	Annoyance From Noise					
Level Flyover Rating	Not At All	Very Little	A Small Amount	A Fair Amount	Quite A Bit	A Great Deal
Very good	11	15	5	2	2	0
Fairly good	10	24	10	5	2	2
Average	30	51	26	12	4	3
Fairly bad	6	21	14	8	4	3
Very bad	2	3	4	3	2	4

4.5 Activities Affected by Aircraft Noise

In order to provide a more complete picture of what is in fact meant by noise annoyance, the respondents were asked a number of questions (Question 10 and Questions 12 to 20) concerning various behavioural responses to aircraft noise. The results are shown in Tables 23, 24, 25, 26, 27 and 28.

Questions 13 to 17 concerned various activities affected by noise; closing windows because of noise, sleep disturbance, difficulty in hearing radio or television, and interference with conversation. In each case, the respondents were asked 'how often?' the phenonemon occurred, and were asked to choose from the following replies: 'never', 'sometimes', 'a lot'. 'Sometimes' complies a relatively infrequent event. Hence, it seems valid to regard the distinction between 'sometimes' and 'a lot' as the point at which people come to regard traffic noise as a serious irritation in that particular respect. Secondly, this group of seriously affected persons is further divided into two categories 'a lot' and 'most of the time'. Now, 'a lot' already implies a frequent event, so that it seems reasonable to assume that if a person passes over 'a lot', in favour of 'nearly all of the time', he or she is reporting a very frequent occurrence, presumably once or more per day (Spickett and Byrne 1979).

Another point to bear in mind is the consideration of the number of people affected in various ways by aircraft noise is the significance of the proportions of people affected. It is not necessary for more than 50 per cent (or any other arbitrary proportion) of the people to be affected in a particular way for a substantial problem to exist. Even if 10 per cent of the people have, for example, their sleep disturbed, this still represents a large number of people. In this connection, the work of Bryan and his co-workers is also relevant (Bryan 1973). Bryan has argued that tolerance of noise does not follow a unimodal distribution throughout the population, but rather that there is one group of people who have a relatively high tolerance, and a second group with relatively low tolerance. Such a distribution would help to explain why some people are more affected than others. If this is true, it is the people who are more sensitive to noise who constitute the 'at risk' population.

Since these questions concerning the effects of noise on people's lives are particularly important, the results are discussed below in some detail.

TABLE 23 WINDOWS NEED SHUTTING BECAUSE OF NOISE

Response	Total Survey Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
Never	237	78.9	79.3	78.6	79.1	78.0	95.2
Sometimes	31	10.3	10.8	14.3	9.2	9.8	4.8
A Lot	10	3.3	2.7	-	4.2	4.9	-
Nearly All The Time	22	7.3	7.2	7.1	7.5	7.3	-

TABLE 24 SLEEP DISTURBED BY NOISE

Response	Total Survey Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
Never	204	68.0	73.0	53.6	61.7	82.9	90.5
Sometimes	77	25.7	24.3	35.7	30.8	7.3	4.8
A Lot	13	4.3	0.9	7.1	5.8	7.3	4.8
Nearly All The Time	6	2.0	1.8	3.6	1.7	2.4	-

TABLE 25 RADIO OR T.V. LISTENING INTERRUPTED BY NOISE

Response	Total Survey Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
Never	226	75.3	82.0	53.6	69.1	90.2	100
Sometimes	51	17.0	13.5	32.1	21.7	6.7	-
A Lot	12	4.0	0.9	10.7	6.7	-	-
Nearly All The Time	11	3.7	3.6	3.6	2.5	7.3	-

TABLE 26 CONVERSATION INTERRUPTED BY NOISE

Response	Total Survey Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
Never	260	86.6	97.3	71.4	79.1	90.2	100
Sometimes	31	10.3	2.7	17.9	17.5	4.9	-
A Lot	6	2.0	-	7.1	3.3	-	-
Nearly All The Time	3	1.0	-	3.6	-	4.9	-

TABLE 27 VALUATION EFFECT OF NOISE

Response	Total Survey Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
Decreased Value	40	13.3	9.9	21.4	15.8	9.8	9.5
No Effect	228	76.0	86.5	64.3	70.8	70.7	85.7
Don't Know	32	10.7	3.6	14.3	13.3	19.5	4.8

TABLE 28 MOVE DUE TO NOISE

Response	Total Survey Control No.	%	Area 1 %	Area 2 %	Area 3 %	Area 4 %	Control %
No	263	87.7	85.6	89.3	90	85.4	100
Thought About	20	6.7	9.0	3.6	5.0	7.3	-
Talked About	10	3.3	5.4	3.6	0.8	4.9	-
Leaving	7	2.3	-	3.6	4.2	2.4	-

4.6 Time of Day at Which is Noticed

Respondents were given a card listing various times of day and asked whether they found the noise 'not noticeable', 'noticeable' or 'very noticeable' at different times of day. The noise is most noticeable during the afternoon peak hour and in the period 9 am to midnight. The fact that noise is most noticeable during the afternoon peak hour is consistent with the finding that more people noticed traffic noise than aircraft noise. Because only 2 per cent of respondents lived on main roads, it is safe to assume that the time 9 pm to midnight is a time when people notice aircraft noise. Midnight to 6 am would fall into a similar category and during this time 22.4 per cent of respondents noticed noise.

5.7 Comparison Between Areas

Comparison between areas for the annoyance score has already been presented in Table 19 and discussed in section 5.3: comparisons will now be made for the effects of noise and the times of day at which noise is noticed most.

The data for the proportions of people reporting different effects due to noise have been presented in Tables 23 to 28. By examining the data for proportions of people in each area reporting 'never' having experienced a particular effect, it can be seen that areas 2 and 3 are more affected by aircraft noise than the other areas.

Three time periods were selected from the data for when 'noise is noticed most' and proportions of people in each area finding noise 'noticeable' to 'very noticeable' during these time periods are shown in Table 29. Examination of this data reveals that in areas 2 and 3 a higher proportion of respondents noticed noise in the 9 am to midnight time period than in the afternoon peak hour. This would seem to indicate that aircraft noise is noticed more than traffic noise in these areas. Proportions of respondents noticing noise in all three time periods were higher in areas 2 and 3 than in areas 1 and 4, the period midnight to 6 pm being the most prominent in this respect. This result further implicates aircraft as the source of noise in areas 2 and 3.

TABLE 29

WHEN NOISE NOTICED MOST

	% Finding Noise Noticeable to Very Noticeable					
Time Period	Total Survey - Control	Area 1	Area 2	Area 3	Area 4	Control
Afternoon 4-6pm	41.4	45.0	46.4	40.0	36.6	33.3
9pm - Midnight	34.3	31.5	50.0	40.9	29.3	0.0
Midnight - 6am	22.4	18.0	25.0	34.1	9.7	0.0

5. DISCUSSION ON SURVEY RESULTS

Table 1 presented survey areas by geographical description and number of valid responses per area. From this it can be seen that Area 2 is the Swan, Midland area, and Area 3 is the Belmont, Perth, Canning area. From looking at the 1976 NEF contours it would have been reasonable to expect to find that Area 3 to be more affected by aircraft noise than Area 2. However, 7.3 per cent of the total sample were found to keep their windows closed 'nearly all of the time' because of noise, and a further 3.3 per cent 'a lot'. There may, of course, be reasons for closing windows other than noise, but the question specifically referred to closing windows 'because of the noise'. Especially in the hot summer months in Perth, it is common to open windows at night to alleviate the heat, and deciding to close windows at this time because of noise represents a choice between two sources of discomfort (Table 23).

