FIFTH INTERNATIONAL CONGRESS ON SOUND AND VIBRATION

DECEMBER 15-18, 1997
ADELAIDE, SOUTH AUSTRALIA

AIRCRAFT NOISE IN SYDNEY: COMMUNITY REACTION IN AREAS BETWEEN 15 AND 30 KM NORTH OF THE AIRPORT

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(Financial support from Ku-ring-gai Council is gratefully acknowledged)

The Australian Noise Exposure Forecast (ANEF) system was applied in Sydney in the decision making process which led to the construction of the 'third runway'. After the opening of this runway in November 1994, a predominantly north-south parallel runway mode of operation was adopted. The Environmental Impact Statement for the third runway and the associated Draft Noise Management Plan (DNMP) predicted, on the basis of the ANEF system, and data contained in Hede and Bullen (1982), that the number of 'at least moderately affected' or 'seriously affected' residents will be zero in the local government area of Ku-ring-gai. This local government area of approximately 106,000 residents is located at least 15 and as much as 30 kilometres north of Sydney airport and is primarily exposed to aircraft landing from the north. This paper reports on the major findings of a questionnaire survey, carried out in September 1995, involving a sample of 5000 randomly selected voters of Ku-ring-gai and using a questionnaire which is essentially identical to that used by Hede and Bullen (1982). The results show that the DNMP underestimated the number of aircraft noise affected people by at least 13 per cent on the basis of the local government area of Ku-ring-gai alone.

I. INTRODUCTION

The Australian Noise Exposure Forecast (ANEF) system was applied in Sydney in the decision making process which led to the construction of the 'third runway' at Kingsford Smith Airport (KSA). With the opening of this runway in November 1994, a predominantly north-south parallel runway mode of operation was adopted. The Environmental Impact Statement for the third runway (EIS) predicted, on the basis of the ANEF system, and data collected by the National Acoustics Laboratories (NAL) in 1980 (see Hede and Bullen (1982), that the number of 'at least moderately affected' or 'seriously affected' residents will be reduced by approximately 60 per cent as a consequence of this airport project (EIS, 1991, Table B, p xxxiii). Furthermore, it was predicted that the number of 'moderately affected' or 'seriously affected' residents would be zero for the local government area of Ku-ring-gai. (The number of affected residents by postcode is given in Table 4.2, Draft Noise Management Plan (DNMP), 1994. None of the postcodes belonging to Ku-ring-gai are listed.)

The local government area of Ku-ring-gai comprises 17 suburbs, grouped into 9 post-code regions, with a total population of approximately 106,000. The council area extends over 84 square kilometres. Built up area is predominantly residential, with only about five per cent of business and other commercial use. Residential areas are located at least 15 and as much as 30 kilometres north of KSA (Sample area, Figure 1). The majority of residential properties consist of low density housing on relatively large blocks of land, in an environment which is renowned for its bushland beauty, large parkland areas, and hilly terrain. Housing construction ranges from light (weatherboard, brick veneer) to heavy (double brick, stone). Climatic conditions favour large windows, verandas, outdoor living and leaving windows open.

