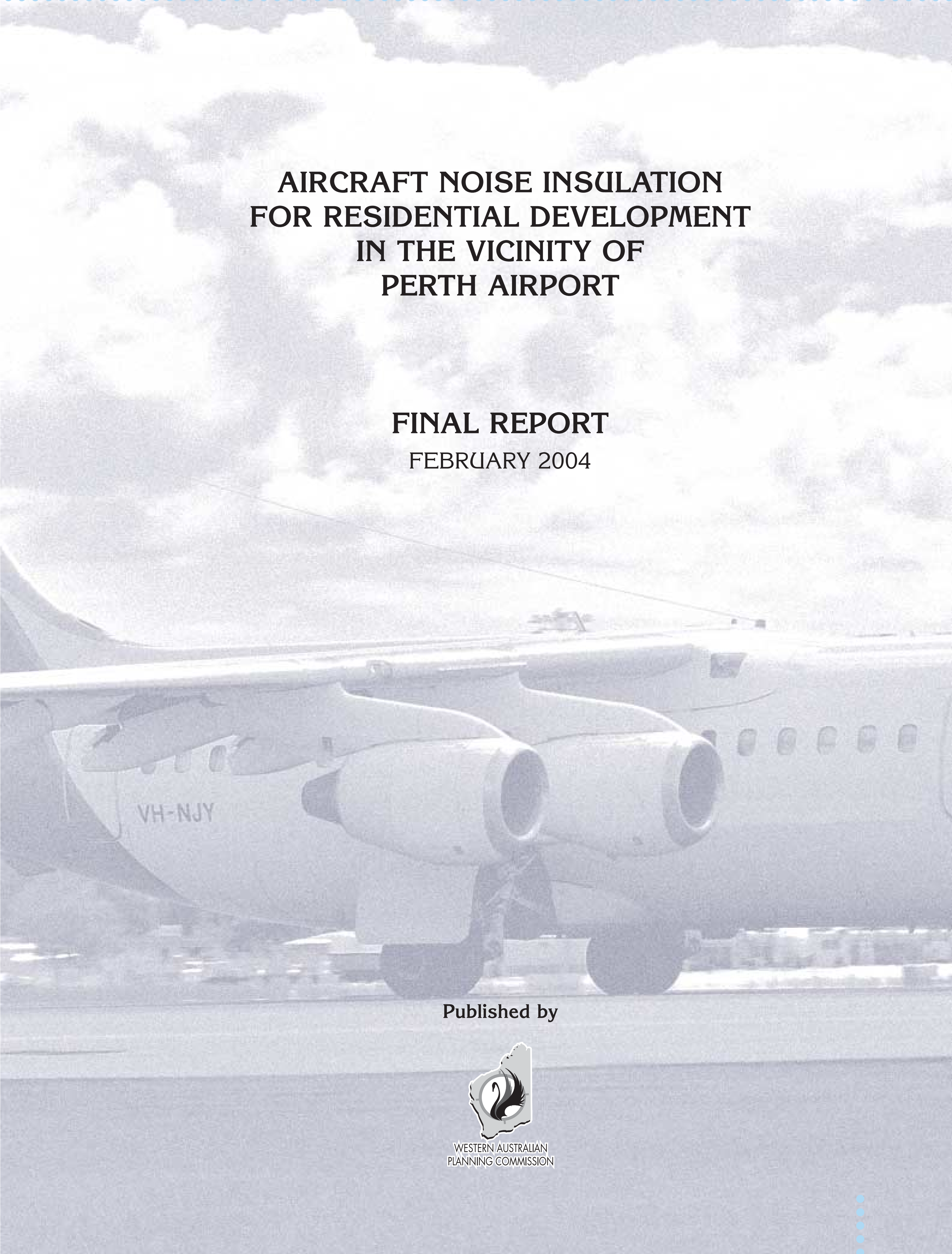

AIRCRAFT NOISE INSULATION FOR RESIDENTIAL DEVELOPMENT IN THE VICINITY OF PERTH AIRPORT

FINAL REPORT

FEBRUARY 2004

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FOREWORD

Perth Airport is fundamental to the continued development of the Perth Metropolitan Region and the State as a whole. Investment in airport infrastructure and the economic opportunities associated with the operation of the airport are now recognized as an important, and perhaps critical element in the prosperity of a city such as Perth.

Accordingly, the airport and its ongoing development need to be recognized in the planning of the region, and its operation protected as far as practicable from development with the potential to prejudice its performance. One of the main issues to be addressed in the planning of areas in the vicinity of the airport is aircraft noise, which is the focus of the Western Australian Planning Commission's *Statement of Planning Policy No. 5.1 - Land Use Planning in the Vicinity of Perth Airport.*

There are a number of existing built-up areas in the vicinity of the airport which are already affected by significant levels of aircraft noise, and the extent of affected areas is likely to expand in the future as a consequence of the growth in air traffic and the development of new runway facilities. The challenge in planning for these areas is to manage the impact of aircraft noise, taking into account the interests of existing communities and the needs of a growing metropolitan region.

In response to this challenge, *Statement of Planning Policy No. 5.1 - Land Use Planning in the Vicinity of Perth Airport*, proposes that noise insulation be required as a condition of local government planning approval, for all new residential development above the 25 ANEF noise exposure contour. Where practicable, the standard of insulation required is to be based on the achievement of indoor design sound levels recommended for the particular building type or activity in AS 2021.

This report is the first of its kind in Australia. It contains recommendations regarding deemed-to-comply noise insulation measures to achieve the indoor design sound levels recommended within AS 2021. An alternative approach would be to engage an acoustic engineer to recommend and certify noise control measures for the building in question to achieve the relevant indoor design sound levels recommended by AS 2021.

Jeremy Dawkins
Chairman
Western Australian Planning Commission

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City of Belmont
Australian Institute of Building Surveyors
Webb and Brown-Neaves Pty Ltd
Jason Windows Pty Ltd
Double Glazing Australasia

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The Western Australian Planning Commission's *Statement of Planning Policy No. 5.1 Land Use Planning in the Vicinity of Perth Airport*, proposes that noise insulation be required as a condition of local government planning approval, for all new residential development above the 25 ANEF aircraft noise exposure contour.[1] Where practicable the standard of insulation required is to be based on the achievement of indoor design sound levels recommended for the particular building type or activity in AS 2021, i.e. 50dB(A) for sleeping areas and 55 dB(A) for living areas.

The Statement of Planning Policy foreshadows the introduction of deemed-to-comply specifications for residential development, with a view to reducing the costs and uncertainty for builders. Guidance as to the practicable standard of insulation required is to be taken from the deemed-to-comply specifications.

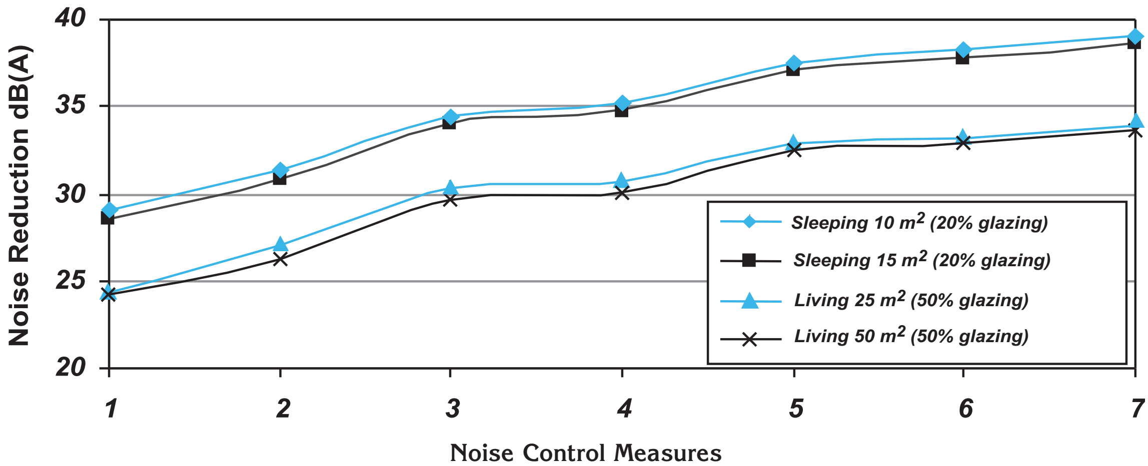
In response to these requirements the aims of this investigation are:

- to determine a practicable level of noise reduction for residential development in those areas subject to the requirement for noise insulation under the policy; and
- to identify noise control measures which will be deemed-to-comply with the noise reduction targets identified as practicable.

Assessment of each of the localities forecast to be affected by noise exposure levels above 25 ANEF shows a significant variation in both maximum noise levels and the number of operations associated with such noise events. While this might suggest the application of different levels of noise reduction and therefore different noise control measures in order to achieve recommended indoor design sound levels, the adoption of noise reduction targets must also take into account the issue of practicability. This involves assessment of the effectiveness of available noise reduction measures together with the cost of such measures.

Noise modelling for rooms of varying size and with differing window proportions reveals an overall variation in noise reduction from around 24dB(A) to 39dB(A) based on the noise control measures listed in Figure 1. This figure illustrates the effect in terms of noise reduction, of sequential improvements to the various building elements for bedrooms of 10m^2 and 15m^2, with 20% openings, and for living areas of 25m^2 and 50m^2 with 50% openings (windows and door).
Analysis of the costs and effectiveness of the noise control measures applied in sequence indicates a

Figure 1: Aircraft Noise Reduction for Sleeping and Living Areas



1. Base level construction (double brick, standard glazing) **2**. Ceiling batts (fibrous insulation between joists) **3**. Laminated 6.38mm glazing with solid-core timber door **4**. Roof sarking (foil over rafters) **5**. Laminated 10.38mm glazing **6**. Impervious flexible insulation membrane 6 kg/m^2 over ceiling joists **7**. Double glazing 6.38mm /12mm air/4mm

[1] While Statement of Planning Policy No. 5.1 requires noise insulation for noise-sensitive development in areas above the 25 ANEF noise contour, the policy recommends a review of zoning in aircraft noise affected areas with a view to avoiding or minimising the effects of aircraft noise.

dramatic rise in costs above measure 4, and a corresponding reduction in cost-effectiveness. At the same time, the level of noise reduction achievable through the application of measures 1 to 4 would meet the indoor design sound levels recommended in Australian Standard AS 2021 for most of the areas affected by noise exposure levels above 25 ANEF.

Areas in which resultant indoor design sound levels would remain above those recommended in AS 2021 include South Guildford, Guildford and Redcliffe. The inner area of South Guildford is the most seriously noise affected area, and consideration should be given to a change of land use for this area.

Additional noise reduction measures such as 10.38mm laminated glazing, sound lagging over ceiling joists, and double glazing are not proposed as part of the deemed-to-comply specifications, as they would involve considerable additional costs, but provide only marginal reductions in noise levels.

RECOMMENDATIONS

1. That minimum aircraft noise reduction levels of 35dB(A) for sleeping areas and 30dB(A) for living areas be accepted as complying with the requirements of *Statement of Planning Policy No. 5.1 Land Use Planning in the Vicinity of Perth Airport*. (These are the same targets adopted for the Sydney Noise Amelioration Program, and can be achieved at a reasonable cost and with reasonable cost-effectiveness.)

2. That the following deemed-to-comply specifications be adopted for residential development as an alternative to certification by a noise control specialist that the development complies with the minimum aircraft noise reduction requirements.

   Openings: Maximum size of openings (windows and doors) of 20% (of floor area) for sleeping areas and 50% (of floor area) for living areas.

   Construction: Slab-on-ground.

   Walls: Double brick cavity.

   Roof: Pitched, minimum 25^0 slope, masonry tiles or metal sheet with acoustically sealed sarking (impervious membrane) over rafters.

   Ceiling: Plasterboard 10mm minimum thickness, with ceiling joists separate from roof structure, i.e. not attached to rafters or roof trusses.

   Insulation: Fibrous thermal insulation R2.5 or greater between ceiling joists.

   Windows: Laminated glass 6.38mm or greater with acoustic or resilient flap weather seals to frames.

   Doors: Solid core 40mm or greater with acoustic or resilient flap weather seals to frames. Doors with glass panels are to match the standard for windows above.

   Note: Where air conditioning or mechanical systems are installed, sound-attenuated ducting will be necessary to limit noise intrusion.

3. That the deemed-to-comply specifications be reviewed after 2 years of operation, during which time, noise measurements can be undertaken to evaluate their efficacy in meeting the noise reduction targets identified in this report, i.e. 35dB(A) reduction for sleeping areas and 30dB(A) reduction for living areas.

4. That local government provide advice to owners in association with planning applications and building licences involving residential development in areas forecast to be affected by aircraft noise exposure above 20 ANEF, of the:

- potential for noise nuisance and increases in noise exposure levels associated with current and/or future aircraft movements;
- noise reduction requirements under Statement of Planning Policy No. 5.1 and the deemed-to-comply specifications detailed in Section 6 of this report;
- limitations on the required noise control measures and the potential for residual indoor sound levels in excess of those recommended in AS 2021;
- need for closure of windows and doors in order to achieve the benefits of noise control measures, and the associated need for noise-attenuated ventilation and/or air conditioning;
- option to seek independent professional advice as to the building specifications required to achieve the minimum aircraft noise reduction standards identified in this report;
- recommendation in Statement of Planning Policy No. 5.1 for noise control measures in areas between the 20 ANEF and 25 ANEF contours; and
- desirability of supplementary noise control measures, in addition to the deemed-to-comply specifications outlined in this report for those rooms in which lower ambient noise levels are sought, or in circumstances where the occupants of the housing are particularly sensitive to aircraft noise.

