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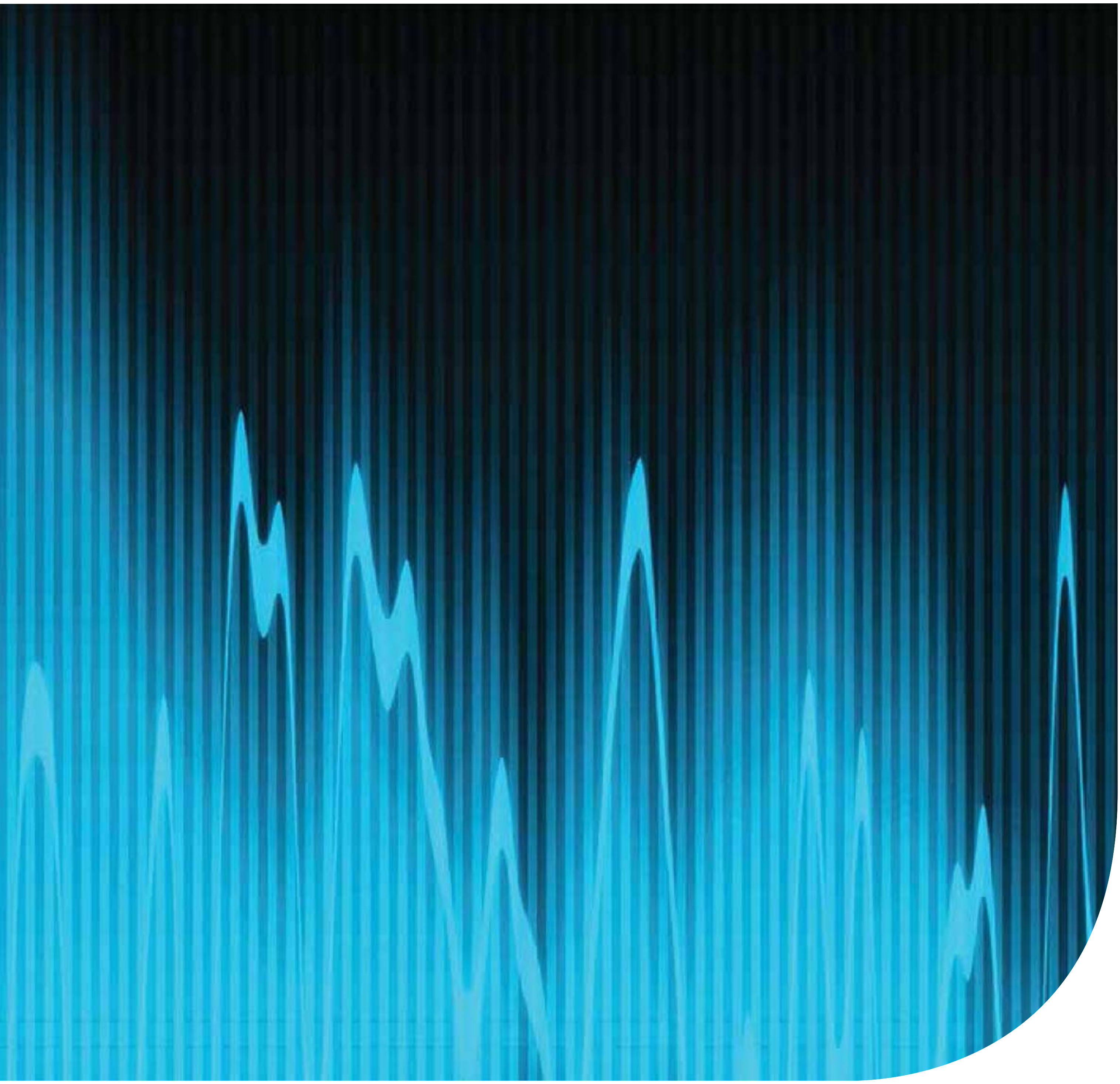
Design initiatives for aircraft noise

Victoria Road, Marrickville NSW

Prepared for E&D Danias Pty Ltd | 30 July 2015



Planning + Environment + Acoustics

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Approved by **Najah Ishac**

Position Director

Signature

Date 30 July 2015

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

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V1	4 May 2015	David Sallak	Najah Ishac
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Table of Contents

Appendices

Tables

Figures

1 Introduction

EMGA Mitchell McLennan Pty Limited (EMM) has been engaged by E&D Danias Pty Ltd to undertake a study of aircraft noise impact on land which is located in the vicinity of Victoria Road Marrickville, (Figure 1.2). The site is currently zoned industrial use.