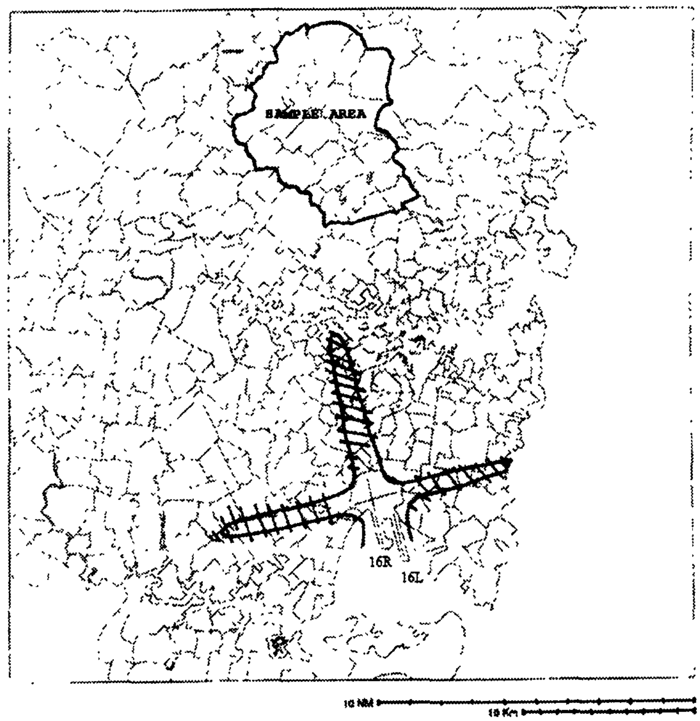


Figure 1

A review of the methodology used in the EIS revealed major shortcomings, particularly concerning areas such as Ku-ring-gai (Gross, 1994). These shortcomings include: (i) In the NAL study, no noise measurements were taken in urban areas outside the 'vicinity of Australian Airports' (Sydney, Melbourne, Adelaide, Perth, and Richmond). The 'vicinity' of an airport was defined as the area within the 25 NEF contour, as projected by the Civil Aviation Authority's (CAA) Integrated Noise Model (INM). This corresponds to about 10 kilometres north of KSA (The 'vicinity of KSA' is indicated in Figure 1 by three arms extending from the runway lines).

(ii) Insufficient data on the reaction of residents in areas outside the 25 NEF zone (36 observations for Sydney). This shortcoming is particularly severe in light of the very low explanatory power of the ANEF noise index (13 per cent). (iii) Disregard of possible self-selection bias when applying the data to relatively quiet residential areas in a bushland setting. (iv) The INM, employed in the EIS, assumes that land elevations under the flight paths are identical to those at the airport (approximately sea level). This assumption is invalid for Ku-ring-gai. (iv) Variations in sound exposure due to 'pilot operations' on approach to KSA have been left unexplored.

Section II details the examination of information, other than direct noise measurements, which led to the conclusion that aircraft noise exposure over many areas of Ku-ring-gai is such that an empirical study of the residents' reaction is warranted. Section III contains the description of the sample and survey method. The main results of the survey are contained in Section IV. Concluding comments are contained in Section V.

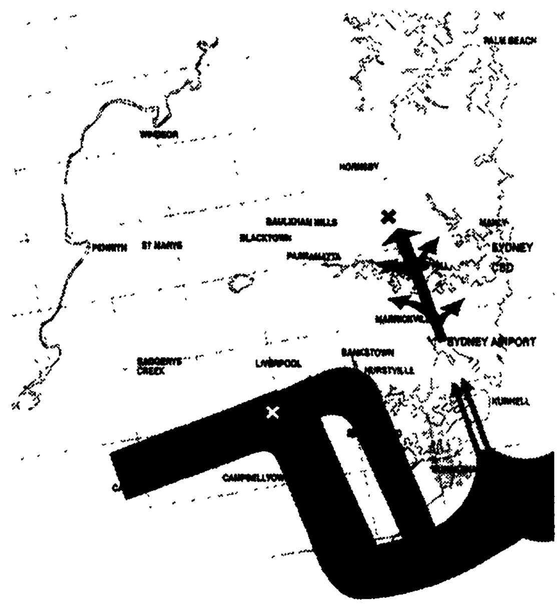
II. AIRCRAFT NOISE EXPOSURE INDICATORS

The absence of official data on aircraft noise measurements for Ku-ring-gai required a search for alternative indicators of aircraft noise exposure. Two sources were explored; flight path information and data on single flyover sound levels for at least some of the noisiest aircraft.

The EIS for the third runway did not provide flight paths maps, which extended as far north as Ku-ring-gai. However, the DNMP shows that under parallel runway operations, this area will be regularly overflown by aircraft landing from the north (Figure 2A) and, less frequently, by some aircraft taking off to the north (Figure 2B)

Major Flight Paths - Southerly Traffic Flow
(Used between 6am & 11pm
by approximately 86% of aircraft)
Source: DNMP, 1994 (Figure 2.6)