1. INTRODUCTION

1.1 Statement of Planning Policy

The Western Australian Planning Commission's *Statement of Planning Policy No 5.1 Land Use Planning in the Vicinity of Perth Airport*, proposes that noise insulation generally be required as a condition of local government planning approval, for all new development involving building types identified as unacceptable with reference to the Building Site Acceptability table in Australian Standard AS 2021.[2] Possible exceptions to this requirement identified in the Statement of Planning Policy include heritage listed buildings, and minor additions to existing residential development.

Noise insulation is one of a number of initiatives designed to minimise the impact of aircraft noise in Statement of Planning Policy. The Policy also recommends a review of land use zoning in aircraft noise affected areas, with a view to avoiding or minimising the effects of aircraft noise. Where practicable, noise-sensitive uses are to be prohibited in noise exposure zones for which the relevant building type is classified as unacceptable. However, the Policy accepts that it may not be practicable to rezone existing residential areas affected by aircraft in some circumstances, and that ameliorative measures are therefore required.

The requirement for noise insulation includes in particular all new residential development above the 25 ANEF aircraft noise exposure contour.[3] In the case of sites which are dissected by the noise exposure contour, the following interpretation is to apply:

(i) Where the site has an area less than 1000m^2, the noise exposure zone for the whole site shall be deemed to be the level to which the majority of the site is subject.

(ii) Where the site has an area greater than 1000m^2, the noise exposure zone shall be determined separately for the individual parts of the site into which it is divided by the noise exposure contour.

Statement of Planning Policy No. 5.1 also recommends noise insulation for residential development in the 20-25 ANEF noise exposure zone, where indoor sound levels are likely to exceed the standards recommended in AS 2021. However, specific noise control measures for such development are not mandatory, and would be at the discretion of the owner and/or builder.

Where practicable the standard of insulation required for areas above the 25 ANEF contour is to be based on the achievement of the indoor design sound levels recommended for the particular building type or activity in Australian Standard AS 2021.[4] Statement of Planning Policy No. 5.1 foreshadows the introduction of deemed-to-comply specifications for residential development, and according to the policy, guidance as to the practicable standard of insulation required is to be taken from the deemed-to-comply specifications.

The deemed-to-comply specifications are intended to simplify application of the aircraft noise reduction requirements, and do not remove the option to pursue alternative measures or designs. Departures from the deemed-to-comply specifications need to be accompanied by certification from a suitable noise control specialist, to the effect that the development will comply with the level of noise aircraft noise reduction required under the Policy[5].

1.2 Aims of Current Investigation

The aims of the current investigation are to:

- determine a practicable level of noise reduction for residential development in those areas subject to the requirement for noise insulation under the policy; and

[2] A copy of the Building Site Acceptability table from AS 2021 is included in Appendix 1 of this report. Noise insulation for development other than residential, which is identified as conditionally acceptable, is to be determined on a discretionary basis, and while the advice in this report may have some application in these circumstances, specialist advice should be sought in relation to such buildings.

[3] A copy of the most recent ANEF contour map is included in Appendix 7. More detailed plans showing the effect of the forecast noise exposure levels on Residential and Rural-Residential zoned land are available from the Department for Planning and Infrastructure or from local governments responsible for the administration of affected areas.

[4] An extract from the Australian Standard listing the recommended indoor design sound levels for a range of building types and activities is included as Appendix 2 of this report.

[5] The term noise control specialist used in this report, refers to a person who is a full member or eligible for full membership of the Australian Acoustical Society with appropriate experience and competence in the field of noise intrusion and control.

- identify noise control measures which will be deemed-to-comply with the noise reduction targets identified as practicable.

In determining the practicable level of noise reduction for residential development, consideration needs to be given to both the effectiveness of noise control measures and their costs in relation to the level of noise reduction effected. It is important also that consideration be given to normal residential design requirements. While developers will have the option to pursue a performance-based approval, deemed-to-comply specifications should provide the basis for a straightforward approval for the majority of housing development.

As noted in the Statement of Planning Policy, some areas in the 20-25 ANEF noise exposure zone may experience noise levels in excess of the recommended indoor design sound levels, and in such cases, noise insulation is recommended, although not mandatory. Therefore while the application of deemed-to-comply noise control requirements are not directly applicable to residential development in these areas, the specifications may nevertheless be of assistance to builders and home owners wishing to reduce aircraft noise intrusion.

1.3 Application of Noise Control

The application of noise control measures under the Policy is predicated upon a requirement for planning approval, which has been recommended for all new residential development in areas affected by forecast noise exposure levels of 25 ANEF and above. In most cases, this will necessitate amendment to local government town planning schemes, and Statement of Planning Policy No. 5.1 recommends the establishment of Special Control Areas to provide for the necessary head of power to control such development. Within such areas, all new residential development would require planning approval, and local government would have the discretion to require noise reduction measures as a condition of approval.

There is no proposal for noise insulation to be applied retrospectively to existing housing under the Statement of Planning Policy. Subject to appropriate control provisions under individual local government town planning schemes, the requirement for noise insulation would apply only to new residential development. The Policy specifically exempts minor additions to existing residential development involving no more than two habitable rooms and no more than 25% increase in habitable floorspace.

Where more substantial additions are proposed, the additional areas are to be insulated in accordance with the requirements applicable to new residential development. Noise insulation is not mandatory for the existing areas of the house, but is recommended, and may, in some circumstances, be appropriate to meet the indoor design sound levels prescribed under AS 2021. According to the Standard, the requirement for different internal design sound levels for different indoor spaces could necessitate the construction of substantial barriers between habitable spaces, and consideration should therefore be given to a uniform perimeter insulation approach.

1.4 Noise Insulation Requirements Applied Elsewhere

In a survey of over 600 airports world-wide, the Boeing company has identified around 125 such facilities at which specific noise charges are imposed. While the survey does not include detail as to the expenditure of revenue derived from noise charges, it seems reasonable to assume that in many if not all of these cases, some funding is provided for insulation of affected buildings.

In addition to those airports at which noise charges are levied, there are others where noise insulation is required in the absence of any financial assistance. This is the case for a number of Australian cities, such as Perth and Melbourne where no publicly funded aircraft noise insulation program has yet been introduced and therefore no noise charges are currently levied.

Most of the publicly funded noise insulation programs appear to be based on the application of a package of measures designed to achieve a target level of noise reduction, rather than a prescribed indoor sound level. The Sydney and Adelaide Noise Insulation Programs are examples of the application of standardized

measures, where a best practicable outcome is sought rather than necessarily strict compliance with recommended indoor design sound levels of AS 2021.[6]

The noise reduction targets adopted for the Sydney Noise Insulation Program, which generally relate to existing houses, include:

1. noise attenuation (reduction) levels for bedrooms of 35dB(A); and,
2. noise attenuation (reduction) levels for living rooms of 30dB(A).

Outside the 30 ANEI contour in Sydney, where noise insulation is required for private housing development in the absence of public funding, the general approach appears to be that noise insulation is required to accord with AS 2021, i.e. compliance with the recommended indoor design sound levels irrespective of the level of aircraft noise reduction which may be required to meet those standards. None of the local governments in the vicinity of Sydney Airport has adopted deemed-to-comply specifications.

A similar situation exists in relation to Melbourne Airport, although the Victorian Department of Infrastructure has undertaken to investigate deemed-to-comply specifications with a view to their future application as an alternative to performance-based compliance. In Queensland, the Department of Local Government and Planning has also undertaken to develop deemed-to-comply measures, although at the time of this report, work on this project had yet to commence.

Overseas, there are numerous examples of publicly funded noise insulation programs, but the application of mandatory noise insulation requirements without any external financial assistance appears to be less common. Examples of publicly funded insulation programs are to be found in Denmark, France, Germany, Japan, Switzerland, United Kingdom and United States. Noise control measures generally involve double glazing, replacement of doors, roof insulation, and acoustic sealing of gaps. The aim of most of these programs is to achieve a best practicable level of noise control rather than prescribed indoor sound levels, although there are exceptions to this approach.

There are however, examples of regulated development, where responsibility for noise reduction measures rests with the property developer. In these cases noise reduction levels have generally been predetermined, based on the external noise environment, with reduction targets ranging from 25dB to a maximum of 35dB. In the city of Killeen, Texas, where two noise zones have been identified, reduction levels of 25dB and 30dB respectively are required, with developers given the option of either certification by an acoustical consultant or the application of prescribed (deemed-to-comply) noise control measures. (Killeen 2003)

In the overseas examples reviewed, aircraft noise reduction targets are generally based on an integrated measure of aircraft noise. This contrasts with the approach adopted in Australia, where noise reduction targets are generally directed towards the achievement of prescribed maximum indoor sound levels. The differences between these two approaches can be more readily understood by a comparison between the integrated noise measures such as represented by ANEF contours and single event, maximum noise level contours.

1.5 Methodology and Approach

The following steps illustrate the general approach adopted in the determination of practicable noise reduction requirements and the measures needed to achieve those reductions. This is based generally on the procedure recommended in AS 2021, but has been adapted to apply to a range of sites, the exclusion of atypical noise events and the application of noise reduction measures based on the requirements of the Statement of Planning Policy No. 5.1.

Step 1: Identify Residential and Rural-Residential zoned land within the 25 ANEF and 30 ANEF contours

Step 2: For each of the affected localities, determine the range of distance coordinates:

[6] An analysis of results of the Sydney program undertaken for more than 600 brick houses in 2001 showed that while the average level of noise reduction exceeded the targets by 3dB(A), a significant minority of the insulated houses still failed to meet the target noise reduction after insulation treatment. It is worth noting also that the average internal noise levels after insulation treatment were still 3dB(A) above the indoor design sound levels recommended in AS 2021.

DL (minimum and maximum distance from closest end of runway)
DT (minimum and maximum distance from furthest end of runway)
DS (minimum and maximum sideline distance from runway)

Step 3: Identify design aircraft for each of the localities based on omission of the noisiest aircraft type, where such operations are atypical and infrequent

Step 4: Determine the level of noise reduction which would be required for each locality to achieve the indoor design sound level recommended in AS 2021 for the relevant activity space

Step 5: Determine noise level reduction achievable for various packages of building specifications, (walls, windows, doors, ceilings, roof) for various room configurations

Step 6: Identify target noise level reduction based on consideration of practicability (cost and effectiveness) of each of the packages of noise control measures

Step 7: Identify an appropriate package of building specifications to achieve the target noise reduction levels for each type of activity space and determine the resultant indoor sound levels for each locality

Application of noise reduction levels in accordance with the Statement of Planning Policy represents a departure from AS 2021, which is based on the achievement of recommended indoor design sound levels irrespective of the practicability, e.g. cost and design implications. The adoption of a best practicable approach to noise control means that in some circumstances, development will not meet the indoor design sound levels recommended in AS 2021. Where this is the case, an assessment has been undertaken to determine the extent to which the indoor design sound levels would be exceeded as a result of the application of the deemed-to-comply noise control measures.

2 IMPACT OF AIRCRAFT NOISE ON RESIDENTIAL AREAS

2.1 Areas Affected by Noise Exposure Above 25 ANEF

Based on assessment of the ANEF (350,000) contours, the residential and rural-residential localities listed in Table 1 have been identified as being affected by forecast noise exposure levels above 25 ANEF.[7] Co-ordinates for various representative sites within each of the localities have also been identified from the noise contour overlay of the land use zoning, in accordance with AS 2021. (Refer to ANEF contour plan in Appendix 7)

2.2 Maximum Noise Levels of Noisiest Aircraft

Maximum noise levels associated with each of the residential and rural-residential areas affected by aircraft noise exposure above 25 ANEF are shown in Table 2 for each of the two noisiest aircraft operations on the respective runways. These have been derived from the noise levels included in AS 2021 for the respective aircraft types, but exclude long-range departures, which can be regarded as atypical operations.[8]

2.3 Selection of Design Aircraft

According to AS 2021, noise attenuation requirements for a particular site are normally determined by reference to the highest noise level affecting the site with reference to the noise level tables for take off and landing for the various types of aircraft which fly over the site. However, where the particular aircraft type and movement associated with the highest maximum noise level does not constitute a typical operation, the next highest value should be used, i.e. the next noisiest aircraft type and movement.

Of the aircraft types which access Perth Airport, the highest maximum noise levels affecting adjacent residential areas are generally attributable to B747-400 landings. The only exception to this is Cloverdale and High

[7] Under the Western Australian Planning Commission's Statement of Planning Policy No. 5.1 Land Use Planning in the Vicinity of Perth Airport, noise insulation is required for all new residential development in those areas forecast to be affected by aircraft noise exposure levels above 25 ANEF (350,000).