The question concerning sleep disturbance is an important indication of the effects of traffic noise. More than is the case with the other activities interfered with by noise, the implications of sleep disturbance for the general health and well-being of the population can be readily perceived. The distribution of replies to this question related to aircraft noise was 2 per cent 'nearly all the time', 4.3 per cent 'a lot' and 25,7 per cent 'sometimes'. In other words, approximately 6 per cent of the population were seriously disturbed in their sleep, and another one quarter occasionally disturbed (Table 24).

The questions concerning interference with radio and television and conversation both involve social activities in which hearing is important. About 8 per cent of the sample said that they had trouble hearing radio or television 'a lot' or 'most of the time'. It would be less likely for conversational to be interrupted, since one can more readily adjust one's voice to fluctuations in background noise than turn up the radio or television. However, 3 per cent of the respondents had their conversation interrupted 'a lot' or 'most of the time' and a further 10.3 per cent 'sometimes' (Tables 25 and 26).

Taking these questions concerning the behavioural effects of noise as a whole, and considering the proportions of people who answered 'a lot' or 'most of the time' to each question, one might say that for one-tenth of people included in this study, aircraft noise exerted a serious adverse effect on their quality of life.

Two other questions concerned people's perceptions of noise in their neighbourhood. One question concerned whether people thought the aircraft noise had affected the value of their property, 13.3 per cent though there had been some effect 76 per cent no effect, and 10.7 per cent were unsure. Another question concerned whether people had considered moving away from the area because of the aircraft noise; 7 per cent had 'thought' about it, 3 per cent had 'talked about' leaving and 2.3 per cent had 'tried to sell'. It is pertinent that the 2.3 per cent who tried to sell represents 7 households who were so disturbed by aircraft noise that they had tried to leave the area (Table 27 and 28).

These behavioural indices can also be used to validate the annoyance scale (Langdon 1968). If these indices do represent the kinds of responses which contribute to annoyance, the proportion of people affected by noise on a particular index should correlate with the annoyance score.

6. NOISE MEASUREMENT PROGRAMME

6.1 Introduction

The objective of the noise measurement programme was to obtain physical measures of the noise levels prevailing in the areas designated, in an attempt to obtain a noise index which correlates well with the annoyance scores obtained through the social survey. That is, a noise index suitable for use in Perth's situation. Besides simply providing a picture of noise level patterns in the area, the noise index can be employed to establish a noise dose-response relationship.

The aim of establishing such a relationship was to enable an accurate judgement of those areas and those people, most affected by aircraft flyover noise. It also provided data on which an assessment of the validity of established NEI[1] contours (Noise Exposure Index: Department of Aviation, 1977), and other indices such as L_{np} (noise pollution level) and L_{eq} (equivalent sound level) can be made.

Limitation of noise, for the purpose of specifying the acceptability of living and working conditions, has previously been recommended in the form of relatively simple noise specifications. These are aweighted sound levels Noise Rating Curves (NRC) and other rating systems, and more complex measures such as the equivalent sound level (L_{eq})[1]. This relatively unsophisticated approach, while desirable in its simplicity, often proved to be insufficient in terms of real conditions. It has been found that a more systematic approach must be made to give a more meaningful scale, in terms of a subjective judgement of annoyance, or some other specified aspect of concern (Burns, 1973).

This systematic approach involves three main aspects;

(i) the intensity of the noise,
(ii) its durations, and
(iii) its variation with time

Different types of noise procedure produce variations in these characteristics, such as a series of aircraft flying over an area of otherwise low noise level. To meet these different demands, the numerous investigations carried out in different countries have resulted in the use of at least a dozen different indices (Burns, 1973).

Footnote: [1] L_{eq} - a level of steady sound which, over a given period of time, would contain the same noise level as the time-varying sound level one is describing.

For example;

Le - aircraft exposure level
Lexp - aircraft noise exposure level
AAI - annoyance index
CNR - composite noise rating
Lq - equivalent disturbance level
NNI - noise and number index
NI - noisiness level
NIL - noise immission level
Lnp - noise pollution level

In addition, the concept of 'Noise Exposure Forecast' (NEF) (Galloway and Bishop, 1970) has been used for predicting noise intrusion in communities by aircraft flyover; a use which is considered questionable by the authors and which receives further discussion in the context of this report.

Of the indices listed above, the majority have been developed to meet the need for a measure of community reaction[2] from aircraft noise.

For the purpose of critical analysis, much of this report is based on an investigation of the NEF system as a suitable indicator of both ground noise levels, and resultant annoyance, neither of which it directly measures. The report attempt to demonstrate the need for a revision and refinement of the NEF systems in terms of the mapped contours specific to Perth, and an assessment of its validity as an indicator of associated levels of annoyance. This study also attempted to expose the need for a reliable noise index for use in noise dose-response analyses, particular to the Perth situation.

The data obtained will also enable a comparison of the effects of increased aircraft activity and development of the Perth Airport in the future with present conditions, (Department of Aviation, May 1982) particularly in terms of existing and future flight paths which are not identified on NEF maps.

<u>Footnote</u>

1. It is important to note that a distinction is sometimes made between Noise Exposure Index (NEI) which measures existing noise exposure, and an NEF which measures projected, future exposure. However, the exposure index is referred to in the scientific literature simply as NEF. To avoid confusion, the term NEF is used throughout this report. Note also that all calculations of noise exposure in terms of NEF are estimates of current exposure (National Acoustics Laboratory, 1982, pp.36)

2. Community reaction means, in the context of this report annoyance, disturbance and other similar responses to environmental noise.

With respect to aircraft noise, information was also sought on the following:-

(a) the various direct effects of aircraft noise and the proportion of those exposed who experienced each effect;
(b) the extent of annoyance by indirect effects;
(c) the characteristics of the noise found annoying and the proportion of people annoyed;
(d) the effect on annoyance of variation is a particular characteristic of the noise;
(e) the social and psychological factors which might influence the degree of annoyance by the noise;
(f) to what extent people could become accustomed to aircraft noise;
(g) whether aircraft noise caused people to move away from the vicinity of te airport;
(h) whether there were limits of exposure to aircraft noise beyond which movements of population away from the area would be enough to make the population remaining unrepresentative of the population as a whole; and
(i) any other data necessary for the understanding of the relation between noise and public reaction, in such a form as to enable predictions to be made on the effect of changes in any relevant variable.

Not all of these, and other questions, were able to be answered in decisive terms, but the results indicate the importance of obtaining such information to enable an accurate picture of the Perth situation to be made. It also highlights those previously unattended areas of importance for future investigation and explanation.

<u>Noise indices</u>

The social survey from Committee on Noise (1963), produced answers from which 58 social and psychological variables could be isolated. The analysis of the noise measurements yielded 14 variables descriptive of noise exposure. Further analysis showed that the physical noise measurements correlating with the community annoyance could be reduced to two, the average peak noise level in PNdB (perceived noise level) and the number of aircraft heard during the daytime of about 12 hours.

The two factors can be combined in a number of ways and different solutions have been developed. In the United Kingdom, the measure used is known as the Noise and Number Index (NNI); however, this index has not been widely accepted. It makes no allowance for the duration of noise events or the relative annoyance of day and of night operations. NNI is simpler to use than the previously mentioned NEF, but is probably less accurate as a predictor of community annoyance.

The present study looked at a variety of other indices in this context.

<u>NEF</u>

The Noise Exposure Forecast system was originally designed as a theoretical, comparative planning tool for use in community development. It is seen as a means of quantifying, for such planning purposes, the exposure on the ground to noise from aircraft flyover.