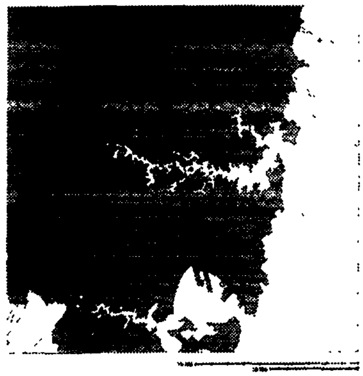
Figure 2A



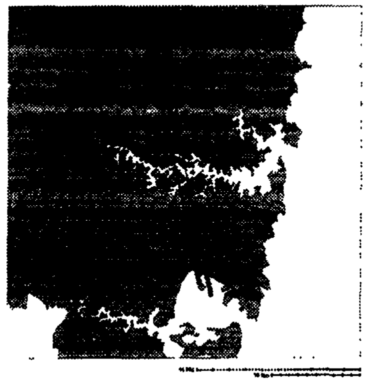
Major Flight Paths - Northerly Traffic Flow
(Used between 6am & 11pm
by approximately 13% of aircraft)
Source: DNMP, 1994 (Figure 2.7)

Figure 2B

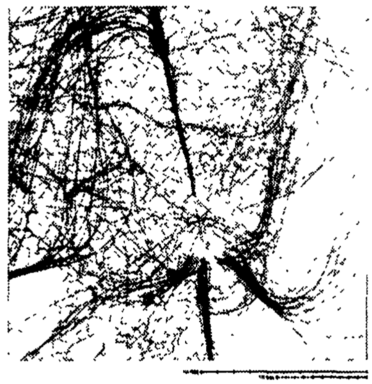
Flight track maps, obtained from the CAA, indicated that the distribution of approach paths over Ku-ring-gai is not even but aircraft movements are concentrated over some areas. (Sample flight track maps are shown in Figure 3A and Figure 3B). Moreover, the parallel runway mode of operation appears to have been tried out during some months prior to the opening of the third runway in November 1994 (see Figure 3C).



All Jet Arrivals 3 April 1995
Source: CAA
Figure 3A



All Prop Arrivals 3 April 1995
Source: CAA
Figure 3B



All aircraft movements
8 June 1994, 0600-1200 hrs
Figure 3C

These observations led to the formation of four 'flight density' categories (Figure 4). Group 1 contains suburbs which are most frequently overflown by aircraft landing from the north. This group is also exposed to heavy aircraft, landing on runway 16R (see Figure 1).

Suburbs in Group 2 are not directly overflown by heavy aircraft but are exposed to some take-offs. Group 3 contains areas which are less frequently overflown by aircraft than Group 1 or Group 2, either because of the absence of landings (south-east part of area 3) or the paucity of take-offs (north-east part of area 3). Group 4 appeared to be sheltered, except for the occasional landing approach. While there is some variation in flight density within each group, this method provides at least a coarse measure of variations in aircraft noise exposure over this large local government area; according to this indicator, aircraft noise exposure is highest in Group 1 and lowest in Group 4.

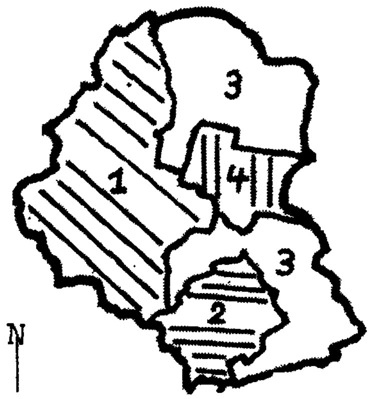


Figure 4

Australian Standard AS2021-1994 tables provide data on noise levels, measured in dB(A), for various aircraft types. According to these tables, the centre line sound level of a landing B747-200 jet is 72 dB(A) at 20 kilometres distance from the airport. The data in these tables extend only to 20 kilometres from the airport. The data is supplied to Standards Australia by Air Services Australia (former CAA) and is based on actual noise measurements as well as predictions made by the INM. Since the NAL study calibrated the INM only up to 10 kilometres, it is assumed here that data in the AS2021-1994 tables for distances beyond 10 kilometres is the output of the INM. Under this assumption, the AS2021-1994 data does not allow for land elevations relative to KSA. In the local government area of Ku-ring-gai, land elevations vary. For example, in the south-eastern part of the municipality (Figure 4) 30 metres AHD is representative of many residential areas. In the south-west land elevations are in the order of 70 to 100 metres, rising to 200 metres AHD in the north-west. Group 1 (Figure 4) is not only the most frequently overflown area but also contains relatively high land elevations. The residents in this group are therefore expected to be relatively more exposed to aircraft noise than those in other groups. The ranking of Group 1 remains unchanged.