[8] Long range departures of the noisiest aircraft type average less than 4 movements per day or less than 0.5 per cent of total operations, with the busiest runway (21R) accounting to less than one such movement per night at capacity. (Valentine 2002)

Table 1: Residential Localities Within the 25 ANEF (350,000) Contour

Locality	Runway and Operation	ANEF Range*	Closest Point to Runway	Furthest Point from Runway	Max Sideline Distance
South Guildford (outer area)	21R Arrival 03L Departure	25-30	1.4 km (DL) 5.1 km (DT) 140 m (DS)	1.7 km (DL) 5.4 km (DT) 140 m (DS)	1.8 km (DL) 5.4 km (DT) 300 m (DS)
South Guildford (inner area)	21R Arrival 03L Departure	30-35	1.4 km (DL) 5.1 km (DT) 0.0 km (DS)	1.6 km (DL) 5.3 km (DT) 0.0 km (DS)	1.7 km (DL) 5.3 km (DT) 140 m (DS)
Redcliffe	06 Arrival 24 Departure	25-27	1.4 km (DL) 4.1 km (DT) 0.0 km (DS)	1.8 km (DL) 4.5 km (DT) 0.0 km (DS)	1.4 km (DL) 4.1 km (DT) 0.1 km (DS)
Guildford	21R Arrival 03L Departure	25-32	2.6 km (DL) 6.3 km (DT) 0.0 km (DS)	3.3 km (DL) 7.0 km (DT) 0.0 km (DS)	3.3 km (DL) 7.0 km (DT) 0.2 km (DS)
Cloverdale	03L Arrival 21R Departure	25-26	0.0 km (DL) 3.7 km (DT) 0.6 km (DS)	1.5 km (DL) 5.2 km (DT) 0.6 km (DS)	0.0 km (DL) 3.7 km (DT) 0.7 km (DS)
Queens Park	03L Arrival 21R Departure	25-27	4.4 km (DL) 8.1 km (DT) 0.0 km (DS)	5.4 km (DL) 9.1 km (DT) 0.0 km (DS)	4.4 km (DL) 8.1 km (DT) 0.4 km (DS)
East Cannington	03R Arrival 21L Departure	25-28	3.7 km (DL) 6.7 km (DT) 0.0 km (DS)	4.7 km (DL) 7.7 km (DT) 0.0 km (DS)	3.7 km (DL) 6.7 km (DT) 0.5 km (DS)
High Wycombe	21L Arrival 03R Departure	25-28	0.2 km (DL) 3.2 km (DT) 0.6 km (DS)	0.5 km (DL) 3.5 km (DT) 0.6 km (DS)	0.2 km (DL) 3.2 km (DT) 0.7 km (DS)
Bellevue/ Greenmount	24 Arrival 06 Departure	25-27	5.6 km (DL) 8.3 km (DT) 0.0 km (DS)	6.6 km (DL) 9.6 km (DT) 0.0 km (DS)	5.6 km (DL) 8.3 km (DT) 0.4 km (DS)
Helena Valley	24 Arrival 06 Departure	25-29	3.8 km (DL) 6.5 km (DT) 0.0 km (DS)	4.4 km (DL) 7.1 km (DT) 0.0 km (DS)	3.8 km (DL) 6.5 km (DT) 0.3 km (DS)
Hazelmere	21L Arrival 03R Departure	25-30	3.2 km (DL) 6.2 km (DT) 0.0 km (DS)	5.0 km (DL) 8.0 km (DT) 0.0 km (DS)	3.2 km (DL) 6.2 km (DT) 0.3 km (DS)

Wycombe, where B747-400 take-offs generate higher maximum noise levels than the corresponding landings. An analysis of the frequency of these particular operations is appropriate in order to determine whether or not they should be used as the basis for determining noise attenuation requirements, i.e. whether they can be regarded as typical noise events.

Although there are no prescribed criteria against which to determine whether a particular operation might be regarded as typical, it is useful to consider both the proportion and absolute number of operations in any such determination. Table 3 includes movement numbers affecting individual localities as well as the absolute and relative contribution of overall air traffic by the noisiest aircraft type, namely the B747-400.

As can be seen from the table, the percentage of movements made up by the B747-400 is relatively small for all runways, being less than 1.5% for all localities except Guildford, South Guildford, Queens Park and Cloverdale. In the case of Queens Park, the percentage of movements made up of B747-400 arrivals alone, is also less than 1.5%. In this area, the maximum noise levels associated with B747-400 departures is generally lower than that for arrivals, and is also less than the maximum noise level of the B767 on arrival.

Table 2: Maximum Noise Levels for the Two Noisiest Aircraft Types

Locality	Runway and Operation	B747-400 Noise Range	B767 Noise Range
South Guildford (25-30 ANEF)	21R Arrival 03L Departure	83-91dB(A) 85-87dB(A)	79-90dB(A) 81-84dB(A)
South Guildford (above 30 ANEF)	21R Arrival 03L Departure	91-99dB(A) 86-87dB(A)	87-94dB(A) 82-84dB(A)
Redcliffe	06 Arrival 24 Departure	95-99dB(A) 88-89dB(A)	90-94dB(A) 84-84dB(A)
Guildford	21R Arrival 03L Departure	88-94dB(A) 81-82dB(A)	83-89dB(A) 79-80dB(A)
Cloverdale	03L Arrival 21R Departure	65-67dB(A) 81-84dB(A)	65-67dB(A) 76-82dB(A)
Queens Park	03L Arrival 21R Departure	79-88dB(A) 79-80dB(A)	75-84dB(A) 76-77dB(A)
East Cannington	03R Arrival 21L Departure	77-90dB(A) 79-82dB(A)	72-85dB(A) 77-79dB(A)
High Wycombe	21L Arrival 03R Departure	63-70dB(A) 80-84dB(A)	60-67dB(A) 79-82dB(A)
Bellevue/ Greenmount	24 Arrival 06 Departure	79-86dB(A) 79-80dB(A)	74-82dB(A) 75-76dB(A)
Helena Valley	24 Arrival 06 Departure	83-90dB(A) 81-82dB(A)	78-85dB(A) 79-79dB(A)
Hazelmere	21L Arrival	83-92dB(A)	79-87dB(A)

Source: Noise levels determined from Tables 3.10-11 and 3.15-16 of AS 2021

Table 3: Average Daily Movements by Locality and B747-400 Contribution

Locality	Runway and Operation	Total Movements	B747-400 Daily Movements			% Total
			Day	Night	24 hour	
South Guildford	21R Arrival 03L Departure	128.33 36.95	4.06 1.28	2.09 0.65	6.15 1.93	3.7% 1.2%
Redcliffe	06 Arrival 24 Departure	18.76 0.35	0.12 0.00	0.11 0.00	0.23 0.00	1.2% 0.0%
Guildford	21R Arrival 03L Departure	128.33 36.95	4.06 1.28	2.09 0.65	6.15 1.93	3.7% 1.2%
Cloverdale	03L Arrival 21R Departure	48.83 144.09	1.45 4.13	0.76 2.13	2.21 6.26	1.1% 3.2%
Queens Park	03L Arrival 21R Departure	48.83 144.09	1.45 4.13	0.76 2.13	2.21 6.26	1.1% 3.2%
East Cannington	03R Arrival 21L Departure	60.11 171.64	0.37 0.78	0.19 0.41	0.56 1.19	0.2% 0.5%
High Wycombe	21L Arrival 03R Departure	103.81 45.24	0.42 0.18	0.22 0.10	0.64 0.28	0.4% 0.2%
Bellevue/ Greenmount	24 Arrival 06 Departure	113.03 74.60	0.71 0.85	0.36 0.44	1.07 1.29	0.6% 0.7%
Helena Valley	24 Arrival 06 Departure	113.03 74.60	0.71 0.85	0.36 0.44	1.07 1.29	0.6% 0.7%
Hazelmere	21L Arrival 03R Departure	103.81 45.24	0.42 0.18	0.22 0.10	0.64 0.28	0.4% 0.2%

Source: Tabular breakdown by runway and aircraft type derived from ANEF (350,000)

In terms of absolute numbers, there is less than one B747-400 movement per night on average for all areas except Guildford, South Guildford, Queens Park and Cloverdale, and in the case of Queens Park, the number of B747-400 arrivals is also less than one per night. The only areas where the number of B747-400 daytime arrivals exceeds four, are Guildford, South Guildford, each of which is forecast to have 4.13 such operations. A ratio of one night movement to four daytime movements, is considered appropriate having regard to the four-times weighting given to night flights under the ANEF system of measurement, i.e. one night flight is equivalent to four daytime flights.

On the basis of the foregoing analysis, it seems reasonable to dismiss B747-400 movements as being atypical for all localities except Guildford, South Guildford and Cloverdale. Table 4 catalogues the maximum noise levels and operations giving rise to noise in excess of that of the design aircraft for each locality using the criteria suggested.

3. NOISE ATTENUATION REQUIREMENTS

3.1 Indoor Noise Standards

Australian Standard AS 2021 includes recommended standards for indoor design sound levels for a variety of building types and activities, and identifies two classes of habitable areas associated with residential development with design levels as follows:

50dB(A)	Sleeping areas, dedicated lounges
55dB(A)	Other habitable spaces

In determining mandatory requirements for various classes of activity, some care is needed to avoid administrative anomalies and confusion resulting from different nomenclature. This is particularly important in relation to the classification of activities used to determine noise control measures, which have the potential to add to the cost of housing construction. In this context, discretionary activity areas such as dedicated lounges might be considered in a somewhat different light from those areas which make up the more essential areas of typical Perth homes.

Table 4: Noise Levels and Aircraft Type Used to Determine Noise Attenuation

Locality	Maximum Noise Range for Design Aircraft	Design Aircraft	Movements With Noise Level Exceeding That of the Design Aircraft			
			Day	Night	24 hour	% Total
South Guildford (25-30 ANEF)	85-91dB(A)	B747-400	Nil	Nil	Nil	Nil
South Guildford (above 30 ANEF)	91-99dB(A)	B747-400	Nil	Nil	Nil	Nil
Redcliffe	90-94dB(A)	B767	0.12	0.11	0.23	1.2%
Guildford	88-94dB(A)	B747-400	Nil	Nil	Nil	Nil
Cloverdale	81-84dB(A)	B747-400	Nil	Nil	Nil	Nil
Queens Park	76-84dB(A)	B767	1.45	0.76	2.21	1.1%
East Cannington	77-85dB(A)	B767	0.37	0.19	0.56	0.2%
High Wycombe	79-82dB(A)	B767	0.18	0.10	0.28	0.2%
Bellevue/ Greenmount	75-82dB(A)	B767	0.71	0.36	1.07	0.6%
Helena Valley	79-85dB(A)	B767	0.71	0.36	1.07	0.6%
Hazelmere	79-87dB(A)	B767	0.42	0.22	0.64	0.4%

New homes in Perth are increasingly becoming less formal with respect to living areas, with a prevalence of open plan living areas in preference to dedicated lounges. Other activity spaces which are becoming more common, include home theatres, home offices and alfresco dining areas. In the context of mandatory noise control measures, where these are to be at the expense of the home builder, it is arguable that such areas should not be subject to the same standards as for sleeping areas.

It is therefore recommended that all internal living areas, including dedicated lounges, be considered as other habitable spaces for the purposes of application of the indoor design sound levels of AS 2021. Other habitable spaces may be taken to include both formal and informal living areas, as well as kitchens and dining areas. It is worth noting in this regard that the Sydney and Adelaide Noise Amelioration Programs do not distinguish between dedicated lounges and other living areas in relation to the noise reduction targets.

3.2 Noise Reduction Requirements

From the above analysis the noise reduction which would be required in order to meet the indoor design sound levels recommended in AS 2021 (Appendix 2) for the habitable areas in the home for each locality have been determined and are detailed in Table 5.

Table 5: Indoor Design Sound Levels And Aircraft Noise Reduction Standards

Locality	Maximum Noise Range	Indoor Design Levels (Note 1)		Noise Reduction Required to Meet Indoor Design Standards
South Guildford (25-30 ANEF)	85-91 dB(A)	Sleeping Living	50dB(A) 55dB(A)	35-41 dB(A) 30-36 dB(A)
South Guildford (above 30 ANEF)	91-99 dB(A)	Sleeping Living	50dB(A) 55dB(A)	41-49 dB(A) 36-44 dB(A)
Redcliffe	90-94 dB(A)	Sleeping Living	50dB(A) 55dB(A)	40-44 dB(A) 35-39 dB(A)
Guildford	88-94 dB(A)	Sleeping Living	50dB(A) 55dB(A)	38-44 dB(A) 33-39 dB(A)
Cloverdale	81-84 dB(A)	Sleeping Living	50dB(A) 55dB(A)	31-34 dB(A) 26-29 dB(A)
Queens Park	76-84 dB(A)	Sleeping Living	50dB(A) 55dB(A)	26-34 dB(A) 21-29 dB(A)
East Cannington	77-85 dB(A)	Sleeping Living	50dB(A) 55dB(A)	27-35 dB(A) 22-30 dB(A)
High Wycombe	79-82 dB(A)	Sleeping Living	50dB(A) 55dB(A)	29-32 dB(A) 24-27 dB(A)
Bellevue/ Greenmount	75-82 dB(A)	Sleeping Living	50dB(A) 55dB(A)	25-32 dB(A) 20-27 dB(A)
Helena Valley	79-85 dB(A)	Sleeping Living	50dB(A) 55dB(A)	29-35 dB(A) 24-30 dB(A)
Hazelmere	79-87 dB(A)	Sleeping Living	50dB(A) 55dB(A)	29-37 dB(A) 24-32 dB(A)

Note 1: The classifications used in this table have been adapted from those used in Table 3.3 of AS 2021. In particular dedicated lounges (which have the same design sound level as sleeping areas) have been omitted, other habitable spaces have been designated as living areas and bathrooms, toilets, laundries have been designated as service areas.