Its basic elements are the actual noise levels produced by the various aircraft types and their declension with distance (measured in 'Effective Perceived Noise decibels' (EPNdB), and aircraft take-off profiles.

$$NEF = EPNL_{ij} + 10 \log (D_{ij} + 16.67 N_{ij}) - 88$$

where: EPNL = Noise level on the ground measured in EPNdB[1]
D = Number of aircraft during the day (0700 - 2200 hrs)
N = Number of aircraft during the night (2200 - 0700)
and ij refers to the i^{th} aircraft type on the j^{th} flight track.

All of the above information is used to construct NEF maps by computer contour lines which link together points of equal cumulative noise exposure. These contours then theoretically describe the community affectedness. (see Fig. 1: pp 21 NAL report #88, Feb 1982).

Other studies concerned with annoyance due to aircraft noise have worked on the assumption that "noise affected areas" surrounding an airport only extend as far as the NEF 25 contour, and confined their studies to within this limit.

In Perth (perhaps partly attributable to the fact that it is an extremely isolated city), community annoyance and disturbance due to aircraft noise may be quite different to that of other Australian cities and international communities. In fact, the present survey suggests that the "noise affected area" could well extend beyond this traditionally accepted limit.

Therefore, doubt is cast upon the suitability of the NEF system as a method of predicting community response to aircraft noise in Perth. It may well be said, in fact, that the NEF system is being employed beyond its intended use - beyond its capabilities. Rather than simply a statistically based <u>estimation</u> of noise exposure levels, it has been seen, and used accordingly, as a valid <u>indicator</u> of such exposure and further more, annoyance. It is the validity of this application that is strongly questioned in this study.

Footnote

1. While PNL (perceived noise level) and A-weighted sound level can be used to monitor the peak noise level of an aircraft flyover, EPNL (effective perceived noise level), measured in decibels, takes into account the variation of the noise and the time it lasts, by integrating the PNL over the duration of the event.

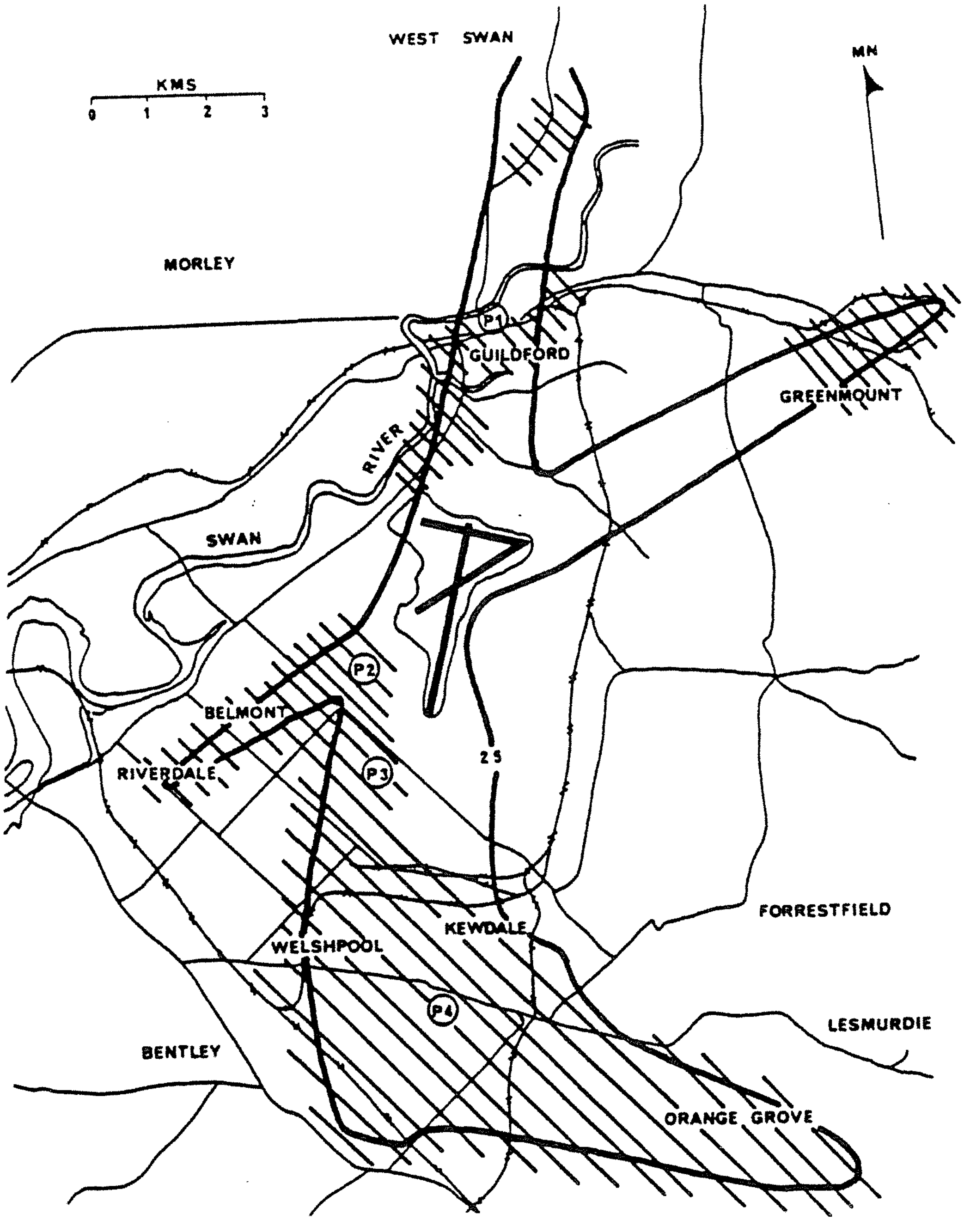


Fig. 1. Perth airport and surrounding areas. The solid line shows the nominal 25 NEF contour used for stratification. The sampled area is shaded. Noise measurement sites and code numbers are circled.

Lnp

The noise pollution level was developed by Robinson in 1970 after he extensively reviewed various indices of disturbance. On his assessment, this index seems to have a wide applicability as a general index of general disturbance.

The NP index is dependent upon the difference between the background noise level (L_{90}) and the noise level (L_{10}) exceeded for 10% of the time. It is assumed that annoyance caused by an intrusive noise depends on how much that noise exceeds the background level. Therefore:

$$L_{np} = L_{eq} + 2.56\sigma$$

where: 2.56σ = the standard deviation of sound level fluctuations during the same time period
$(2.56\sigma = L_{10} - L_{90})$
and Leq = total sound energy for that time period.

This noise climate index is based on assumptions as a result of these main findings:

(i) that the amount of sound energy in the stimulus in a given period of time is a primary component;
(ii) that annoyance due to increased numbers of noise episodes (eg aircraft flyover) increases at a rate greater than the increase of total energy of the series; and
(iii) that the range of variation in level of noise fluctuation about a mean value influences annoyance.

(Burns, pp. 167, 1973)

Lnp was included in the present study in the attempt to identify a suitable noise index. The assumptions of which Lnp is based, and previous studies indicate that it may be a viable index, applicable to the Perth situation.

Leq

The equivalent continuous sound level is the level of a constant sound having the same sound energy as an actual time-varying sound over a given time period. That is, the same amount of noisiness occurs from a sound having a high level for a short period, as from a sound having a lower level but occurring for a long enough period that the same amount of energy is involved (May, 1978).

Leq has the advantage over Ln measures [1] in that it shows no abrupt change as the duration of a sound intrusion exceeds a particular proportion of the sample period, while a description like L_{10} may not register an event such as aircraft flyover at all. It also has the further advantage of being additive when looking at different measurement areas. Such an addition is not necessarily accurate when Ln is involved.