A further source of underestimation of actual maximum flyover noise may be due to 'pilot operations'. The NAL study assumed a constant 3° descent slope. Inquiries with the Civil Aviation Authority (CAA) into the nature of 'pilot operations' revealed that not all landing aircraft descend on a constant glide slope over Ku-ring-gai. Often aircraft cruise at approximately 3000 ft above sea level for many kilometres north of a navigational aid, located on the south-western edge of the municipality (marked X in Figure 2A). While the CAA was unable to supply detailed data on the difference in sound levels between cruising and descending operations, the estimates supplied indicate that for B747 aircraft, a cruising operation causes between 4 dB(A) and 6 dB(A) additional noise, relative to a constant descent operation, at a distance of 20 kilometres (Gross, 1994). Taking the AS2021-1994 table as the base data and allowing for 100 m land elevation, a B747-200 cruising on approach to KSA from the north may be expected to generate 79 dB(A) at 20 kilometres distance, centre line.

The foregoing considerations led to the conclusion that a survey of residents' reaction to aircraft sound exposure in Ku-ring-gai is warranted.

III. METHOD AND SAMPLE

In light of the fact that the NAL study underlies predictions of the number of 'seriously' or 'moderately' affected residents in all discussions concerning the third runway project and flight path determinations, it is considered sensible to obtain comparable data. For this reason, the questionnaire used in the present study is essentially identical to that used in the NAL survey, except for minor modifications[1].

The modifications take note of local population characteristics in terms of relatively high education levels (ABS Census data)[2]. The introductory sentences to questions were rewritten to suit a mail-out rather than an interview type of survey. For the purpose of a pilot study, aimed at estimating the dollar value of activity disturbances, caused by aircraft noise, a suitable question was added.

Because of the relatively high educational level of the population in this local government area a mail-out style survey was considered to be feasible.

A random sample of 5000 was selected from the electoral roll for Ku-ring-gai. This roll contained 70,398 addresses. Each questionnaire mailed was encoded with a 15 digit security number, including post-code and gender. The questionnaire was mailed by Ku-ring-gai Council in the week ending 1 September 1995. Questionnaires received after 30 October were

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[1] The questionnaire and details of the survey results may be obtained from the authors.

[2] The lowest education level specified in this survey was primary school instead of the NAL categories of the number of years of primary school completed.

excluded. Questionnaires returned with the security code in place were deemed secure responses.

The response rates for the total sample and by flight density groups are reported in Table 1. As can be seen from this table, the secure response rate for the total sample is a little over what is typical for this type of survey, namely a little over 20 per cent. Only flight density Group 4 had a markedly different response rate: 17.5% (secured) as compared to about 21 % for the remaining three groups.

Table 1

Responses and Response Rates*

	Flight Density Groups				
	1	2	3	4	Total
(a) Mail-out	2124	843	1347	686	5000
	(.425)	(.169)	(.269)	(.137)	(1)
(b) Secure responses	440	174	291	119	1024
	(.430)	(.170)	(.284)	(.116)	(1)
(c) Returned to sender	27	11	18	5	61
	(.443)	(.180)	(.295)	(.082)	(1)
(d) Unsecured					114
(e) Gross response: b + d					1138
Gross response rate: e / (a-c)					23.0%
Secure response rate: b / (a-c)	21.0%	20.9%	21.9%	17.5%	20.7%

* Figures in brackets are fractions.
(b) includes blank responses marked 'not affected'
(c) includes 2 late submissions, blanks marked 'sick', or 'away', or no information

The quality of the secure responses was excellent in terms of completion of the lengthy questionnaire and in terms of unambiguous answers. The unambiguous response rate to individual questions, used in the following analysis, was in the order of 97 to 99 per cent.