4. NOISE CONTROL MEASURES

4.1 Selection of Noise Control Measures

A number of standard noise reduction measures have been identified, and the effectiveness of each calculated for a variety of room configurations. Noise reduction measures included in this modelling were derived from an evaluation of performance standards of a selection of commonly used elements and materials as well as specific measures currently applied as part of the Sydney and Adelaide Noise Amelioration Programs. They include:

- Up-rated single glazing (6.38mm and 10.38mm laminated windows)
- Double glazing (6.38 mm/12mm air/4 mm windows)
- Up-rated external door (40 mm solid core timber)
- Up-rated roof/ceiling (fibrous insulation batts, under-roof sarking and impervious flexible sound insulation ceiling membrane 6 kg/m^2)
- Sound attenuated ducting of air-conditioning or mechanical ventilation systems (all packages)

On the basis of a preliminary assessment of a range of combinations of measures, seven distinct noise reduction packages have been identified and are detailed in Table 6.

Table 6: Description Of Alternative Noise Attenuation Packages

Package	Description of Noise Attenuation Measures	STC/R_W Rating*
Base Level Construction[9]	Walls - double masonry with cavity Floors - concrete slab (includes upper floor) Roof/ - tile or sheet metal, pitched - 25^0 min[10] } Ceiling - 10mm plasterboard, flat } Windows - single 4 mm glass Doors - 38mm hollow core	50 50 33 roof/ceiling combined 26 18
Package 2 (changes to Package 1)	Insulation - R2.5 fibre thermal insulation batts }	41 roof/ceiling combined
Package 3 (changes to Package 2)	Windows - single 6.38mm laminated Doors - 40mm solid core (external only) acoustically sealed	30 30
Package 4 (changes to Package 3)	Roof - sarking (foil) over rafters	45 roof/ceiling combined
Package 5 (changes to Package 4)	Windows - single 10.38mm laminated	33
Package 6 (changes to Package 5)	Ceiling - 6 kg/m^2 impervious flexible insulation membrane over joists	50 roof/ceiling combined
Package 7 (changes to Package 6)	Windows - double 6.38mm/12mm air/4mm	34

* STC/Rw rating has been based on a variety of industry and research centre sources, as referenced in the Appendix 6 of this report.

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[9] The base level construction, does not include the deemed-to-satisfy energy efficiency measures which are to be required under the Building Code of Australia for all development approved after July 2003. These include minimum standards of ceiling/roof insulation and weather sealing of windows and doors.

[10] A nominal roof pitch of 25^0 has been selected based on the advice in AS 2021 that "pitched roofs with voluminous ceiling space reduce noise more effectively than those with lesser space". There has also been some research into the effect of angle of incidence on facade attenuation, which indicates a lower angle of incidence such as would result from overhead flights of buildings with steeper roof pitches, would reduce noise intrusion from above. (Bradley 1996)

The noise control measures are sequenced on the principle of upgrading the weakest link in the building envelope in each succeeding stage. Departure from this principle, is shown to result in little improvement in overall noise reduction, irrespective of the improvement in individual elemental performance. While this approach differs marginally from the principle of equal noise energy entering from each building element recommended in AS 2021, it represents a more realistic approach to the discrete application of available measures. It also accords with the general approach adopted in the *Sydney Noise Amelioration Program*. (Narang 1997)

4.2 Efficacy of Noise Control Measures

Six room configurations ranging in size from 10m^2 to 50m^2 and with openings ranging from 15% to 50% of floor area were modelled in accordance with the methodology detailed in Appendix 4. The use of percentage floor area for the purpose of classification of rooms is designed to accord with the approach adopted under the *Building Code of Australia* for a range of other design requirements, e.g. daylighting, ventilation.

The results of noise modelling are included in Appendix 5. Figure 1 illustrates the noise reduction, of sequential improvements to the various building elements for bedrooms of 10m^2 and 15m^2, with 20 per cent openings, and for living areas of 25m^2 and 50m^2 with 50% openings (windows and door).

As can be seen from Figure 1, there is a general decrease in the level of noise reduction with increasing size of openings (as a percentage of floor area) and increasing room size. The variation based on the proportional size of openings provides a basis for the application of noise control packages to specific activity areas which will limit the extent and therefore cost of noise attenuation for those designs which fall within the prescribed limits. This approach is similar to that adopted for the energy efficiency provisions of the *Building Code of Australia*, which also include deemed-to-satisfy specifications for dwellings.

Size range of openings used in the calculations range from 15% to 50% of floor area. Smaller openings will result in lower indoor sound levels for any particular noise control package, and the lower limit of 20% is recommended for sleeping areas where lower indoor design sound levels are specified in AS 2021. A higher figure of 50% of floor space is acceptable for living areas, because of the higher noise levels specified for these areas.

4.3 Cost of Noise Control Measures

An assessment of costs associated with each of the measures referred to above has been undertaken, in relation to two standard housing designs in the size range 150m^2 to 200m^2. The cost estimates together with the average cumulative noise reduction associated with each measure when applied sequentially, are detailed in Table 7[11].

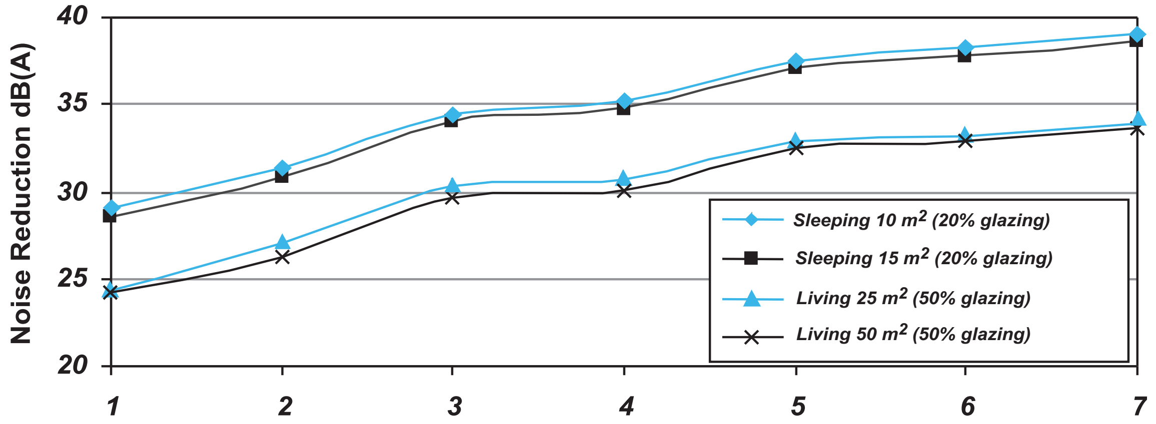
Figure 2 illustrates the cumulative cost and effectiveness in terms of noise reduction, of the sequential noise control measures. As can be seen from the graph, costs increase gradually up to measure four after which the they rise dramatically to more than $30,000 by measure seven.

The cost-effectiveness of the sequential noise control measures beyond measure 4 also increases sharply, with measure 5 (10.38mm glazing) involving a marginal cost-benefit of around $5,000 per dB(A), while the cost-benefit resulting from the use of an impervious flexible sound insulation ceiling membrane is nearly $20,000 per dB(A). One of the reasons why the additional ceiling insulation has such limited effect, is that the windows still allow transmission of relatively high levels of noise into the rooms.

In addition to the direct cost of noise reduction measures, mechanical ventilation or air-conditioning would be necessary as a result of the closure of windows and doors necessary to achieve the benefit from the upgraded building elements. The cost of such systems has not

[11] The cost estimates for the various noise control measures have been based on separate information provided by the Department of Housing and Works, Webb and Brown Neaves, Jason Windows and Double Glazing Australasia. The cost estimates have been based on single storey housing with floor space ranging from 150m^2 to 200m^2, excluding carport/garage. The estimates exclude the cost of thermal ceiling insulation which will be mandatory under the BCA from July 2003, and also exclude the cost of air conditioning, which can be regarded as incidental to the noise control measures.

Figure 1: Aircraft Noise Reduction for Sleeping and Living Areas



Noise Control Measures

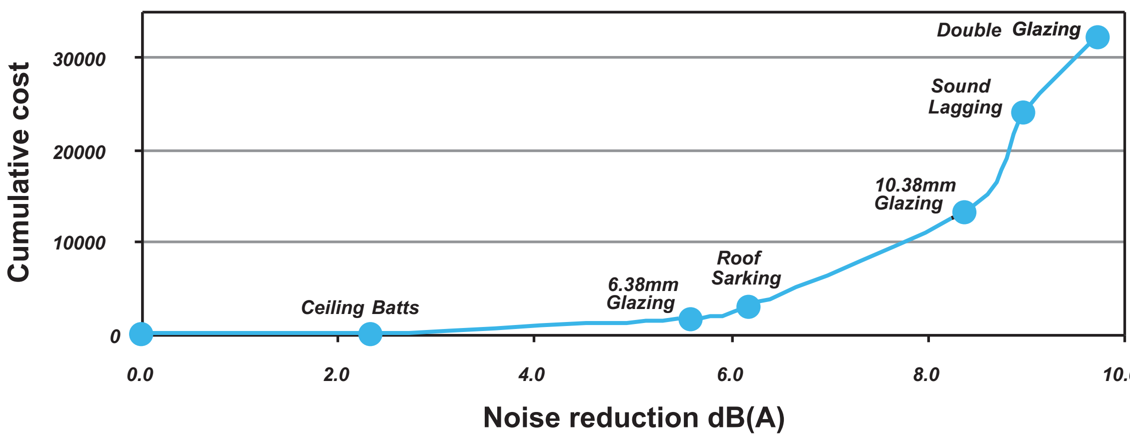
1. Base level construction (double brick, standard glazing) **2**. Ceiling batts (fibrous insulation between joists) **3**. Laminated 6.38mm glazing with solid-core timber door **4**. Roof sarking (foil over rafters) **5**. Laminated 10.38mm glazing **6**. Impervious flexible insulation membrane 6 kg/m^2 over ceiling joists **7**. Double glazing 6.38mm /12mm air/4mm

Table 7: Cost Estimates And Noise Reduction Of Sequential Noise Control Measures[11]

	1. Base Level	2. Ceiling Batts	3. 6.38mm Glazing	4. Roof Sarking	5. 10.38mm Glazing	6. Sound Lagging	7. Double Glazing[12]
Item Cost	-	N/A	$1,500	$1,250	$12,500	$10,000	$22,500
Cumulative Cost	-	N/A	$1,500	$2,750	$13,750*	$23,750	$32,250*
Cumulative Noise Reduction	-	2.3 dB(A)	5.6 dB(A)	6.2 dB(A)	8.5 dB(A)	9.0 dB(A)	9.7 dB(A)
Cumulative Cost/Benefit	-	N/A dB(A)	$268/ dB(A)	$446/ dB(A)	$1,627/ dB(A)	$2,652/ dB(A)	$3,319/

* The additional cost of upgraded glazing is calculated by subtracting the cost of the lower standard glazing which it replaces from the item cost of the upgraded glazing.

Figure 2: Cost and Effectiveness of Noise Control Measures



[12] Double glazing costs included in this table relate to standard, narrow-gap glazing of the type normally used for thermal insulation, with an air gap of 12mm, e.g. 6.38mm/12mm/4mm or for larger windows, 6.38mm/12mm/6.38mm. A larger air gap will generally provide improved levels of noise reduction, but such windows are not readily available, and would be significantly more costly than standard double glazing.

been included in the foregoing analysis, as it cannot be directly attributed to noise reduction requirements. Air conditioning, is becoming increasingly common in new housing, and this has now been recognised in the proposed new energy efficiency provisions of the Building Code of Australia which are predicated in part, upon the use of closed circuit heating and cooling systems.

4.4 Conclusions (Practicable Noise Reduction Targets)

In determining a practicable level of noise reduction for residential development, consideration needs to be given to both the effectiveness and cost of individual measures, and whether the measures may have any additional benefits such as improved energy efficiency or comfort. Consideration also needs to be given to the affordability of noise control measures, bearing in mind that the costs are to be borne by individual property owners.

On the basis of the foregoing analysis, noise reduction Package 4 is recommended for residential development in those areas in which noise insulation is required under Statement of Planning Policy No. 5.1. This is calculated to achieve a minimum noise reduction of 35dB(A) for sleeping areas with openings of no more than 20% of floor area, and 30dB(A) for living areas (other habitable spaces) with openings of no more than 50% of floor area.

The recommended noise reduction levels are the same as the targets adopted for the Sydney Noise Amelioration Program, and can be achieved at what might be regarded as a reasonable cost and with reasonable cost effectiveness. The cost of noise reduction measures under the Sydney program relates to existing houses, and is substantially higher than that estimated to achieve comparable results for new housing. The noise reduction levels recommended for Perth are also comparable or better than those adopted in a number overseas countries.[13]

Higher aircraft noise reduction targets than those proposed, would not only be expensive but may be seen as anomalous in comparison with the maximum indoor sound levels accepted outside the 25 ANEF contour where noise reduction measures are not mandatory. This anomaly is a consequence of the use of maximum noise levels rather than an integrated measure, as the basis for aircraft noise attenuation requirements.