The land proposed to be rezoned to allow residential development is located in the 25 to 30 ANEF zone of Sydney Airport. Local and state government recognise the pressures for increasing housing opportunities and this site provides a high level of accessibility to public transport, jobs and services.

The planners for the project, JBA, is developing an Aircraft Noise Strategy to accompany the proposal and will take into account Section 117 Direction 3.5 *'Development near licensed aerodromes'*. EMM's study herein provides input to that strategy, including design measures and initiatives required to ensure conducive long term residential amenity. EMM's input includes documented noise levels across the area, noise criteria for aircraft operations, identification of potential design measures and initiatives that will improve internal noise levels and quantify the effectiveness of such measures and provide recommendations on building design and construction materials. To that end, our focus will be on aircraft noise, however by default, ameliorative measures that address aircraft noise will effectively combat other transport related sources (eg road and rail if relevant).

Noise from aircraft approaching and leaving Sydney Airport affects a number of Sydney metropolitan areas as presented in the Sydney Airport Master Plan 2033 figures, including Marrickville. These impacts need to be placed in perspective and appropriately assessed against relevant criteria on a site by site basis. Aircraft noise at a site should not necessarily preclude certain types of land use. Noise exposure should be appropriately quantified and assessed against relevant criteria. Such an objective analysis is a critical input in determining the feasibility of future land uses at the subject site.

1.1 Consultation

As part of our study, we engaged with Sydney Airport Corporation Limited's (SACL) representatives Mr Ted Plummer (Head of Government and Community Relations) and Mr Joseph Chan (Senior Planning Manager Aviation Services). We also met with representatives of the Department of Infrastructure and Regional Development (DIRD) Mr Scott Stone (General Manager Aviation Environment) and his successor to that role Shona Rosengren.

Both SACL and DIRD provided valuable advice and discussions were positive and we believe items raised have been addressed herein.

1.2 Glossary

A number of technical acoustic descriptions are used in this report. A list of terms and a brief explanation are provided in Table 1.1.

Table 1.1 Glossary

Term	Descriptions
ASA	Air Services Australia
ANR	Aircraft noise reduction
Curfew	Defined as the hours 11pm to 6am
dB	Unit of sound in decibels
dB(A)	A unit of sound measurement which has its frequency characteristics modified by a filter (A-weighted) so that it approximates the frequency response of the human ear.
DL	The distance in metres from the closer end of the runway to the intersection of the extended runway centre-line and a line drawn perpendicular to the extended runway centre-line and passing through the building site, known as the 'sideline projection' (refer to AS 2021 - 2015 Figure 3.1).
DS	The distance in metres from the building site to the extended runway centre-line along a line drawn perpendicular to the extended runway centre-line and passing through the building site, known as the 'sideline projection' (refer to AS 2021 - 2015 Figure 3.1).
DT	The distance in metres from the further end of the runway to the intersection of the runway centre-line and a line drawn perpendicular to the extended runway centre-line and passing through the building site, known as the 'sideline projection' (refer to AS 2021 - 2015 Figure 3.1).
EPNL	Effective Perceived Noise Level, is the measure of aircraft noise taking into account spectral, temporal and spatial aspects of the noise.
L_{max}	The absolute maximum noise level in a noise sample (measured in units of dB).
L_{Smax}	Maximum noise level with slow time response.
L_{eq}	The “equivalent continuous noise level” is the summation of noise events integrated over a selected period of time. This noise metric is the energy-averaged noise level over the measurement period and is commonly used to correlate noise exposure and human annoyance.
N70	The number of daily aircraft noise events that are above a maximum noise threshold of 70 dB(A) L_{Smax}. Similarly for N60 etc.
NEC	Noise Exposure Concept, is a single number index for predicting the cumulative exposure to aircraft noise during a specified time period (normally one future year) during consideration of options for development, based on a hypothetical set of conditions. This shows the average daily aircraft noise exposure for that period and is usually presented graphically in the form of noise contours.
NEF (or ANEF)	Noise Exposure Forecast, is an index for predicting the cumulative exposure to aircraft noise during a particular future year, generally 10 to 20 years from the date of issue, based on a firm forecast of aircraft operations. This shows the average daily aircraft noise exposure for that period and is usually presented graphically in the form of noise contours.
NEI (or ANEI)	Noise Exposure Index, is an index for calculating the cumulative exposure to aircraft noise during a specified time period, based on historical data, where exact types and numbers of aircraft, which used the aerodrome, are known. This shows the average daily aircraft noise exposure for that period and is usually presented graphically in the form of noise contours.
PCA	Point of Closest Approach is the aircraft's position when it is closest (from plan view) to the nominated ground position, defined for this project as the ASA's noise monitor location which is at the Kurnell Public School.
Daytime	For aircraft noise modelling purposes, the day period is 7am to 7pm.
Evening/Night	For aircraft noise modelling purposes, the evening/night period is 7pm to 7am.
Movement	One pass of an aircraft as it takes off or lands.