IV. ANALYSIS AND RESULTS

As in the NAL study, the reaction of residents to aircraft noise is measured by an index, referred to as *general reaction* (*GR*). *GR* is computed from the answers to two questions (variables) and a sub-index involving several variables, weighted by cross-sectional linear regression coefficients. This aggregate is standardised such that the value of the index (score) lies between 0 and 10. Since the variables are identical to those in the NAL study, in terms of the questions asked, only the general specification of *GR* is given here: $GR = (G + g)/k$, where $G = A + D$, $g = c + x_1 a + x_2 d + x_3 cd + x_4 f$; c, k *are* constants

The values of the variables are scores on a scale of 1-10, given in answer to questions on *personally affected by aircraft noise* (*A*), *dissatisfied with the amount of aircraft noise (D)*, *annoyance (a)*, *disturbance (d)*, *complaint disposition (cd)*, and *fear of a crash (f)*.

Two sets of weights for the sub-index, g, are used in this study. Firstly, the weights and standardisation scheme of the NAL study. This is justified because the EIS and the DNMP assume that the reaction of individuals are time and space independent. Second, weights have been estimated from the data collected (K- weights). As in the NAL study, the estimation of the weights, x_i, $i = 1...4$, was carried out by regressing the variables *a, d, cd,* and *f* on *G*. This is based on a 'modified' questionnaire in the sense that the questions underlying the variables *a, d, cd,* and *f,* were to be ignored by those respondents who stated that they are 'not affected'. For the estimation of the K-weights, all 'not affected' respondents were assigned a zero value for relevant variables. (Since *G* contains also the responses of 'not affected' respondents, the NAL study has presumably followed the same method to be able to apply OLS regression.)

In the Ku-ring-gai sample, 24.32% of the respondents stated that they are not affected by aircraft noise. The corresponding figure for the NAL sample is 19.8%. The proportion of not affected residents in the Ku-ring-gai Group 1 sub-sample (17.73%) is similar to that of the Sydney sub-sample in the NAL study (16.5%). The percentage of not affected respondents in Group 1 is smaller than that of the Melbourne and Perth sub-samples in the NAL study (23.8%and 29.5% respectively).

This is remarkable, considering that the NAL study was restricted to areas within the 25 NEF contour, as projected in 1980, while Ku-ring-gai has been classified as 'not affected'. However, while the NAL study surveyed constant NEF (or ANEF) zones, the number of aircraft movements differed significantly among the five airport locations. Even in 1980, Sydney had the largest number of aircraft movements among all locations. In the Ku-ring-gai case, the percentage of unaffected residents depends negatively on 'flight density'. See Figure 5

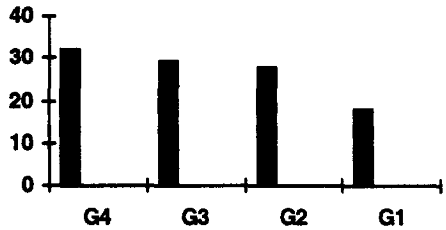

Figure 5

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As in the NAL study, the 'annoyance' variable is highly significant, while the 'fear' variable has very little explanatory power. However, in contrast to the NAL study, it is the 'disturbance' variable which has the greatest weight (see Table 2).

Table 2
Estimated coefficients

	NAL	Ku-ring-gai*
C	.43	.29 (2.37)
x_1	.44	.36 (28.6)
x_2	.38	.60 (11.7)
x_3	.31	.50 (10.0)
x_4	.20	.13 (3.84)
R^2	.867	.868
k	4.125	4

*t-statistics are shown in brackets

Within the context of the NAL study, and hence the EIS and the DNMP, an individual is considered to be 'at least moderately affected' if the *GR* score is greater or equal to 4. An individual is considered to be 'seriously affected' if the *GR* scrore is greater or equal to 8. By definition, the set of moderately affected individuals includes the set of seriously affected individuals.

The above official definition is adopted in this study.

Table 3 contains the summary statistics of the *GR* index (mean and standard deviation). Furthermore, the expected number and percentage of respondents who are 'at least moderately affected' or 'seriously affected' are shown for the total sample and for the flight density groups. The results obtained from using within sample weights (K-weights) are shown in brackets.