5. APPLICATION OF RECOMMENDED NOISE REDUCTION PACKAGE

5.1 Indoor Sound Levels

The recommended noise control measures (Package 4) has been based on the best practicable level of noise reduction, taking into account both the effectiveness of individual measures and their cost relative to the level of aircraft noise reduction calculated to result. Accordingly, the reduction in the noise level will be insufficient in some situations to meet the indoor design sound levels recommended in AS 2021.

Table 8 includes an assessment of the effect of the recommended noise reduction package for each locality against the indoor design sound levels recommended in AS 2021. This identifies those areas in which there will be residual noise above the indoor design standard, and the range by which the indoor sound level would exceed the recommended design standard.

In areas outside the 25 ANEF contour, the noise reduction necessary to meet the indoor design sound level recommended in AS 2021 is less than that required in the higher noise exposure zone, although it should be borne in mind that noise reduction measures are not mandatory in this area. With the introduction of the new energy efficiency requirements under the *Building Code of Australia* in July 2003, construction Package 2 will effectively become the minimum standard of construction, although the standard of weather sealing required under the new code provisions can be expected to provide noise reduction in excess of the levels calculated for Package 2.

[13] In France for example, the outer two noise exposure zones are subject to 30 dB(A) and 35 dB(A) noise attenuation requirements respectively. While this approach has been adopted as the basis for determining noise reduction under AS 2021, it is not universal. In France for example, the integrated noise measure used for land use planning rather than the maximum noise level, is also used as a basis for determining the level of noise reduction required, (Bradley 1996)

Table 8: Effect of Recommended Noise Reduction Package on Indoor Sound Levels

Locality	Maximum Noise Range	Indoor Design Sound Level AS 2021		Sound Level Reduction	Residual Noise Above AS 2021 Design Standard
South Guildford (25-30 ANEF)	85-91dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	0-6dB(A) 0-6dB(A)
South Guildford (above 30 ANEF)	91-9 dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	6-14dB(A) 6-14dB(A)
Redcliffe	90-94dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	5-9dB(A) 5-9dB(A)
Guildford	88-94dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	3-9dB(A) 3-9dB(A)
Cloverdale	81-84dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Nil Nil
Queens Park	76-84dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Nil Nil
East Cannington	77-85dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Nil Nil
High Wycombe	79-82dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Nil Nil
Bellevue/ Greenmount	75-82dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Nil Nil
Helena Valley	79-85dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Nil Nil
Hazelmere	79-87dB(A)	Sleeping Living	50dB(A) 55dB(A)	35dB(A) 30dB(A)	Up to 2dB(A) Up to 2dB(A)

As can be seen from the results of the modelling in Appendix 5 as illustrated in Figure 1, this would provide a noise reduction of around 31dB(A) for bedrooms with openings up to 20% of floor area, and around 27dB(A) for living areas with openings up to 50% of floor area. The result would be comparable or lower indoor sound levels in areas subject to noise exposure between 20 and 25 ANEF than would be achieved from the mandatory application of construction Package 4 to the areas above the 25 ANEF.

Table 9: Effect of Recommended Noise Reduction Package on Indoor Sound Levels

Locality	Maximum Noise Range	Activity Area	Sound Level db(A) Reduction (Package)			Residual Noise above Design Standard		
			P5	P6	P7	P5	P6	P7
Sth Guildford (25-30 ANEF)	85-91dB(A)	Sleeping Living	37 32	38 33	39 34	≤4 ≤ 4	≤ 3 ≤ 3	≤ 2 ≤ 2
Sth Guildford (> 30 ANEF)	91-99dB(A)	Sleeping Living	37 32	38 33	39 34	4-12 4-12	3-11 3-11	2-10 2-10
Redcliffe	90-94dB(A)	Sleeping Living	37 32	38 33	39 34	3-7 3-7	2-6 2-6	1-5 1-5
Guildford	88-94dB(A)	Sleeping Living	37 32	38 33	39 34	1-7 1-7	0-6 0-6	≤ 5 ≤ 5
Hazelmere	79-87dB(A)	Sleeping Living	37 32	38 33	39 34	Nil Nil	Nil Nil	Nil Nil

Higher levels of noise reduction can be achieved through the application of optional Packages 5 to 7 as identified previously in this report. Table 9 illustrates the effectiveness of these additional measures for areas in which the recommended noise control measures (Package 4) would be insufficient to meet the indoor design standard recommended in AS 2021.

5.2 Residual High Levels of Indoor Noise

As can be seen from the foregoing analysis, application of the recommended noise control measures (Package 4) within some areas would fail to meet the indoor design sound levels recommended in AS 2021 by a significant margin:

- South Guildford
- Guildford
- Redcliffe

South Guildford

Of these areas, the inner area of South Guildford will be the most seriously affected both in terms of maximum noise levels and cumulative noise exposure as expressed by the ANEF level, with around 30 residential properties situated above the 30 ANEF contour. This will be the highest level of noise exposure experienced by any urban residential area in the region, and is also subject to maximum noise levels up to 5dB(A) above the next most seriously affected areas of Guildford and Redcliffe. A portion of this area is already within the 30 ANEI (2001) contour, and as such would meet the criteria for noise insulation funding applied in both Sydney and Adelaide.

The level of noise attenuation required to meet the indoor design sound levels recommended in AS 2021 for the inner area of South Guildford (above 30 ANEF) would be prohibitively expensive, and there is doubt that they could be achieved using conventional design and readily available building elements. The limited effectiveness of the optional noise reduction measures included in Table 9 (Packages 5 to 7) highlight the difficulty in controlling aircraft noise intrusion in the most seriously noise-affected areas, and this is confirmed by the results of the Sydney Noise Amelioration Program where noise reduction for bedrooms is limited to around 40dB(A). (Narang 1997)[15]

In these circumstances, a change of land use should be seriously considered, particularly for those parts of South Guildford affected by the most extreme levels of aircraft noise. Such an approach was recommended for consideration in the Report of the 1990 Airport Working Group , and has been alluded to again in *Statement of Planning Policy No. 5.1 Land Use Planning in the Vicinity of Perth Airport*. While the Policy accepts that existing zoning may remain in place where it is not practicable to allocate the land for alternative uses, it states that:

> *"In considering the practicability of alternative land uses, local government should give particular emphasis to areas forecast to be affected by aircraft noise exposure levels above 30 ANEF".*

Redcliffe and Guildford

With regard to Redcliffe and Guildford, the level of non-compliance with the indoor design sound levels recommended in AS 2021 has been estimated to vary by between 3dB(A) and 9dB(A). It is recommended this be brought to the attention of builders and potential purchasers of existing housing, in association with the noise attenuation requirements proposed in this report.

In evaluating the effectiveness of noise control measures in these two areas, it needs to be appreciated that there will be a limited number of movements involving indoor sound levels in excess of those recommended in AS 2021. Based on the aircraft noise reduction levels recommended, the majority of Guildford would be subject to only six movements per day with indoor sound levels above the recommended standard while in the case of Redcliffe, there will be less than half this number.

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15 Funding allocated for the up-grading of existing housing under the Sydney and Adelaide Noise Amelioration Programs is currently set at a maximum of $57,000 per dwelling, although is needs to be appreciated that the cost of retrofitting existing housing is significantly higher than the cost of similar measures applied to new housing.

6. DEEMED-TO-COMPLY SPECIFICATIONS

6.1 Building Elements

Based on the best practicable level of noise reduction recommended in Section 4, the following package of noise reduction measures was identified. Specifications based on these measures and limitations would therefore be deemed-to-comply with the aircraft noise reduction levels recommended above, i.e. 35dB(A) reduction for sleeping areas and 30dB(A) reduction for living areas (all other habitable spaces).

Openings: Maximum size of openings (windows and doors) of 20% (of floor area) for sleeping areas and 50% (of floor area) for living areas.

Construction: Slab-on-ground

Walls: Double brick cavity

Roof: Pitched, minimum 25^0 slope, masonry tiles or metal sheet with acoustically sealed sarking (impervious membrane) over rafters.

Ceiling: Plasterboard 10 mm minimum thickness, separate from roof structure, i.e. not attached to rafters or roof trusses.

Insulation: Fibrous thermal insulation R2.5 or greater between ceiling joists.

Windows: Laminated glass 6.38mm or greater with acoustic or resilient flap weather seals to frames.

Doors: Solid core 40mm or greater with acoustic or resilient flap weather seals to frames. Doors with glass panels are to match the standard for windows above.

Note: Where air conditioning or mechanical systems are installed, sound-attenuated ducting will be necessary to limit noise intrusion.

6.2 Ventilation Requirements

In order for any aircraft noise reduction measures to be effective, it would be necessary to close windows and doors, and this raises the issue of ventilation and/or air conditioning.[17] Requirements for acceptable indoor air quality are included in the *Building Code of Australia*. While these standards are not the subject of application as part of the recommended noise control measures, it is important that they be adhered to by builders and owners wishing to benefit from the improved indoor sound levels enabled by the foregoing aircraft noise control measures.

In relation to the installation of air conditioning systems and/or mechanical ventilation necessary as a consequence of window closure, it will also be necessary to ensure the benefits of the aircraft noise control measures will not be lost by poor design or installation of ducting and outlets. These features can provide an effective short circuit for external noise, and suitable noise-attenuation should be provided for all openings, including fresh air intakes, exhaust vents and internal air registers.

Ventilation or air conditioning ducts (supply and return air) are to be designed and/or acoustically treated to minimise the transmission of aircraft noise to the rooms they serve. In the absence of certification from a noise control specialist, such ducts are to be lined with fibrous insulation, according to the following specifications:

(i) Sleeping areas [35dB(A) Aircraft Noise Reduction]:

Duct lining for a minimum length equal to 5-times the diagonal measurement of the air grill, using 25mm minimum thickness fibrous insulation.

(ii) Living Areas [30dB(A) Aircraft Noise Reduction]:

Duct lining for a minimum length equal to 3-times the diagonal measurement of the air grill;

- For air grills up to 600mm diagonal measurement, using 25mm minimum thickness fibrous insulation; or

- For air grills in excess of 600mm diagonal measurement, using 50mm minimum thickness fibrous insulation.

Although closure of windows is essential to the effective control of aircraft noise, operational management of private housing, including closure of windows will remain the prerogative of the occupier. This may include open air ventilation during those times when aircraft noise is not considered a particular problem, or as part of the overall management of ambient temperatures to minimise energy use and/or improve other aspects of the living environment apart from aircraft noise.

6.3 Installation

The effectiveness of any noise attenuation measures will depend to a degree on the quality of installation and workmanship, and this must be seen as a caveat on the level of aircraft noise reduction which can ultimately be expected. Fitting of seals and the sealing of gaps is important for the control of noise transfer, and while the sealing of gaps associated with elements such as windows and doors will generally expected in conjunction with weather protection, in areas such as the ceiling there will be potential for significant sound leakage without any associated implications for other building functions.

Safety will also be a critical consideration in relation to the design and installation of noise reduction measures, particularly those involving electrical wiring and equipment. Any penetration of a continuous ceiling material for the purposes of electrical fittings (other than wiring) will require specific noise reduction treatment and certification from a noise control specialist, with reference to both the effectiveness of noise control and the safety of the installation. This includes particularly downlights, which can involve excessive heat build-up and premature electrical failure where situated in proximity to insulation material.

7. RECOMMENDATIONS

1. That minimum aircraft noise reduction levels of 35dB(A) for sleeping areas and 30dB(A) for living areas be accepted as complying with the requirements of *Statement of Planning Policy No. 5.1 Land Use Planning in the Vicinity of Perth Airport*. (These are the same targets adopted for the Sydney Noise Amelioration Program, and can be achieved at a reasonable cost and with reasonable cost effectiveness.)

2. That the following deemed-to-comply specifications be adopted for residential development as an alternative to certification by a noise control specialist that the development complies with the minimum aircraft noise reduction requirements under Statement of Planning Policy No 5.1, i.e. 35dB(A) reduction for sleeping areas and 30dB(A) reduction for living areas.

Openings:	Maximum size of openings (windows and doors) of 20% (of floor area) for sleeping areas and 50% (of floor area) for living areas.
Construction:	Slab-on-ground
Walls:	Double brick cavity.
Roof:	Pitched, minimum 25^0 slope, masonry tiles or metal sheet with acoustically sealed sarking (impervious membrane) over rafters.
Ceiling:	Plasterboard 10mm minimum thickness, with ceiling joists separate from roof structure, i.e. not attached to rafters or roof trusses.
Insulation:	Fibrous thermal insulation R2.5 or greater between ceiling joists.
Windows:	Laminated glass 6.38mm or greater with acoustic or resilient flap weather seals to frames

Doors:	Solid core 40mm or greater with acoustic or resilient flap weather seals to frames. Doors with glass panels are to match the standard for windows above.
Note:	Where air conditioning or mechanical systems are installed, sound-attenuated ducting will be necessary to limit noise intrusion.