Its merits as a suitable indicator of noise dose-response relationship when looking at community affectedness, as opposed to other indices is evaluated in this study.

Ldn

In order to represent the greater annoyance assumed by sound intrusion at night, the day-night sound level has been derived. It is based on the energy-equivalent, A-weighted sound level Leq, and supposed that for the equivalent sound level occurring between 10 pm and 7 am a 10dB(A) increment should apply before combining with the equivalent sound level for the period 7 am to 10 pm to give the day-night level.

While the relative merits of Ldn and Leq are not fully resolved (pg 27, May 1978), the day-night index was included in the present study to determine the importance of a time factor when gauging community annoyance responses.

Lne

Based upon the combined allowances and assumptions involved in Lnp and Ldn noise indices. Lne (Noise Exposure Level) was devised, in this study, in the search for the noise index best suited to Perth conditions.

Incorporating the noise climate aspects of Lnp (ie $L_{10} - L_{90}$) and the day-night weighting during 2200 and 0700 hours given to Leq to develop the Ldn index, Lne can be said to equal Ldn + ($L_{10} - L_{90}$).

By taking the effects of background noise and the time of day intrusion by noise events occur, Lne appears a promising index in the determination of a noise dose-response relationship in the study of community annoyance responses.

It is these 5 indices which were "put to the test" in the present study. While the results obtained are by no means conducive, they do suggest the inadequacy, for the Perth experience, of available noise indices in determining noise dose-response relationships.

It may well be that a different noise index will be necessary for each geographical area or city when it is affected by aircraft noise. It may also be that some independent variables unaccounted for in past and present studies strongly determine the reliability and validity of the noise index employed.

Therefore, any conclusions as to the inadequacy of the noise indices (Ldn, Leq, Lnp, Lne & NEF) as predictors of community annoyance can only be taken as valid for the community surrounding the Perth Airport. However, these results may be useful for comparison with other studies in other areas.

SITE SELECTION

23 sites were selected within the Perth Metropolitan areas, both within and outside the NEF 25 contour, and in relation to the social survey areas (see Appendix A), for the purpose of this study.

Each site had the equivalent of six days monitoring by means of a staggered weekly cycle. Each site was continually monitored for a period of 24 hours or six separate occasions over a period of weeks

Equipment

Two BRUEL and KJAER statistical noise level analysers TYPE 4426, coupled to BRUEL and KJAER alpha - numeric printers TYPE 2312 were used. These instruments enabled the hard copy production of data such as Leq, L10, and L90, on an hourly basis over the monitoring period. This data in turn was used to calculate LDN for each site.

One 4426/2312 combination utilized a BRUEL and KJAER TYPE 4721 outdoor microphone unit, which had inbuilt external calibration check facility.

The other utilized a BRUEL and KJAER TYPE 4165 microphone, coupled to a BRUELand KJAER TYPE UA 0308 dehumidifier and TYPE 2619 preamplifier. This microphone system was housed in a CEL 165 outdoor enclosure.

Thus, both systems were able to be installed without regard to inclement weather conditions. Each system was checked for calibration at the commencement and cessation of each 24 hour monitoring period.

The instruments were provided with internal power supply and mains supply, ensuring security of the integrated data should mains supply fail. They were located at each site with care to minimization of environmental noise other than aircraft noise (eg sites with no dogs, placed at rear of buildings, no after hours band practice or hobby woodworkers etc) so as to obtain as accurately as possible the environmental noise due to aircraft noise.

To minimise any acoustic interferences such as standing wave effects the microphones were positioned at distances greater than 1.5 m from any building facade or fence line and 1.5 m above ground level.

Data collection

Noise Measurements

For each of the 23 sites monitoring by the B & K 4426/2312, instruments were set to present integrated data on an hourly basis. One of the indices obtained in this way was the Leq. From the hourly Leq's, a 24 hour (daily) Leq was computer, using the following relationship.

$$Leq = 10 \log \left(\sum_{i=1}^{n} fi \ 10 \ Li/10 \right)$$

where Fi is the fraction of time the constant level Li is present ie.

$fi = 1/24$ (Cunniff, 1977).

Having determined the 24 hour Leq for each of the six days, the following indices were calculated in a similar way:

(i) An "average" daily Leq for each site. This was calculated on a mean energy basis, ie the Leq for each day was converted from dB(A) to Pascals pressure, arithmetically averaged, and reconverted to the logarithmic decibel expression.

(ii) An "average" daily Ldn, computed on the same basis, with a 10dB(A) penalty added to the hourly Leq's between 2200 hours and 0700 hours.

(iii) An adjusted Ldn [referred to simply as Ldn(2)] with an additional 5dB(A) penalty on to the hourly Leq's between 1600 hours and 2100 hours.

L_{10} and L_{90} measurement readings were also obtained and utilized in the calculation of two other indices.

(i) Lnp (Noise Pollution Level) whereby

$$
\begin{aligned}
Lnp &= Leq + 2.56\sigma \\
& Leq + (L_{10} - L_{90})
\end{aligned}
$$

(ii) Lne (Noise Exposure Level - a newly formulated and therefore untested index created by the authors) whereby

$$Lne \quad Ldn + (L_{10} - L_{90})$$

Data Collection

Having obtained six 24-hour noise measurement readings for the 23 sites[1], the values were averaged on an energy base, to give single noise level values of L_{10}, L_{90} and Leq for each site.

To incorporate data obtained from the social surveys, a 1.5 kilometre radius surrounding each of the 23 noise measurement sites was used to create 23 specified data sites (see Appendix B).

A 1.5 km radius around each noise measurement site was considered a valid distance in terms of the noise levels which would not significantly vary over that distance in terms of the purpose of this study. An area any larger could not be considered as consisting of the same overall noise levels, and any area smaller would not contain sufficient social survey results. While some overlapping of areas occurred, a 1.5 km radius proved suitable in meeting the objectives of the study.

Annoyance Scores

Annoyance scores obtained from the social surveys were collected in each of the data sites and averaged to give 23 mean annoyance scores. However, by setting an effective radius of 1.5 km, four of the sites, which had been selected for noise measurement purposes, contained no survey responses and therefore no annoyance scores.

However, noise level data from all 23 sites was considered valid and all noise measurements were included in the data pool and subsequent calculations.

At a further four sites mean annoyance values were considered invalid as they were calculated using less than five survey results. That is, there was less than five survey responses recorded within each of these four sites. Less than 5 responses is not considered a representative sample of the four areas and therefore any annoyance responses given not indicative of the annoyance level for that site.

The data obtained from these four sites on noise levels was used in assessing the accuracy of the NEF contours for predicting noise levels.

By combining the noise level data and the mean annoyance scores, it is possible to establish a noise dose-response relationship for each of the noise indices.

Footnote

1. Two sites' measurements (# 22 & #23) were carried out at a later stage (June 1983) and, due to time restrictions, were not monitored over a staggered cycle, but for 6 consecutive days/ See section of "Limitations of the data" in this report.

STATISTICS - Rationale

The noise dose-response relationship for each of the indices is expressed in terms of a regression line of mean annoyance versus noise exposure. An SPSS program employing New Regression provided such data along with correlations and scattergrams showing the relationships diagramatically.

Mean Annoyance

There seems to be a certain amount of debate concerning the use of "mean" annoyance values as opposed to "median" values in past and present studies. (Schultz, 1978).