The first observation is that all areas in Ku-ring-gai contain residents who are seriously affected by aircraft noise. Second, when flight density data was used, a crude indicator of aircraft noise exposure, to define 4 sub-samples, a difference in the percentage of affected residents is discernible. Group 1 has the highest percentage of seriously affected respondents, about 16 per cent. In this group of respondents, almost 50 per cent are at least moderately affected. About 40 per cent of Group 2 respondents are at least moderately affected. The difference between Group 3 and Group 4 is marginal. For Ku-ring-gai (All), about 41 per cent of the respondents are at least moderately affected, of which 12 per cent are seriously affected.

The within sample weights (K-weights) do not change the overall conclusion. The difference in the percentage of at least moderately affected respondents is negligible. However, the NAL weights underestimate the percentage of seriously affected respondents in Ku-ring-gai by 1.1 per cent. The underestimation is particularly noticeable for Group 1 where the difference amounts to 2 per cent. This is the group which has the highest exposure to aircraft noise, as discussed in this study.

Table 3
General Reaction (GR)#

Sample	mean	s.d.	Moderately affected Number	%	Seriously affected Number	%
All	3.706 (3.722)	2.971 (3.065)	421 (425)	41.1 (41.5)	119 (130)	11.6 (12.7)
1	4.225 (4.273)	3.037 (3.141)	211 (215)	48.0 (48.9)	68 (77)	15.5 (17.5)
2	3.538 (3.543)	3.098 (3.186)	69 (69)	39.7	22 (22)	12.6
3	3.290 (3.277)	2.778 (2.854)	103 (103)	35.4	22 (22)	7.6
4	3.044 (3.020)	2.693 (2.766)	38 (38)	31.9	7 (9)	5.9 (7.6)

The results obtained using the K-weights are shown in brackets.

The coarse measure of aircraft noise exposure, used in this study, ranked the percentages of 'at least moderately affected' people correctly and both sets of weights gave identical results. However, relative to the K-weights, the NAL weights underestimated the percentage of 'seriously affected' people for Group 1 (highest exposure) and for Group 4 (lowest exposure).

In contrast to the NAL study, which employed an interview style survey, a mail-out style was used. The response rate of a mail-out style survey is typically less than the success rate of interviews (ie. the proportion of randomly selected residents who agreed to give an interview). In order to predict the number of affected residents in Ku-ring-gai, the problem has to be faced as to what assumptions are to be made about the reactions of those who were randomly selected but did not respond.

Without further data collection to assist in applying additional statistical methods to improve the information base, there are two assumptions which are sufficient to provide bounds on the set of possible outcomes.

Applied to the present problem, a lower bound on the number of at least moderately or seriously affected residents is obtained by assuming that those who did not respond are not affected at all. An upper bound is obtained by assuming that responses obtained represent an unbiased sub-sample of the random sample of the population.

Assuming the characteristics of the population of voters is representative of the characteristics of the total population of Ku-ring-gai, the expected number of affected people in Ku-ring-gai can be estimated by means of extrapolation. The results of this operation are shown in Table 4. The following notations is used: E[Max] denotes the estimate obtained assuming that the respondents are an unbiased sub-sample; E[Min] denotes the estimate obtained assuming that all non-respondents are unaffected by aircraft noise.

The 99% and 95% confidence limits have been calculated but are not shown here due to space constraints

Table 4

Projections of the number of people affected*

Study	At least Moderately Affected		Seriously Affected	
	E[Min]	E[Max]	E[Min]	E[Max]
DNMP**	0	0	0	0
Ku-ring-gai survey	9,035 (9,121)	43,580 (43,994)	2,553 (2,790)	12,318 (13,457)

* Estimates obtained using K-weights are shown in brackets. ** From Table 4.2, DNMP

The DNMP predicted that the total number of seriously affected residents will be 19,990 (DNMP, pp 4.9-4.10). The above results imply that the DNMP underestimated the number of seriously affected residents by at least 13% (ie. using E[Min]) on the basis of the local government area of Ku-ring-gai alone.

V. CONCLUDING COMMENTS

The predictions contained in the DNMP, cited above, are confined to areas within the 15 ANEF zone by the year 2010. Assuming there is sufficient agreement among planning authorities that aircraft noise predictions, made 15 years into the future, should at least fulfil the condition that the prediction is order preserving in the noise measure categories (ie an area classified as lying within the noise category A at the beginning of the prediction period will also be in this category at the end of the prediction period, even though there may be intra-category variations), Ku-ring-gai is outside the 15 ANEF zone.