3. That the deemed-to-comply specifications be reviewed after two years of operation, during which time, noise measurements can be undertaken to evaluate their efficacy in meeting the noise reduction targets identified in this report, i.e. 35dB(A) reduction for sleeping areas and 30dB(A) reduction for living areas.

4. That local government provide advice to owners in association with planning applications and building licences involving residential development in areas forecast to be affected by aircraft noise exposure above 20 ANEF, of:

   - the potential for noise nuisance and increases in noise exposure levels associated with current and/or future aircraft movements;
   - the noise reduction requirements under Statement of Planning Policy No. 5.1 and the deemed-to-comply specifications detailed in Section 6 of this report;
   - the limitations on the required noise control measures and the potential for residual indoor sound levels in excess of those recommended in AS 2021;
   - the need for closure of windows and doors in order to achieve the benefits of noise control measures, and the associated need for noise-attenuated ventilation and/or air conditioning;
   - the option to seek independent professional advice as to the building specifications required to achieve the minimum aircraft noise reduction standards identified in this report;
   - the recommendation in Statement of Planning Policy No. 5.1 for noise control measures in areas between the 20 ANEF and 25 ANEF contours; and
   - the desirability of supplementary noise control measures, in addition to the deemed-to-comply specifications outlined in this report for those rooms in which lower ambient noise levels are sought, or in circumstances where the occupants of the housing are particularly sensitive to aircraft noise.

5. That the City of Swan be requested to consider options to promote a change of use for that part of South Guildford which is forecast to be affected by noise exposure levels above 30 ANEF, in view of the impracticability of achieving acceptable indoor sound levels for this area.

Building Site Acceptability Based on ANEF Zones

BUILDING TYPE	FORECAST NOISE EXPOSURE LEVEL (ANEF)			
	less than 20 ANEF (Note 1)	20 to 25 ANEF (Note 2)	25 to 30 ANEF	30 to 35 ANEF
House, home unit, flat, caravan park	Acceptable	Conditionally Acceptable	Unacceptable (Note 4)	Unacceptable (Note 4)
School, university	Acceptable	Conditionally Acceptable	Unacceptable (Note 4)	Unacceptable (Note 4)
Hospital, nursing home	Acceptable	Conditionally Acceptable	Unacceptable (Note 4)	Unacceptable (Note 4)
Hotel, motel, hostel	Acceptable	Acceptable	Conditionally Acceptable	Unacceptable (Note 4)
Public building	Acceptable	Conditionally Acceptable	Conditionally Acceptable	Unacceptable (Note 4)
Commercial building	Acceptable	Acceptable	Conditionally Acceptable	Conditionally Acceptable
Light Industrial	Acceptable	Acceptable	Acceptable	Conditionally Acceptable
Other industrial	Acceptable	Acceptable	Acceptable	Acceptable

Notes:

1. The actual location of the 20 ANEF contour is difficult to define accurately, mainly because of variation in aircraft flight paths.
2. Within 20 ANEF to 25 ANEF, some people may find that the land is not compatible with residential or educational uses. Land use authorities may consider that the incorporation of noise control features in the construction of residences or schools is appropriate.
3. There will be cases where a building of a particular type will contain spaces used for activities which would generally be found in a different type of building (e.g. an office in an industrial building). In these cases, the above table should be used to determine site acceptability, but internal design noise levels within the specific spaces should be determined by Table 3.3 of AS 2021 (Appendix 2).
4. This Standard does not recommend development in unacceptable areas. However, where the relevant planning authority determines that any development may be necessary within existing built-up areas designated as unacceptable, it is recommended that such development should achieve the required aircraft noise reduction determined according to AS 2021. For residences, schools, etc., the effect of aircraft noise on outdoor areas associated with the buildings should be considered.
5. In no case should new development take place in greenfield sites deemed unacceptable because such development may impact airport operations.

Indoor Design Sound Levels* for Determination of Aircraft Noise Reduction

Building type and activity	Indoor design sound level*, dB(A)
Houses, home units, flats, caravan parks	
Sleeping areas, dedicated lounges	50
Other habitable spaces	55
Bathrooms, toilets, laundries	60
Hotels, motels, hostels	
Relaxing, sleeping	55
Social activities	70
Service activities	75
Schools, universities	
Libraries, study areas	50
Teaching areas, assembly areas (see Note 5)	55
Workshops, gymnasia	75
Hospitals, nursing homes	
Wards, theatres, treatment and consulting rooms	50
Laboratories	65
Service areas	75
Public buildings	
Churches, religious activities	50
Theatres, cinemas, recording studios (see Note 4)	40
Court houses, libraries, galleries	50
Commercial buildings, offices and shops	
Private offices, conference rooms	55
Drafting, open offices	65
Typing, data processing	70
Shops, supermarkets, showrooms	75
Industrial	
Inspection, analysis, precision work	75
Light machinery, assembly, bench work	80
Heavy machinery, warehouse, maintenance	85

* These indoor design sound levels are not intended to be used for measurement of adequacy of construction. For measurement of the adequacy of construction against aircraft noise intrusion, see Appendix C (AS 2021).

NOTES:

1 The indoor design sound levels in column 2 are hypothesized values based on Australian experience. A design sound level is the maximum level (dB(A)) from an aircraft flyover which, when heard inside a building by the average listener, will be judged as not intrusive or annoying by that listener while carrying out the specified activity. Owing to the variability of subjective responses to aircraft noise, these figures will not provide sufficiently low interior noise levels for occupants who have a particular sensitivity to aircraft noise.

2 Some of these levels, because of the short duration of individual aircraft flyovers, exceed some other criteria published by Standards Australia for indoor background noise levels (see AS 2107).

3 The indoor design sound levels are intended for the sole purpose of designing adequate construction against aircraft noise intrusion and are not intended to be used for assessing the effects of noise. Land use planning authorities may have their own internal noise level requirements which may be used in place of the levels above.

4 For opera and concert halls and theatres, and for recording, broadcast and television studios and similar buildings where noise intrusion is unacceptable, specialist acoustic advice should always be obtained.

5 Certain activities in schools may be considered particularly noise sensitive and 50dB(A) may be a more desirable indoor sound level to select for any teaching areas used for such activities. However, the effect of other noise sources should be considered.

6 The provisions of this Standard relating to different internal design sound levels for different indoor spaces could result in the use of different construction and materials in contiguous spaces, and require the construction of substantial barriers between habitable spaces, e.g. heavy self-closing internal doors, detracting from the amenity of the building. Therefore consideration should be given to a uniform perimeter insulation approach.

APPENDIX 3: AIRCRAFT TYPE AND MOVEMENTS USED FOR ANEF 350,000

RUNWAY	INM AIRCRAFT	ARRIVALS		DEPARTURES		TOTAL MOVEMENTS		
		DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	TOTAL
03L	737 7D	0.20	0.10	0.18	0.09	0.38	0.19	0.57
	737 7I	0.11	0.06	0.12	0.06	0.24	0.12	0.36
	737400	0.53	0.27	0.58	0.30	1.11	0.57	1.68
	747 4D	0.01	0.01			0.01	0.01	0.02
	747 4F	0.03	0.02	0.03	0.01	0.06	0.03	0.09
	747 4I	1.41	0.73	1.25	0.64	2.66	1.37	4.03
	767 I	1.65	0.85	1.77	0.91	3.43	1.77	5.19
	767300	0.55	0.28			0.55	0.28	0.84
	767400	0.20	0.10			0.20	0.10	0.31
	777300	2.02	1.04	2.20	1.13	4.22	2.17	6.39
	A300	0.11	0.06			0.11	0.06	0.17
	A320	1.99	1.02	1.47	0.76	3.46	1.78	5.23
	A330 D	0.44	0.23			0.44	0.23	0.67
	A330 I	0.87	0.45	0.93	0.48	1.79	0.92	2.72
	A340	0.67	0.34	0.63	0.33	1.30	0.67	1.97
	A380	0.10	0.05	0.11	0.06	0.22	0.11	0.33
	BAE3 D	5.92	3.05	5.52	2.84	11.44	5.89	17.33
	BAE3 F	0.00	0.00	0.00	0.00	0.01	0.00	0.01
	BEC58P	3.17	1.63	2.18	1.12	5.34	2.75	8.09
	CL601	1.71	0.88	1.54	0.79	3.25	1.68	4.93
	CNA441	2.30	1.18	1.50	0.77	3.80	1.96	5.76
	CNA55B	0.29	0.15	0.17	0.09	0.47	0.24	0.71
	GULF V	0.04	0.02	0.05	0.02	0.09	0.05	0.14
	DHC6	1.80	0.93	1.18	0.61	2.98	1.54	4.52
	DHC8 D	1.92	0.99	1.73	0.89	3.65	1.88	5.52
	DHC8 F	0.39	0.20	0.24	0.12	0.62	0.32	0.95
	DHC8 G	0.44	0.23	0.29	0.15	0.73	0.38	1.11
	GASEPF	1.33	0.68	0.12	0.06	1.45	0.74	2.19
	GASEPV	1.33	0.68	0.12	0.06	1.45	0.74	2.19
	SF340	0.68	0.35	0.49	0.25	1.17	0.60	1.78
03L Total		**32.23**	**16.60**	**24.39**	**12.56**	**56.62**	**29.17**	**85.78**
03R	737 7D	0.36	0.19	0.25	0.13	0.61	0.31	0.92
	737 7I	0.02	0.01			0.02	0.01	0.02
	737400	0.08	0.04			0.08	0.04	0.12
	747 4D	0.10	0.05	0.07	0.04	0.17	0.09	0.25
	747 4F	0.06	0.03	0.04	0.02	0.10	0.05	0.15
	747 4I	0.21	0.11	0.07	0.04	0.28	0.15	0.43
	767 I	0.42	0.22	0.13	0.07	0.55	0.28	0.84
	767300	4.57	2.36	3.32	1.71	7.89	4.06	11.96
	767400	1.68	0.86	1.21	0.63	2.89	1.49	4.38
	777300	0.30	0.15			0.30	0.15	0.45
	A300	0.91	0.47	0.66	0.34	1.58	0.81	2.39
	A320	5.49	2.83	3.84	1.97	9.32	4.80	14.12
	A330 D	3.68	1.89	2.66	1.37	6.34	3.27	9.60
	A330 I	0.22	0.11	0.07	0.04	0.29	0.15	0.44
	A340	0.07	0.03			0.07	0.03	0.10
	A380	0.02	0.01			0.02	0.01	0.02
	BAE3 D	7.87	4.06	5.16	2.66	13.03	6.71	19.75
	BAE3 F	0.00	0.00	0.00	0.00	0.01	0.00	0.01

RUNWAY	INM AIRCRAFT	ARRIVALS		DEPARTURES		TOTAL MOVEMENTS		
		DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	TOTAL
	BEC58P	2.40	1.24	2.11	1.12	4.52	2.36	6.87
	CL601	2.65	1.37	1.77	0.91	4.43	2.28	6.71
	CNA441	2.06	1.06	1.92	0.94	3.98	2.01	5.99
	CNA55B	0.31	0.16	0.27	0.14	0.57	0.29	0.87
	GULF V	0.01	0.00			0.01	0.00	0.01
	DHC6	1.61	0.83	1.44	0.70	3.05	1.53	4.59
	DHC8 D	2.99	1.53	1.99	1.04	4.97	2.57	7.54
	DHC8 F	0.41	0.21	0.35	0.18	0.75	0.39	1.14
	DHC8 G	0.40	0.20	0.34	0.18	0.74	0.39	1.13
	GASEPF	0.39	0.20	1.10	0.57	1.49	0.77	2.27
	GASEPV	0.39	0.20	1.10	0.57	1.50	0.77	2.27
	SF340	0.01	0.01			0.01	0.01	0.02
03R Total		**39.68**	**20.43**	**29.88**	**15.36**	**69.55**	**35.79**	**105.34**
06	737 7D	0.08	0.04	0.40	0.21	0.48	0.25	0.73
	737 7I	0.03	0.01	0.10	0.05	0.12	0.06	0.19
	737400	0.12	0.06	0.45	0.23	0.58	0.30	0.87
	747 4D	0.01	0.01	0.07	0.04	0.09	0.05	0.13
	747 4F	0.01	0.01	0.06	0.03	0.08	0.04	0.12
	747 4I	0.19	0.10	0.72	0.37	0.91	0.47	1.38
	767 I	0.41	0.21	1.53	0.79	1.94	1.00	2.94
	767300	0.63	0.32	3.51	1.81	4.14	2.13	6.27
	767400	0.23	0.12	1.28	0.66	1.52	0.78	2.30
	777300	0.48	0.24	1.72	0.89	2.20	1.13	3.33
	A300	0.13	0.06	0.70	0.36	0.83	0.43	1.26
	A320	1.05	0.54	5.20	2.68	6.25	3.22	9.47
	A330 D	0.51	0.26	2.82	1.45	3.32	1.71	5.03
	A330 I	0.21	0.11	0.80	0.41	1.01	0.52	1.54
	A340	0.10	0.05	0.38	0.20	0.48	0.25	0.73
	A380	0.02	0.01	0.09	0.05	0.11	0.06	0.17
	BAE3 D	2.17	1.12	9.78	5.04	11.96	6.16	18.11
	BAE3 F	0.00	0.00	0.00	0.00	0.01	0.00	0.01
	BEC58P	1.19	0.61	3.86	1.99	5.05	2.60	7.65
	CL601	0.67	0.35	3.08	1.59	3.75	1.93	5.69
	CNA441	0.91	0.47	3.01	1.55	3.91	2.02	5.93
	CNA55B	0.12	0.06	0.41	0.21	0.53	0.27	0.81
	GULF V	0.01	0.01	0.04	0.02	0.05	0.02	0.07
	DHC6	0.71	0.37	2.36	1.22	3.07	1.58	4.65
	DHC8 D	0.75	0.39	3.46	1.78	4.21	2.17	6.37
	DHC8 F	0.16	0.08	0.54	0.28	0.70	0.36	1.06
	DHC8 G	0.17	0.09	0.58	0.30	0.76	0.39	1.14
	GASEPF	0.63	0.33	1.07	0.59	1.70	0.92	2.62
	GASEPV	0.63	0.33	1.07	0.59	1.70	0.92	2.62
	SF340	0.02	0.01	0.07	0.04	0.10	0.05	0.14
06 Total		**12.38**	**6.38**	**49.18**	**25.42**	**61.56**	**31.79**	**93.35**
21L	737 7D	0.57	0.30	1.05	0.54	1.63	0.84	2.47
	747 4D	0.16	0.08	0.30	0.16	0.46	0.24	0.70
	747 4F	0.09	0.05	0.17	0.09	0.26	0.14	0.40
	747 4I	0.17	0.09	0.31	0.16	0.48	0.25	0.72
	767 I	0.31	0.16	0.56	0.29	0.87	0.45	1.32
	767300	7.73	3.98	14.20	7.31	21.93	11.30	33.22