Mean annoyance values were employed in preference to a median value in this study for several reasons. While it was originally considered by the researchers that the median values would be truer indicators of the most often occurring responses, and therefore more indicative of the same population, several short comings of this logic were identified.

When viewing noise pollution as a problem, extreme responses are of great importance. Median annoyance is diluted in that it is anchored by the responses of the 'general' and ignores the responses of those either highly or not annoyed. Mean values are affected by extreme responses and are therefore taking these extremes as no less valid and worthy of consideration.

Ldn(2)

Preliminary statistics strongly indicated that the time factor expressed in the Ldn index was responsible for a degree of annoyance expressed by respondents. Based on this observation and survey results which showed 42% of respondents noticed aircraft noise between the hours of 4 pm and 6 pm, and 34% between the hours of 6 pm and 9 pm, an additional weighting of 5dB(A) between the hours of 4 pm and 9 pm was given to the equivalent noise, time adjusted Ldn.

Consequent correlation statistics supported that time factor as an influential variable when looking at levels of annoyance from aircraft noise, and for the purposes of this report the adjusted Ldn will be referred to a Ldn(2).

Therefore: Ldn(2) = Ldn within an additional weighting of 5dB(A) between the hours of 1600 & 2100

Correlation Statistics

Noise Index	Mean Annoyance	% Accounted For
Ldn(2)	0.456	21
NEF	-0.177	-
Leq	0.284	8
Lnp	0.088	0.8
Lne	0.108	1.2
Ldn	0.345	12

Table 1: Noise dose-response relationship for the five indices expressed in terms of correlation co-efficients (r) and percentages accounted for.

Noise Index	NEF	% Accounted For
Ldn(2)	0.397	16
Leq	0.367	14
Lnp	0.327	11
Lne	0.397	16
Ldn	0.504	25

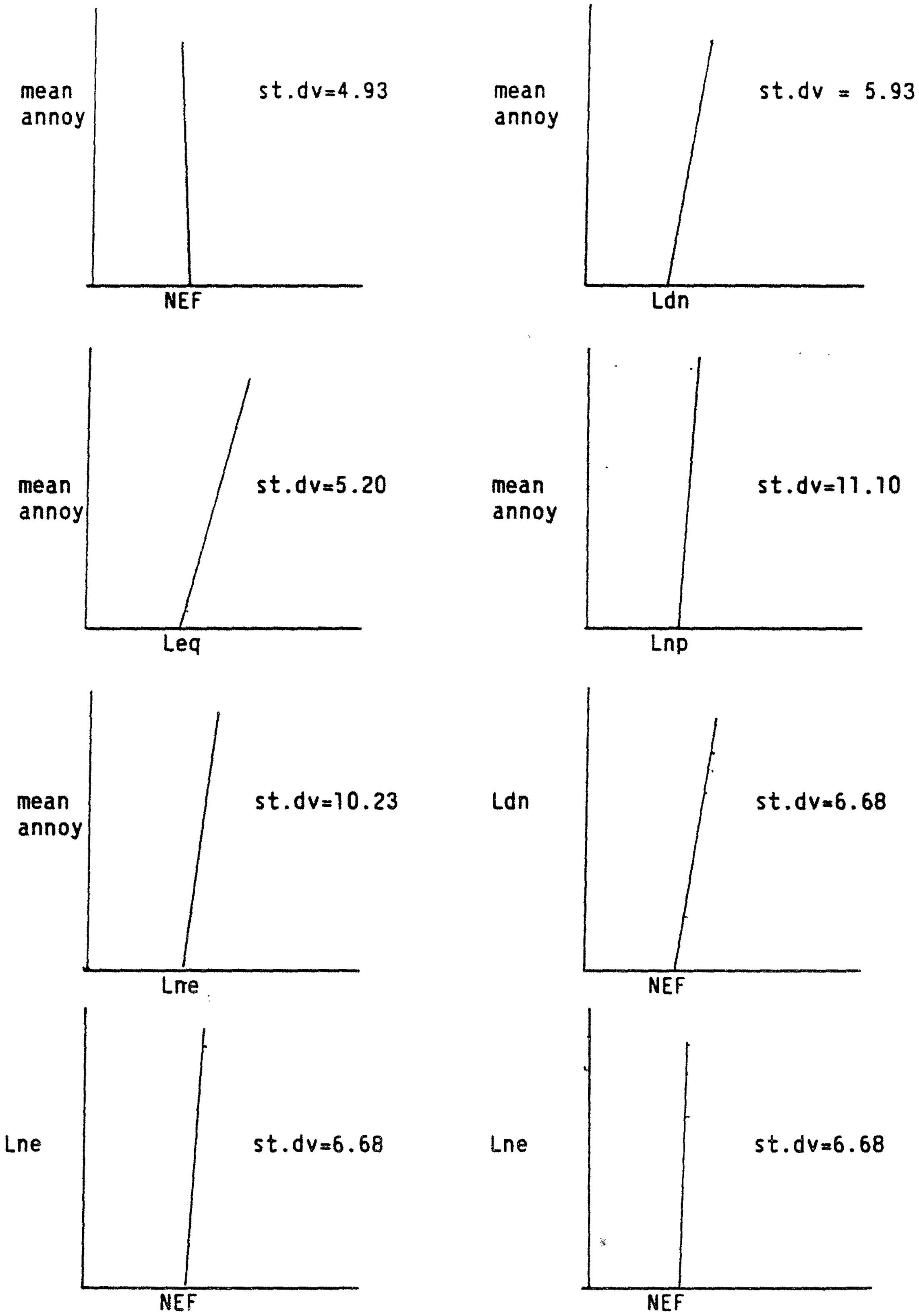
Table 2: Relationships between NEF and the various noise indices expressed in terms of correlation co-efficients (r) and percentages accounted for.

Indices	Ldn(2)	Leq	Lnp
Ldn(2)	1.000	-	-
Leq	0.851	1.000	-
Lnp	0.681	0.893	1.000
Lne	0.726	0.890	0.990

Table 3: Relationships between the various noise indices expressed as correlation co-efficients (r).

Regression Analysis

Mean lines of regression were calculated for the relationship between the six variables.



RESULTS AND DISCUSSION

Noise monitoring programme

From the long term monitoring programme, the data obtained was used for 2 purposes. Th first was for the calculation of indices with which to test the NEF model as a predictor of absolute noise levels on the ground, the second being utilized in the development of a dose-response relationship of Perth.

In order to evaluate the NEF model, Ldn's were calculated since it has been suggested that a relationship between Ldn and NEF exists such that;

$$Ldn = NEF + 35 \pm 3dB(A)$$

(Cunniff, 1977)

The assumption can be made that if the relationship holds, then a strong correlation should exist between the empirically obtained Ldn's and the theoretically modelled NEF's if the NEF contours do explain the noise level on the ground.

For table 2, it is apparent that the measured noise levels, Leq, Ldn(2), correlate weakly with NEF ($r = 0.367$ and $r = 0.397$ respectively), leading to the conclusion that the NEF contours do not present an accurate picture of the physical noise environment on the ground. If the NEF system is truly indicative of the ground-level noise exposure, stronger correlations should have occurred. As the highest percentage which can be accounted for when correlating NEF with noise indices based on on-ground noise measurements is 25%, (as illustrated by Ldn) there is little support, from this study, for the assumptions on which the NEF system is based.

The relationship between NEF and the other indices reinforces this conclusion with correlations of $r = 0.324$ and $r = 0.397$ for Lnp and Lne respectively.