The DNMP justified limiting its analysis to areas within the 15 ANEF zone on two grounds. Firstly, "to allow comparison with the results presented in the Draft Environmental Impact Statement for the Proposed Third Runway..." Second, "There is disagreement concerning the importance of such effects and the feasibility of taking these into account in noise assessment" (DNMP, pp 4.7-4.8)

The results of the present study show that areas outside the 15 ANEF zone should not be excluded. The expected number of 'seriously affected residents' in the local government area of Ku-ring-gai was found to be at least 2,600 (ie even when assuming that all non-respondents are not at all affected). This number is greater than the number of 'seriously affected' residents in the 30-35 ANEF zone (2,400), as predicted in the DNMP (Table 4.1, p 4.9). Considering that under a parallel runway mode of operation there are large residential areas to the west, north-west, north and north-east of Ku-ring-gai, which are overflown by aircraft, but which are outside the 15 ANEF zone, the error in estimating the number of seriously affected residents in the DNMP cannot be considered to be anything else than serious.

It seems that the feasibility of taking the analysis beyond the 15 ANEF zone was the constraining factor. As indicated before, there was no data available for areas such as Ku-ring-gai and the estimates for the 15-20 ANEF zone are based on statistically inadequate data.

The Federal Airport Corporation (FAC), the proponent of the Third Runway, claimed that in areas outside the 20 ANEF contour aircraft noise is a minor issue in relation to other noise sources. This claim has been repeated by the FAC at the Senate Select Committee on Aircraft Noise in Sydney: "But it is also a fact, as revealed by the NAL survey, that as those levels approach less than 20 ANEF, the response to aircraft noise and other noises is starting to get confused, to the point where, at levels below 20 ANEF, people were actually rating road noise as more intrusive than aircraft noise." (Falling on Deaf Ears? 1995, p 206)

The results of the present survey do not support this view. In the Ku-ring-gai survey, 25.39% of respondents considered 'the amount of aircraft noise' as that feature of the neighbourhood which they would most like to have improved, followed by 'amount of traffic' (22.95%). When decomposing the sample into flight density groups, 32.95% of Group 1 respondents (greatest exposure to aircraft noise in terms of aircraft movements) selected aircraft noise as feature (27.27%). Thus, even among those residents in the sample area who feel that the amount of traffic is an important environmental issue, aircraft noise is an even bigger environmental problem. Only Group 4 (lowest aircraft noise exposure) ranked the 'amount of aircraft noise' as less important than 'amount of traffic' (13.45% and 17.65% respectively). (Perhaps only Group 4 is 'outside the 20 ANEF zone'.) These 'community preferences' were corroborated by a question on the relative desirability of eliminating alternative noise sources.

It may be argued that the present survey was carried out too soon after the opening of the 'third runway' and the introduction of a parallel runway system on the grounds that residents had insufficient time to become 'habituated' to aircraft noise. We reject this argument. Neither aircraft noise exposure nor the respondents to aircraft noise are likely to reach a 'steady state' condition. For example, between 1980, the time when the NAL survey was carried out, and 1988, the year used as the base year for comparison in the EIS, the number of aircraft movements at KSA had doubled. Thus, even eight years is not long enough for residents to become 'habituated' to aircraft noise because the exposure conditions changed. Only if the ANEF (equal energy) index is adequate to standardise for exposure conditions, can the change in the number of aircraft movements be ignored. Given that variations in ANEF levels explained only 13% in the variation of responses (NAL), this condition is not fulfilled in the case of Sydney. Alternatively, the conditions on the ground change. Individuals have a finite life. Consequently, the 'habituation period' needs to be related to the life expectancy of individuals. One year seems to be a long time in relation to the life expectancy of individuals. Moreover, individuals or families do change their residential locations, possibly in response to actual or predicted changes in environmental conditions. Unless the 'habituation period' is short, relative to the period of residency, 'steady state' conditions cannot be assessed.

As for Ku-ring-gai, the noise exposure conditions, however measured, have changed again since the time when this survey was carried out. As a consequence of the 'Sydney Airport Long Term Operating Plan (1997), aircraft movements are to be spread as widely as possible over the entire Sydney metropolitan area.

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