RUNWAY	INM AIRCRAFT	ARRIVALS		DEPARTURES		TOTAL MOVEMENTS		
		DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	TOTAL
	767400	2.83	1.46	5.20	2.68	8.03	4.14	12.17
	A300	1.55	0.80	2.84	1.46	4.39	2.26	6.65
	A320	8.94	4.60	16.41	8.46	25.35	13.06	38.41
	A330 D	6.21	3.20	11.40	5.87	17.61	9.07	26.68
	A330 I	0.16	0.08	0.29	0.15	0.45	0.23	0.69
	BAE3 D	12.04	6.20	22.12	11.39	34.16	17.60	51.76
	BAE3 F	0.01	0.00	0.01	0.01	0.02	0.01	0.03
	BEC58P	4.86	2.50	6.55	3.37	11.40	5.88	17.28
	CL601	4.13	2.13	7.59	3.91	11.73	6.04	17.77
	CNA441	4.11	2.12	5.76	2.97	9.87	5.09	14.96
	CNA55B	0.60	0.31	0.87	0.45	1.48	0.76	2.24
	DHC6	3.23	1.66	4.52	2.33	7.74	3.99	11.73
	DHC8 D	4.63	2.39	8.51	4.38	13.14	6.77	19.91
	DHC8 F	0.80	0.41	1.15	0.59	1.95	1.00	2.95
	DHC8 G	0.79	0.41	1.11	0.57	1.90	0.98	2.89
	GASEPF	2.30	1.18	1.17	0.60	3.47	1.79	5.25
	GASEPV	2.30	1.18	1.17	0.60	3.47	1.79	5.25
21L Total		**68.51**	**35.30**	**113.28**	**58.36**	**181.79**	**93.65**	**275.45**
21R	737 7D	0.62	0.32	0.59	0.30	1.20	0.62	1.82
	737 7I	0.44	0.22	0.42	0.21	0.85	0.44	1.29
	737400	2.03	1.04	1.93	1.00	3.96	2.04	6.00
	747 4F	0.10	0.05	0.09	0.05	0.19	0.10	0.29
	747 4I	3.96	2.04	4.04	2.08	8.00	4.12	12.12
	767 I	6.23	3.21	5.94	3.06	12.18	6.27	18.45
	777300	7.73	3.98	7.37	3.80	15.10	7.78	22.87
	A320	5.16	2.66	4.92	2.53	10.08	5.19	15.27
	A330 I	3.26	1.68	3.11	1.60	6.38	3.29	9.66
	A340	2.07	1.07	2.07	1.06	4.14	2.13	6.27
	A380	0.39	0.20	0.38	0.19	0.77	0.40	1.17
	BAE3 D	19.36	9.97	18.47	9.51	37.83	19.49	57.31
	BAE3 F	0.01	0.00	0.01	0.01	0.02	0.01	0.03
	BEC58P	7.64	3.94	9.93	5.11	17.57	9.05	26.62
	CL601	5.41	2.79	5.17	2.66	10.58	5.45	16.03
	CNA441	5.29	2.72	6.94	3.57	12.23	6.30	18.52
	CNA55B	0.64	0.33	0.87	0.45	1.51	0.78	2.28
	GULF V	0.16	0.08	0.16	0.08	0.32	0.16	0.48
	DHC6	4.14	2.14	5.51	2.84	9.66	4.98	14.63
	DHC8 D	6.06	3.12	5.78	2.98	11.85	6.10	17.95
	DHC8 F	0.84	0.43	1.15	0.59	1.99	1.02	3.01
	DHC8 G	1.02	0.53	1.36	0.70	2.38	1.22	3.60
	GASEPF	0.41	0.21	3.70	1.91	4.11	2.12	6.23
	GASEPV	0.41	0.21	3.70	1.91	4.11	2.12	6.23
	SF340	1.32	0.68	1.51	0.78	2.83	1.46	4.29
21R Total		**84.70**	**43.63**	**95.10**	**48.99**	**179.80**	**92.62**	**272.42**
24	737 7D	0.62	0.32			0.62	0.32	0.94
	737 7I	0.04	0.02			0.04	0.02	0.07
	737400	0.20	0.10			0.20	0.10	0.31
	747 4D	0.16	0.08			0.16	0.08	0.24
	747 4F	0.10	0.05			0.10	0.05	0.15
	747 4I	0.45	0.23			0.45	0.23	0.69

RUNWAY	INM AIRCRAFT	ARRIVALS		DEPARTURES		TOTAL MOVEMENTS		
		DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	TOTAL
	767 I	0.92	0.47			0.92	0.47	1.40
	767300	7.53	3.88			7.53	3.88	11.41
	767400	2.76	1.42			2.76	1.42	4.18
	777300	0.77	0.40			0.77	0.40	1.17
	A300	1.51	0.78			1.51	0.78	2.28
	A320	9.22	4.75			9.22	4.75	13.98
	A330 D	6.05	3.12			6.05	3.12	9.17
	A330 I	0.48	0.25			0.48	0.25	0.73
	A340	0.17	0.09			0.17	0.09	0.26
	A380	0.04	0.02			0.04	0.02	0.06
	BAE3 D	13.67	7.04			13.67	7.04	20.71
	BAE3 F	0.01	0.00	0.00	0.00	0.01	0.00	0.01
	BEC58P	5.42	2.79	0.04	0.02	5.47	2.82	8.28
	CL601	4.57	2.35			4.57	2.35	6.92
	CNA441	4.48	2.31	0.03	0.02	4.51	2.32	6.84
	CNA55B	0.64	0.33	0.00	0.00	0.65	0.33	0.98
	GULF V	0.02	0.01			0.02	0.01	0.02
	DHC6	3.51	1.81	0.03	0.01	3.54	1.82	5.36
	DHC8 D	5.12	2.64			5.12	2.64	7.76
	DHC8 F	0.85	0.44	0.01	0.00	0.86	0.44	1.30
	DHC8 G	0.86	0.45	0.01	0.00	0.87	0.45	1.32
	GASEPF	2.18	1.13	0.06	0.03	2.24	1.15	3.39
	GASEPV	2.18	1.13	0.06	0.03	2.24	1.15	3.39
	SF340	0.03	0.02			0.03	0.02	0.05
24 Total		**74.60**	**38.43**	**0.23**	**0.12**	**74.83**	**38.55**	**113.37**
GRAND TOTAL		**312.10**	**160.77**	**312.06**	**160.80**	**632.86**	**326.05**	**958.91**

Calculation of the average Sound Reduction Index (R_w) for each combination of building elements, was determined according to the following relationships:

$$T_{av} = (T_1S_1 + T_2S_2 + T_3S_3 + \ldots) \div (S_1 + S_2 + S_3 + \ldots)$$

and

$$R_w = -10 \text{ Log}_{10} T$$

Where: T_{av} is the average sound transmission coefficient
T_1, T_2, . . . are the transmission coefficients for building elements 1, 2, . . .
S_1, S_2, . . . are the areas of the respective building elements 1, 2, . . .
R_w is the Sound Reduction Index for the particular building element

The Sound Reduction Index R_w is generally considered to be numerically very similar to the Sound Transmission Class STC previously used in the Building Code of Australia. The measures themselves differ in respect of the frequency range over which sound reduction is measured, with the index R_w being based on a range from 100Hz to 3150Hz while the STC is based on a frequency range of 125Hz to 4000Hz.

The relationship between R_w or STC and Aircraft Noise Reduction (ANR), is assumed to be as follows:

$$ANA_c = R_w - 5 \text{ or } ANR = R_w \text{ (Average)} - 5$$

The differences between these two indices relates to the frequency range over which noise reduction is measured, and may accordingly vary from the constant factor of 5 depending on the response characteristics of the particular building element. In order to arrive at a more precise measure of aircraft noise reduction, it would be necessary to perform the above calculations for varying frequencies, typically at one-third octave intervals from 63Hz to 5000Hz. However, detailed performance data for some common building elements are not readily available, and the use of single number indices is therefore generally accepted as providing a satisfactory level of accuracy, for the purpose of building design.

A 5.1 Constant Proportion of Openings - 15% of Floor Area

NOISE REDUCTION FOR BEDROOM 1 - 10m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	14.3	50	50	50	50	50	50	50
Windows	1.5	26	26	30	30	33	33	34
Floor/Ceiling	10.0	33	41	41	45	45	50	50
Door								
STC/R_w		34.6	37.4	40.2	41.2	43.3	44.1	44.9
ANR (R_w - 5)		29.6	32.4	35.2	36.2	38.3	39.1	39.9

NOISE REDUCTION FOR BEDROOM 2 - 10m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	19.4	50	50	50	50	50	50	50
Windows	3.0	26	26	30	30	33	33	34
Floor/Ceiling	15.0	33	41	41	45	45	50	50
Door								
STC/R_w		33.9	36.2	39.3	40.1	42.4	43.1	43.9
ANR (R_w - 5)		28.9	31.2	34.3	35.1	37.4	38.1	38.9

NOISE REDUCTION FOR BEDROOM 3 - 20m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	19.5	50	50	50	50	50	50	50
Windows	3.0	26	26	30	30	33	33	34
Floor/Ceiling	20.0	33	41	41	45	45	50	50
Door								
STC/R_w		33.8	36.6	39.5	40.5	42.6	43.5	44.3
ANR (R_w - 5)		28.8	31.6	34.5	35.5	37.6	38.5	39.3

NOISE REDUCTION FOR LIVING ROOM 4 - 25m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	19.3	50	50	50	50	50	50	50
Windows	3.8	26	26	30	30	33	33	34
Floor/Ceiling	25.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		30.7	35.3	38.0	38.7	40.1	40.6	41.0
ANR (R_w - 5)		25.7	30.3	33.0	33.7	35.1	35.6	36.0

NOISE REDUCTION FOR LIVING ROOM 5 - 36m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	22.6	50	50	50	50	50	50	50
Windows	5.4	26	26	30	30	33	33	34
Floor/Ceiling	36.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		31.0	35.2	38.0	38.8	40.4	41.0	41.4
ANR (R_w - 5)		26.0	30.2	33.0	33.8	35.4	36.0	36.4

NOISE REDUCTION FOR LIVING ROOM 6 - 50m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	26.0	50	50	50	50	50	50	50
Windows	7.5	26	26	30	30	33	33	34
Floor/Ceiling	50.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		31.2	35.1	37.9	38.8	40.5	41.2	41.7
ANR (R_w - 5)		26.2	30.1	32.9	33.8	35.5	36.2	36.7

A 5.2 Constant Proportion of Openings - 20% of Floor Area

NOISE REDUCTION FOR BEDROOM 1 - 10m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	13.8	50	50	50	50	50	50	50
Windows	2.0	26	26	30	30	33	33	34
Floor/Ceiling	10.0	33	41	41	45	45	50	50
Door								
STC/R_w		34.0	36.4	39.4	40.2	42.5	43.2	44.0
ANR (R_w - 5)		29.0	31.4	34.4	35.2	37.5	38.2	39.0

NOISE REDUCTION FOR BEDROOM 2 - 12.5m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	16.4	50	50	50	50	50	50	50
Windows	3.0	26	26	30	30	33	33	34
Floor/Ceiling	15.0	33	41	41	45	45	50	50
Door								
STC/R_w		33.5	35.9	39.0	39.8	42.1	42.8	43.6
ANR (R_w - 5)		28.5	30.9	34.0	34.8	37.1	37.8	38.6

NOISE REDUCTION FOR BEDROOM 3 - 20m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	18.4	50	50	50	50	50	50	50
Windows	4.0	26	26	30	30	33	33	34
Floor/Ceiling	20.0	33	41	41	45	45	50	50
Door								
STC/R_w		33.2	35.5	38.7	39.4	41.8	42.5	43.3
ANR (R_w - 5)		28.2	30.5	33.7	34.4	36.8	37.5	38.3