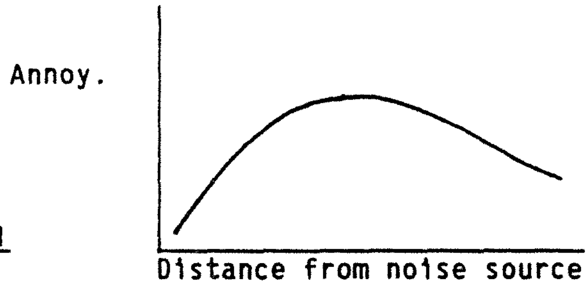
These results also question the validity of the above equation.

NEF and Mean annoyance results

While the results present the NEF system as a poor indicator of on-the-ground noise exposure, they also place doubt upon its use as a predictor of community response. The negative correlative factor found ($r = -0.178$) strongly suggests a lack of relationship between NEF and mean annoyance. In fact, the results suggest annoyance actually increases where it is theorized, by the NEF, it should be decreasing.

While it may be assumed that the NEF system is simply an inadequate indicatorof community reaction, a possible explanation for the results may be that the assumption of a linear relationship between noise levels and annoyance is not valid. That is, the assumption that the higher the noise or the closer one is to the noise source, the higher the annoyance.

There is no conclusive evidence to suggest that a linear relationship actually exists, and it could be that a curvilinear explanation would be more accurate. That is, a peak occurring at some distance (at some noise level) and then a gradual fall-off (see diag. 1).



Diag. 1

For example, while it may be expected (when assuming a linear relationship) that a higher degree of annoyance be recorded closer to the noise source (the airport), this may not necessarily occur.

Populations living near to the airport may comprise of people who are not particularly annoyed by the aircraft noise despite its magnitude. Similarly, individuals living a moderate distance from the airport may be less tolerant of the effects of aircraft flyover.

If individuals were very annoyed by aircraft noise, they would probably choose not to live near to the airport or, alternatively, would move away as the level of aircraft noise increased beyond tolerance level over the years. This would, of course, be subject to a large range of socio-economic factors.

Regardless of possible explanations, the results generated by this study showed NEF to be a poor indicator of on-the-ground noise exposure levels and, as may well be expected as a consequence of this, does not act of an accurate predictor of community annoyance. While the other indices can only account for as much of 21% of the annoyance, they are all markedly better indicators than the Noise Exposure Forecast system.

Noise dose-response relationship

The SPSS Regression Analysis procedure was utilized between the noise indices (Leq, Ldn, Ldn(2), NEF, Lnp and Lne) and the mean annoyance scores computed for each of the 23 sites. The correlation coefficients generated (table 1) indicate that Ldn(2) correlates the strongest of all the indices, with the annoyance factor of community response ($r = 0.456$).

However, Ldn(2) measures only explain mean annoyance scores for 21% of the time indicating that although it is the strongest correlate with community response, unexplained factors other than those related to aircraft noise and the associated time factor are contributing significantly to that annoyance response. Other noise sources, for example, may be major contributors such as road, rail and domestic noise.

Other indices proved to be insignificantly correlated with the decreasing order being, Ldn (r = 0.345), Leq (r = 0.284), NEF (r = -0.178), Lne (0.108) and Lnp (0.088).

Regardless of the magnitude of the relationships, certain observations can be made in terms of the relative suitability or unsuitability of the indices as predictors of community annoyance.

The inverse relationship between NEF and median annoyances exemplifies its lack of applicability in gauging community annoyance reactions. As NEF was originally designed for use as a planning tool, and as its relationship with the various "on the ground" measurements and noise indices is poor, it is not surprising that attempts to relate the contours to community annoyance responses give negative results.

Another observation which can be made from the limited data obtained in this study, is one which adds further weight to the growing belief that time factors involved in the noise-dose relationship are influential areas. The slight increase in the correlation coefficient for Lnp (0.088) when a time weighting is applied for events occurring between 2200 hours and 0700 hours (ie L_{ne} = 0.198) can be attributed to this alteration.

While the increase is not nearly as significant as that observed when a weighting was incurred on he overall sound energy (ie Leq = 0.284, adjusted to give Ldn = 0.456) it did have <u>some</u> effect.

The poor correlations between mean annoyance values and Lnp fail to support the assumptions on which this index is based (r = 0.088). Lnp assumes that increasing degrees of annoyance will be experienced as the level of background noise decreases.

However, this noise rating, dependent upon the difference between the background noise level (L_{90}) and the quasi-peak noise level (L_{10}) correlated significantly less with community response than did simpler ratings such as Leq and Ldn(2). This observation also applies to the Lnp time adjusted index Lne (r = 0.0108).

Intervening Variables

Results generated by this study are limited in the extent to which they explain the amount of annoyance revealed through responses to the survey; with three of the noise indices (NEF, Lnp and Lne) showing little or no relationship, and Ldn, Leq and Ldn(2) showing only a fair degree of relationship.

At best, noise resulting from aircraft activity was found to be responsible for 21% of the annoyance expressed by survey respondents (ie the Ldn(2) index). Taking Ldn(2) as the 'best' indicator of community annoyance resulting from aircraft flyover leaves 79% of experienced annoyance unexplained. This large gap between accounted for and unaccounted for disturbance may be due to one or more, or a combination of the following;

(i) intervening non-acoustic variations
(ii) other noise-generating events
(iii) errors in the noise data collection procedures
(iv) incorrect assumptions within the noise indices
(v) incorrect assumptions in the interpretation of survey data.

[(i), (iii) and (iv) will be expanded below]

Non-acoustic variables

Dealing with individuals and individual's responses to their environment suggests the probability of results fraught with numerous intervening variables. At any given degree of noise exposure, for example, a person's attitudes toward the source of noise, or toward the neighbourhood in general, or toward noise in general, appear to affect whether or not they will express annoyance and to what extent.

It has even been suggested (Schultz, 1973) that noise exposure itself is one of the least important determinants of people's tendencies toward noise annoyance, that one can more accurately predict whether an individual will be annoyed by noise from a study of his/her personality traits (fear, mood, hostility, depression etc) rather than by measurement. This could account for the lack of relationship between community reaction and the various noise indices found in this study.

Attitudes towards various aspects of aircrafts, and associated activities can directly influence an individuals disposition toward acknowledging and reporting feeling of annoyance. Attitudes may be governed by such things as;

(i) an individual's perception of the effects of aircraft activity has on the value depreciation of property;
(ii) how much aircraft generated noise interferes with activities an individual deems as important (which also varies greatly between people and groups of people);
(iii) the degree to which an individual believes complaining can bring about positive action;
(iv) an individual's degree of fear of debris falling from overflying aircraft, or a fear of planes in general;
(v) the perceived desirability of the neighbourhood as a place to live;
(vi) the degree of association with the airport, or the aircraft industry (for example, how often an individual uses aeroplanes as a means of transport);
(vii) the extent to which the aircraft industry is seen as essential;
(viii) an individual's thoughts on viable, alternative place to live.

Positive and negative attitudes toward the airport and aircrafts may be formed, as may cases of learned helplessness whereby people perceive they have no control over aircraft activity. This often results in a belief that the individual can in no way alter their environment, and so view themselves as helpless 'victims', where complaining or simply acknowledging annoyance would be fruitless.

All these inter- and intra- personal variables may be important determinants of people's propensity for noise annoyance. Identification of these variables in order to gauge the influence they exert upon individual's annoyance responses is a desirable element for use in future studies on noise-dose relationships.

It is also important to mention, at this stage, the subtle difference between what is termed "noisiness" and what we refer to an "annoyances". Noisiness is defined as the degree of unwantedness of a sound considered by itself (May, 1978); that is, a sound in isolation. Whereas annoyance is defined as the overall unwantedness of a sound heard in a natural situation, and therefore not usually in isolation.

A person's assessment of a sound's annoyance will include not only the unwantedness of the sound (its noisiness), but also many other variables which depend on the source of the noise and the context in which it is experienced.

It is these variables, some of which have been mentioned, which may account for the varying levels of annoyance expressed toward similar "noisiness" events (aircraft flyover).

Limitations of study

The amount of variation in the results ("data scatter") suggests the possibility of the actual data collection and processing being partly responsible for the inconclusive results obtained.

Schultz (1978) suggests several reasons why such a scatter occurs, which can be related to the present study. Included are other possible explanations:

(i) inaccuracies in the translation of noise data for original surveys to Ldn. Are the hours 0200 to 0700 accurately weighted?

(ii) measured noise may vary from the actual noise individuals are exposed to. Placement of the B & K noise measurement instruments did not allow for such things as distance of the dwelling from the measurement location, shielding by other buildings or terrain, and the difference in noise levels inside and outside the dwelling;

(iii) seasonal variations may be more influential than previously assumed, as people tend to remain indoors more often and for longer periods in winter than during any other season;

(iv) the size variation between the 23 survey response sites in terms of the number of respondents per 1.5 km radius area may be an important intervening variable; with the range being from 5 to 19 respondents (see Appendix C);

(v) Differences in the noise attenuation of the exterior walls of the dwelling which would affect the amount of noise exposure an individual is subjected to;

(vi) the lack of continuity and consistency which occurred during noise data collection. For example, the inclusion of data from sites 22 and 23; which was obtained at a later date than data from the other 21 sites, and without the implementation of the cyclical protocol;

(vii) human error incurred during instrument readings and the numerous calculation undertaken to calculate Lnp, Lne and Ldn(2) noise indices;

(viii) When events occur may be more important than actual noise level measurements [dB(A)]. That is, the focus or emphasis may be incorrect when results are gathered.

Assumptions within noise indices

The lack of evidence (displayed by the low correlation coefficients generated by the data), that a suitable noise index is available for determining a noise dose-response relationship for Perth, may be due to the inadequacy of the noise indices themselves.

If the assumptions on which these indices are based are incorrect, then their use as predictors of community annoyance becomes invalid.

While the purpose of this study was not to test the validity of such indices, the results suggest that an investigation into the logical bases could reveal shortcomings and areas of weakness.

The Noise Pollution Level index (Lnp), for example, is based on the assumption that annoyance caused by an intrusive noise depends on how much that noise exceeds the background level. Results from the present study fail to support this and therefore question the basis assumptions on which it is made in regard to aircraft noise in Western Australia.

The possible shortcomings of the NEF system as an indicator of community reactance has been discussed at some length in the context of this report and the results support the need to question its suitability as such.

The basis on which Leq and Ldn were formulated may also be in need of verification. Leq is largely employed as a foundation for the study of noise and its associated effects due to its consistent correlations with annoyance.

Crocker (1978) illustrates how using the different ratings (L_{10}, L_{50}, L_{90}, L_{np} etc) produce considerable annoyance variance particularly when the annoyance is less than very annoying (Fig 2-8: p 51), and claims that by using Leq there is more confidence on the annoyance scores.

It may be, however, that such variance within the different noise measurements and what creates such variance is of crucial importance in understanding community annoyance reactions.

A separate problem from that of combining noise levels from the various noise indices, is the question of whether events occurring at different times of the day should be given different weightings, and if so, how large should the ratings be. Although most existing noise indices incorporate such weightings, it has been noted that little experimental evidence has been produced to justify their use (Fidell and Schultz, 1980).

It may be that weightings are too high or that the specified "night-time" period is not truly related to high-annoyance time. It may be, also, that time-of-day weighting factors need to be geographical and/or situation specific.

Finally, it may be, in fact, that a different noise index will be necessary for each geographical area or city when it is affected noise. It may also be that some independent variables unaccounted for in past and present studies strongly determine the reliability and validity of the noise index employed.

Revision of NEF for Australia

The National Acoustic Laboratories report, February 1982, produced results from a study which showed that community reaction to aircraft noise in Australia is best described by a revised noise exposure index based on the NEF system. The resultant index is known as $NEF_{x,y}$; where x represents the night weighting in dB and y the evening weighting/ "Night" and "evening" are taken as 2200-0700 and 1900-2200 hours respectively.

The report examined at three other variations of the NEF system before concluding $NEF_{3,6}$ to be most applicable to the Australian situation (p 40 Nal Report 1982)

(i) NEF 2 Based on NEF, but using EPNL values and departure profiles which have been corrected on the basis of measurements at each airport.

(ii) NEF 3 As for NEF 2, but including noise from aircraft using reverse thrust, and those taking off on other runways.

(iii) NEF 4 As for NEF 3, but including the effects of shielding or reflection by structure near each residence.

As the inadequacies of the NEF system discussed in this report remain an inherent part of this revised NEF, the present study suggests that the $NEF_{x,y}$ index remains an unsuitable means of establishing a noise dose-response relationship. While it allows for the time factor considered important by the authors in the measurement of related community annoyance reactions, the NEF system (and any derivations) by using statistical estimations of on-ground noise levels, is not thought to be an accurate index for such a study.

The present study also fails to support the revised NEF ($NEF_{x,y}$) as the revised contour map suggests a large decrease in the amount of people and areas affected (that is, outside $NEF_{x,y}$ contour) while studies suggested that affected areas occurred beyond the standard NEF 25 (see Fig. 1) (pg 150 NAL Report, 1982)