NOISE REDUCTION FOR LIVING ROOM 4 - 25m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	20.0	50	50	50	50	50	50	50
Windows	3.0	26	26	30	30	33	33	34
Floor/Ceiling	25.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		30.9	35.9	38.4	39.2	40.5	41.0	41.4
ANR (R_w - 5)		25.9	30.9	33.4	34.2	35.5	36.0	36.4

NOISE REDUCTION FOR LIVING ROOM 5 - 36m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	22.8	50	50	50	50	50	50	50
Windows	5.2	26	26	30	30	33	33	34
Floor/Ceiling	36.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		31.1	35.3	38.1	38.9	40.4	41.0	41.5
ANR (R_w - 5)		26.1	30.3	33.1	33.9	35.4	36.0	36.5

NOISE REDUCTION FOR LIVING ROOM 6 - 50m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	25.4	50	50	50	50	50	50	50
Windows	8.0	26	26	30	30	33	33	34
Floor/Ceiling	50.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		31.2	34.9	37.8	38.6	40.4	41.0	41.6
ANR (R_w - 5)		26.2	29.9	32.8	33.6	35.4	36.0	36.6

A 5.3 Constant Proportion of Openings - 30% of Floor Area

NOISE REDUCTION FOR BEDROOM 1 - 10m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	12.8	50	50	50	50	50	50	50
Windows	3.0	26	26	30	30	33	33	34
Ceiling	10.0	33	41	41	45	45	50	50
Door								
STC/R_w		33.1	34.8	38.2	38.7	41.2	41.7	42.6
ANR (R_w - 5)		28.1	29.8	33.2	33.7	36.2	36.7	37.6

NOISE REDUCTION FOR BEDROOM 2 - 12.5m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	14.9	50	50	50	50	50	50	50
Windows	4.5	26	26	30	30	33	33	34
Ceiling	15.0	33	41	41	45	45	50	50
Door								
STC/R_w		32.6	34.3	37.7	38.3	40.8	41.3	42.2
ANR (R_w - 5)		27.6	29.3	32.7	33.3	35.8	36.3	37.2

NOISE REDUCTION FOR BEDROOM 3 - 20m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	16.4	50	50	50	50	50	50	50
Windows	6.0	26	26	30	30	33	34	34
Ceiling	20.0	33	41	41	45	45	50	50
Door								
STC/R_w		32.2	34.0	37.4	37.9	40.5	41.9	41.9
ANR (R_w - 5)		27.2	29.0	32.4	32.9	35.5	36.9	36.9

NOISE REDUCTION FOR LIVING ROOM 4 - 25m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	15.5	50	50	50	50	50	50	50
Windows	5.5	26	26	30	30	33	33	34
Ceiling	25.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		30.1	34.0	37.0	37.5	39.3	39.7	40.2
ANR (R_w - 5)		25.1	29.0	32.0	32.5	34.3	34.7	35.2

NOISE REDUCTION FOR LIVING ROOM 5 - 36m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	17.2	50	50	50	50	50	50	50
Windows	8.8	26	26	30	30	33	33	34
Ceiling	36.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		30.3	33.5	36.7	37.2	39.2	39.6	40.3
ANR (R_w - 5)		25.3	28.5	31.7	32.2	34.2	34.6	35.3

NOISE REDUCTION FOR LIVING ROOM 6 - 50m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	18.4	50	50	50	50	50	50	50
Windows	13.0	26	26	30	30	33	33	34
Ceiling	50.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		30.3	33.2	36.4	37.0	39.1	39.6	40.3
ANR (R_w - 5)		25.3	28.2	31.4	32.0	34.1	34.6	35.3

A 5.4 Constant Proportion of Openings - 50% of Floor Area

NOISE REDUCTION FOR BEDROOM 1 - 10m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	10.8	50	50	50	50	50	50	50
Windows	5.0	26	26	30	30	33	33	34
Ceiling	10.0	33	41	41	45	45	50	50
Door								
STC/R_w		31.6	32.8	36.4	36.8	39.4	39.8	40.7
ANR (R_w - 5)		26.6	27.8	31.4	31.8	34.4	34.8	35.7

NOISE REDUCTION FOR BEDROOM 2 - 12.5m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	11.9	50	50	50	50	50	50	50
Windows	7.5	26	26	30	30	33	33	34
Ceiling	15.0	33	41	41	45	45	50	50
Door								
STC/R_w		31.1	32.3	35.9	36.3	39.0	39.3	40.2
ANR (R_w - 5)		26.1	27.3	30.9	31.3	34.0	34.3	35.2

NOISE REDUCTION FOR BEDROOM 3 - 20m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	12.5	50	50	50	50	50	50	50
Windows	10.0	26	26	30	30	33	33	34
Ceiling	20.0	33	41	41	45	50	50	50
Door								
STC/R_w		30.8	32.0	35.6	36.0	39.0	39.0	39.9
ANR (R_w - 5)		25.8	27.0	30.6	31.0	34.0	34.0	34.9

NOISE REDUCTION FOR LIVING ROOM 4 - 25m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	12.5	50	50	50	50	50	50	50
Windows	10.5	26	26	30	30	33	33	34
Ceiling	25.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		29.3	32.0	35.3	35.7	37.9	38.2	38.8
ANR (R_w - 5)		24.3	27.0	30.3	30.7	32.9	33.2	33.8

NOISE REDUCTION FOR LIVING ROOM 5 - 36m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	12.0	50	50	50	50	50	50	50
Windows	16.0	26	26	30	30	33	33	34
Ceiling	36.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		29.3	31.5	35.0	35.3	37.7	38.0	38.7
ANR (R_w - 5)		24.3	26.5	30.0	30.3	32.7	33.0	33.7

NOISE REDUCTION FOR LIVING ROOM 6 - 50m² Floor Area

Element	Area m²	P1 (dB)	P2 (dB)	P3 (dB)	P4 (dB)	P5 (dB)	P6 (dB)	P7 (dB)
Walls	10.36	50	50	50	50	50	50	50
Windows	23.0	26	26	30	30	33	33	34
Ceiling	50.0	33	41	41	45	45	50	50
Door	2.0	20	28	30	30	30	30	30
STC/R_w		29.2	31.2	34.7	35.0	37.5	37.8	38.6
ANR (R_w - 5)		24.2	26.2	29.7	30.0	32.5	32.8	33.6

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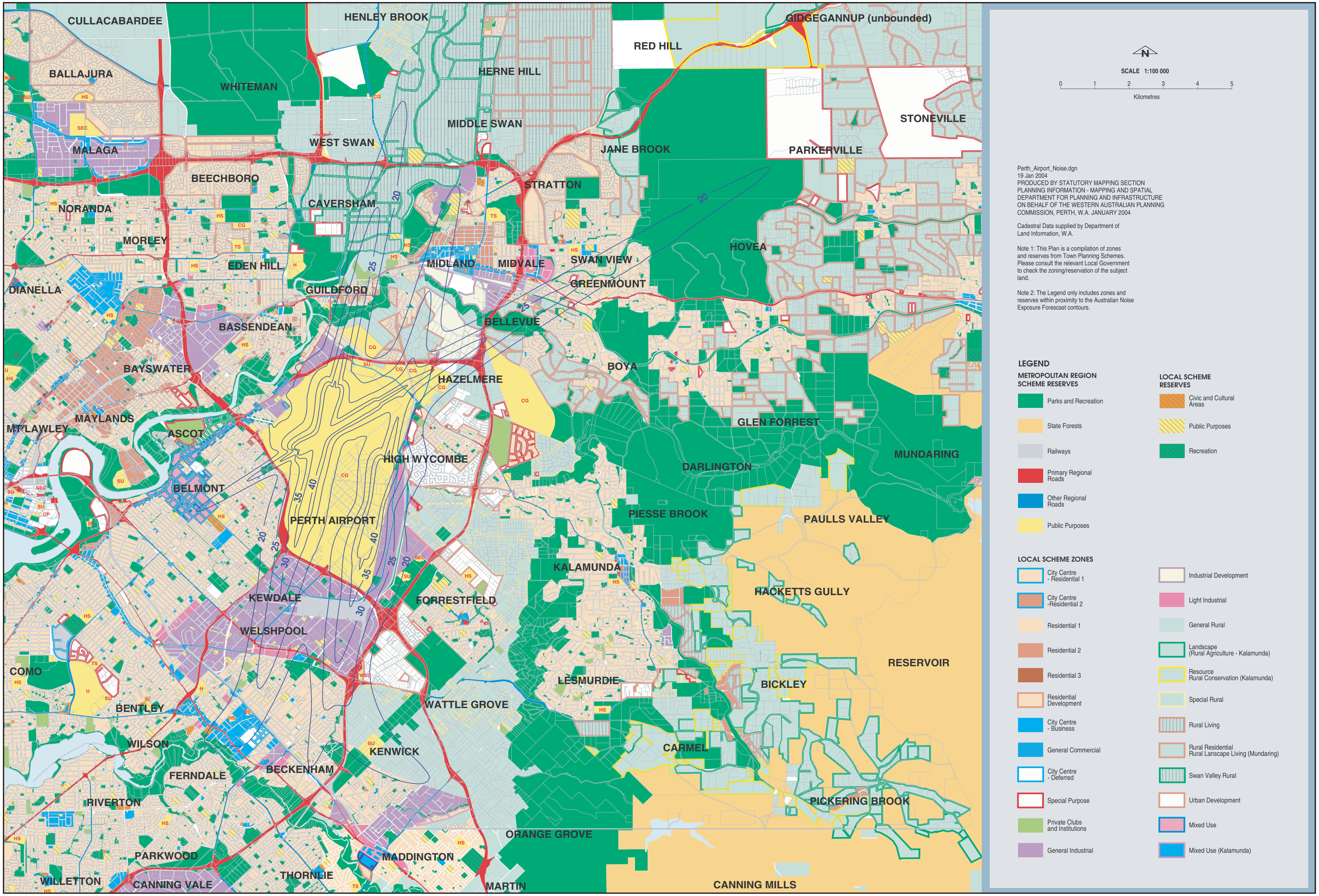

CULLACABARDEE
HENLEY BROOK
GIDGEGANNUP (unbounded)
RED HILL
BALLAJURA
WHITEMAN
HERNE HILL
MIDDLE SWAN
STONEVILLE
WEST SWAN
JANE BROOK
PARKERVILLE
MALAGA
BEECHBORO
STRATTON
CAVERSHAM
NORANDA
MORLEY
HOVEA
EDEN HILL
MIDLAND
MIDVALE
SWAN VIEW
GREENMOUNT
DIANELLA
GUILDFORD
BASSENDEAN
BELLEVUE
BOYA
BAYSWATER
HAZELMERE
MAYLANDS
MT LAWLEY
ASCOT
GLEN FORREST
MUNDARING
HIGH WYCOMBE
DARLINGTON
BELMONT
PIESSE BROOK
PAULLS VALLEY
PERTH AIRPORT
KALAMUNDA
KEWDALE
FORRESTFIELD
HACKETTS GULLY
WELSHPOOL
RESERVOIR
COMO
LESMURDIE
BICKLEY
BENTLEY
WATTLE GROVE
WILSON
CARMEL
KENWICK
FERNDALE
BECKENHAM
RIVERTON
PICKERING BROOK
ORANGE GROVE
PARKWOOD
MADDINGTON
WILLETTON
CANNING VALE
THORNLIE
MARTIN
CANNING MILLS
N
SCALE 1:100 000
0 1 2 3 4 5
Kilometres
Perth_Airport_Noise.dgn
19 Jan 2004
PRODUCED BY STATUTORY MAPPING SECTION
PLANNING INFORMATION - MAPPING AND SPATIAL
DEPARTMENT FOR PLANNING AND INFRASTRUCTURE
ON BEHALF OF THE WESTERN AUSTRALIAN PLANNING
COMMISSION, PERTH, W.A. JANUARY 2004
Cadastral Data supplied by Department of
Land Information, W.A.
Note 1: This Plan is a compilation of zones
and reserves from Town Planning Schemes.
Please consult the relevant Local Government
to check the zoning/reservation of the subject
land.
Note 2: The Legend only includes zones and
reserves within proximity to the Australian Noise
Exposure Forescast contours.
LEGEND
METROPOLITAN REGION SCHEME RESERVES
Parks and Recreation
State Forests
Railways
Primary Regional Roads
Other Regional Roads
Public Purposes
LOCAL SCHEME RESERVES
Civic and Cultural Areas
Public Purposes
Recreation
LOCAL SCHEME ZONES
City Centre - Residential 1
City Centre -Residential 2
Residential 1
Residential 2
Residential 3
Residential Development
City Centre - Business
General Commercial
City Centre - Deferred
Special Purpose
Private Clubs and Institutions
General Industrial
Industrial Development
Light Industrial
General Rural
Landscape (Rural Agriculture - Kalamunda)
Resource Rural Conservation (Kalamunda)
Special Rural
Rural Living
Rural Residential Rural Lanscape Living (Mundaring)
Swan Valley Rural
Urban Development
Mixed Use
Mixed Use (Kalamunda)