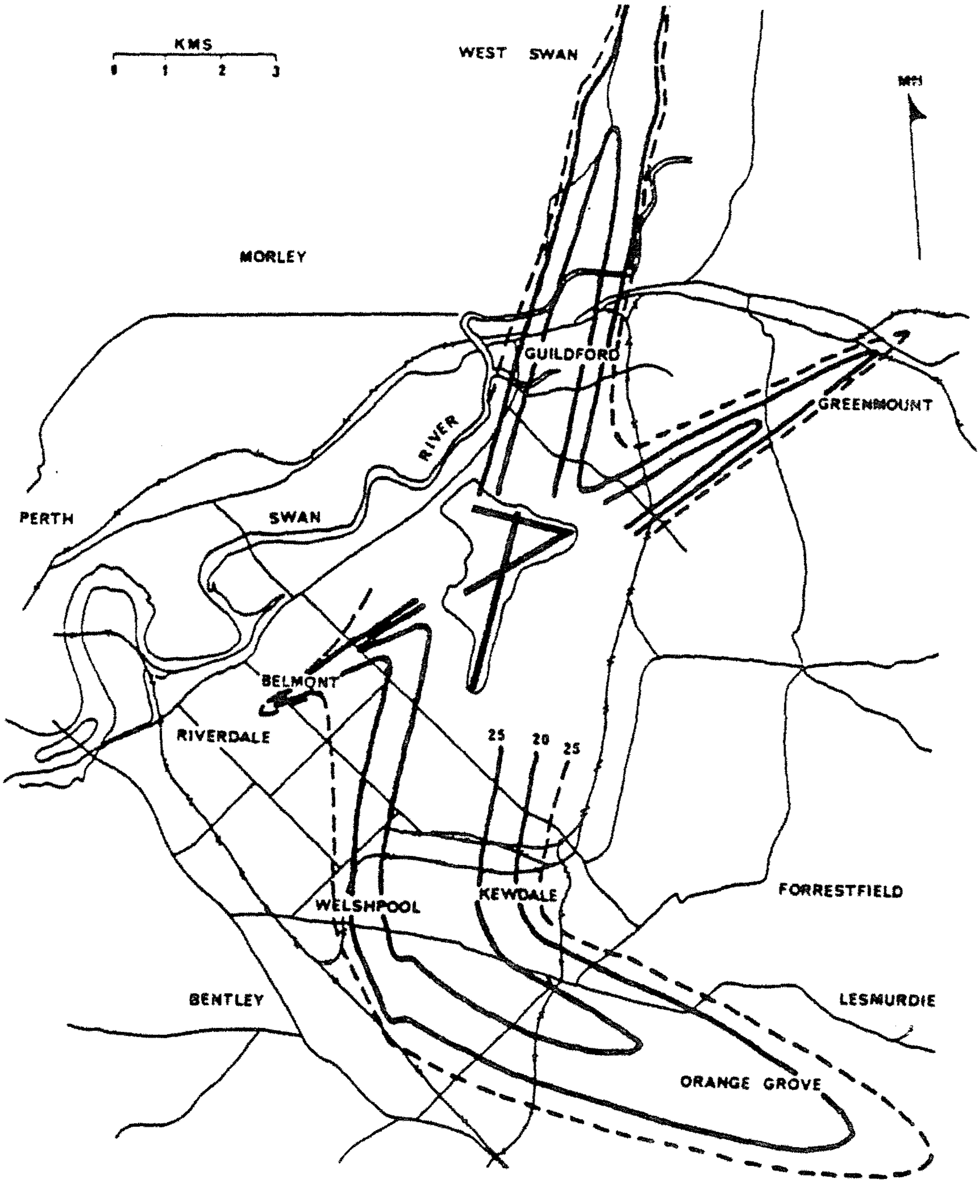


Fig:1. Noise exposure contours around PERTH airport.
—— Revised NEF (20 & 25), - - - standard NEF (25).

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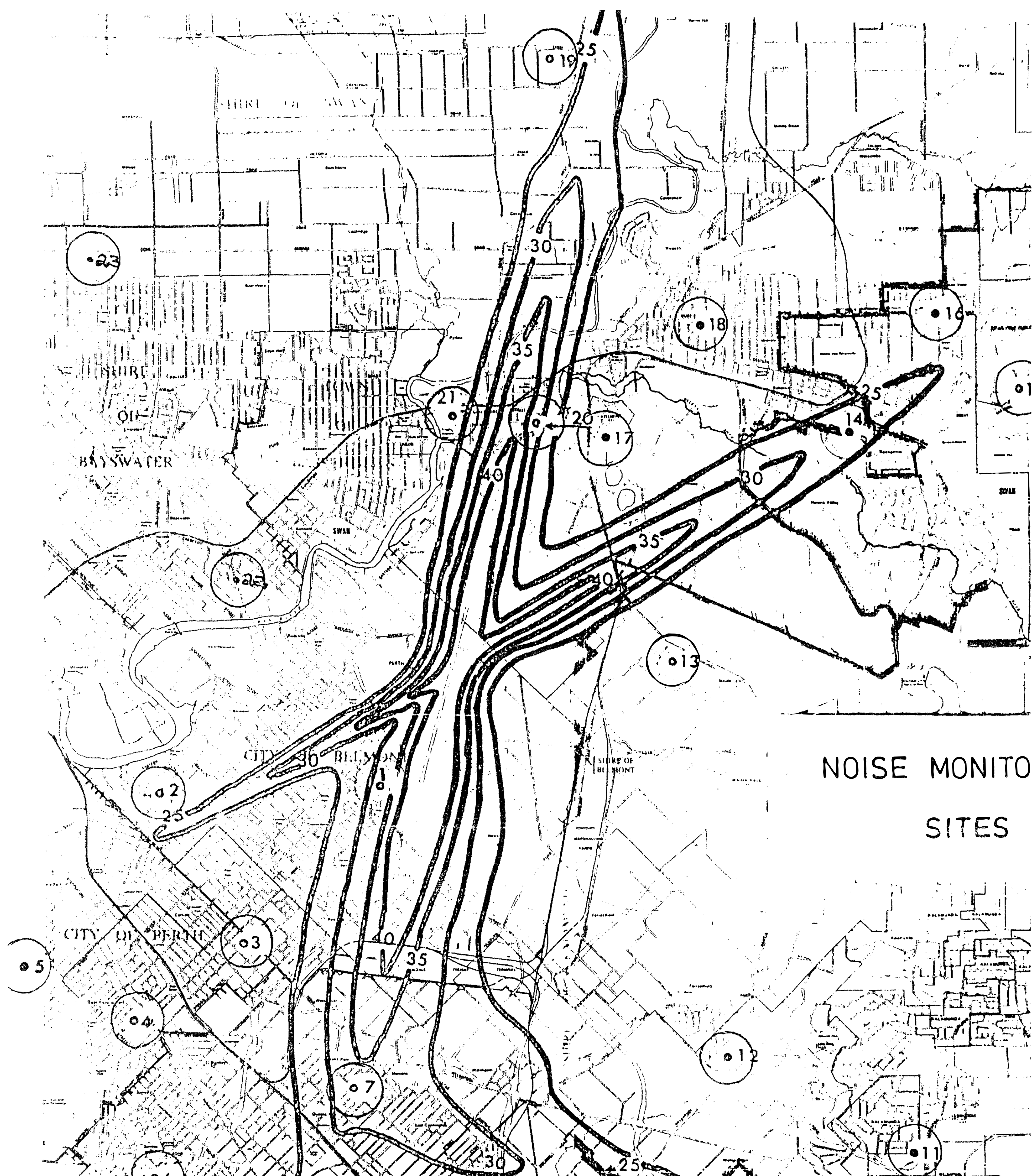
- APPENDIX A -

SITE	ADDRESS
1	10 Middleton St., Cloverdale
2	60 Toorak Rd., Rivervale
3	23 Astral Ave., Carlisle
4	18 Patricia St., East Victoria Park
5	16 Pitt St., Kensington
6	10 Coulson St., Wilson
7	70 Gibbs St., East Cannington
8	25 Foxwood Way, Langford
9	73 Lalor St., Kensington
10	Lot 225 Clifford Rd., Orange Grove
11	10 Gilbert Rd., Lesmurdie
12	11 Norfolk St., Forrestfield
13	43 Hamilton Rd., Greenmount
14	14 Croydon St., Bellevue
15	3 High View Rd., Greenmount
16	400 Morrison Rd., Swanview
17	1 West Pde., Hazelmere
18	56 North St., Midland
19	Lot 10 Harrow Rd., West Swan
20	74 Helena St., Guildford
21	11 Market St., Guildford
22	60 Wyatt Rd., Bayswater
23	41 Ramsden Way, Morley



NOISE MONITO
SITES
MAF
CITY OF PERTH
CITY OF CANNING
CITY OF BELMONT
SHIRE OF SWAN
BAYSWATER

- APPENDIX C -

NOISE SITE POPULATION
MEAN ANNOY. SCORE N.E.F.

1*	-	-	30
2	8	3.4	25
3	-	-	20
4	11	2.7	15
5	11	2.5	15
6	11	2.1	20
7*	-	-	35
8	19	2.3	15
9	7	1.6	20
10	2	1.5	30
11	8	2.0	15
12	3	2.7	20
13	8	2.3	20
14	6	1.3	30
15	5	5.2	15
16	5	5.2	20
17	4	2.8	20
18	5	3.4	15
19*	-	-	25
20*	-	-	35
21	8	2.4	30
22	9	2.8	15
23	19	1.9	10

* Sites omitted from annoyance data.