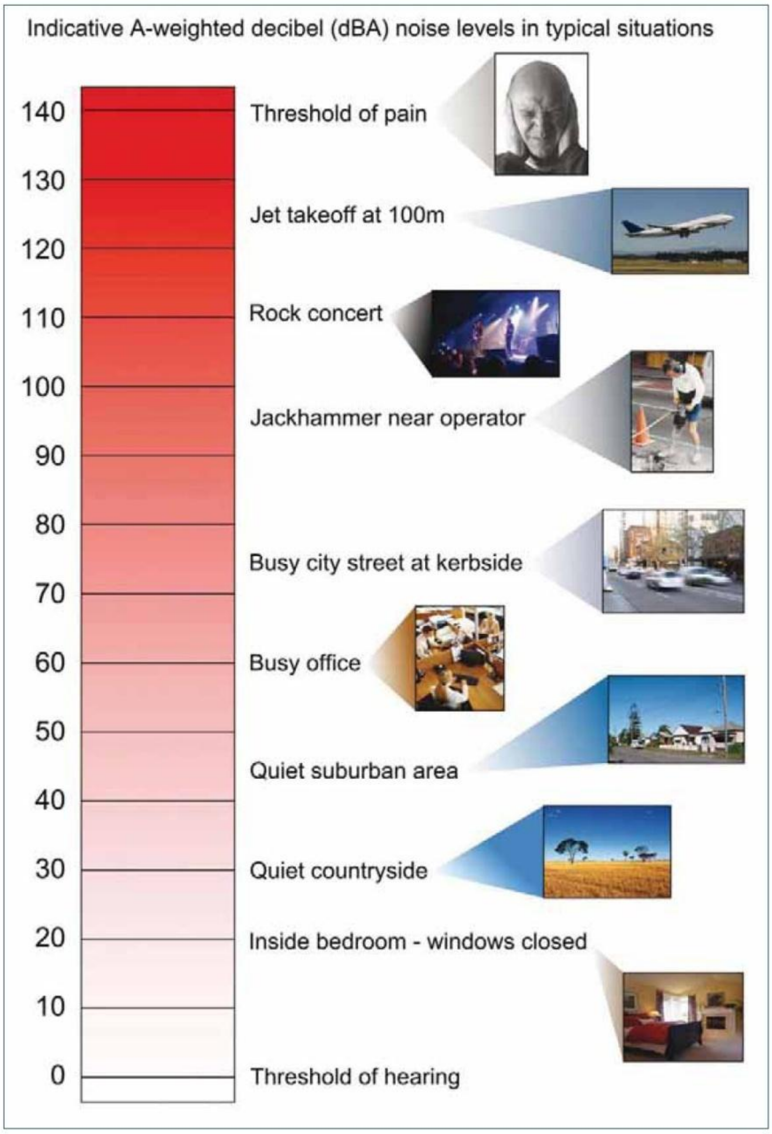
1.3 Common noise levels

It is useful to have an appreciation of decibels (dB), the unit of sound measurement when reading this assessment. Table 1.2 gives some practical indication of what an average person perceives about changes in noise levels.

Table 1.2 Perceived change in noise

Change in sound level (dB)	Perceived change in noise
3	just perceptible
5	noticeable difference
10	twice (or half) as loud
15	large change
20	four times as loud (or quarter) as loud

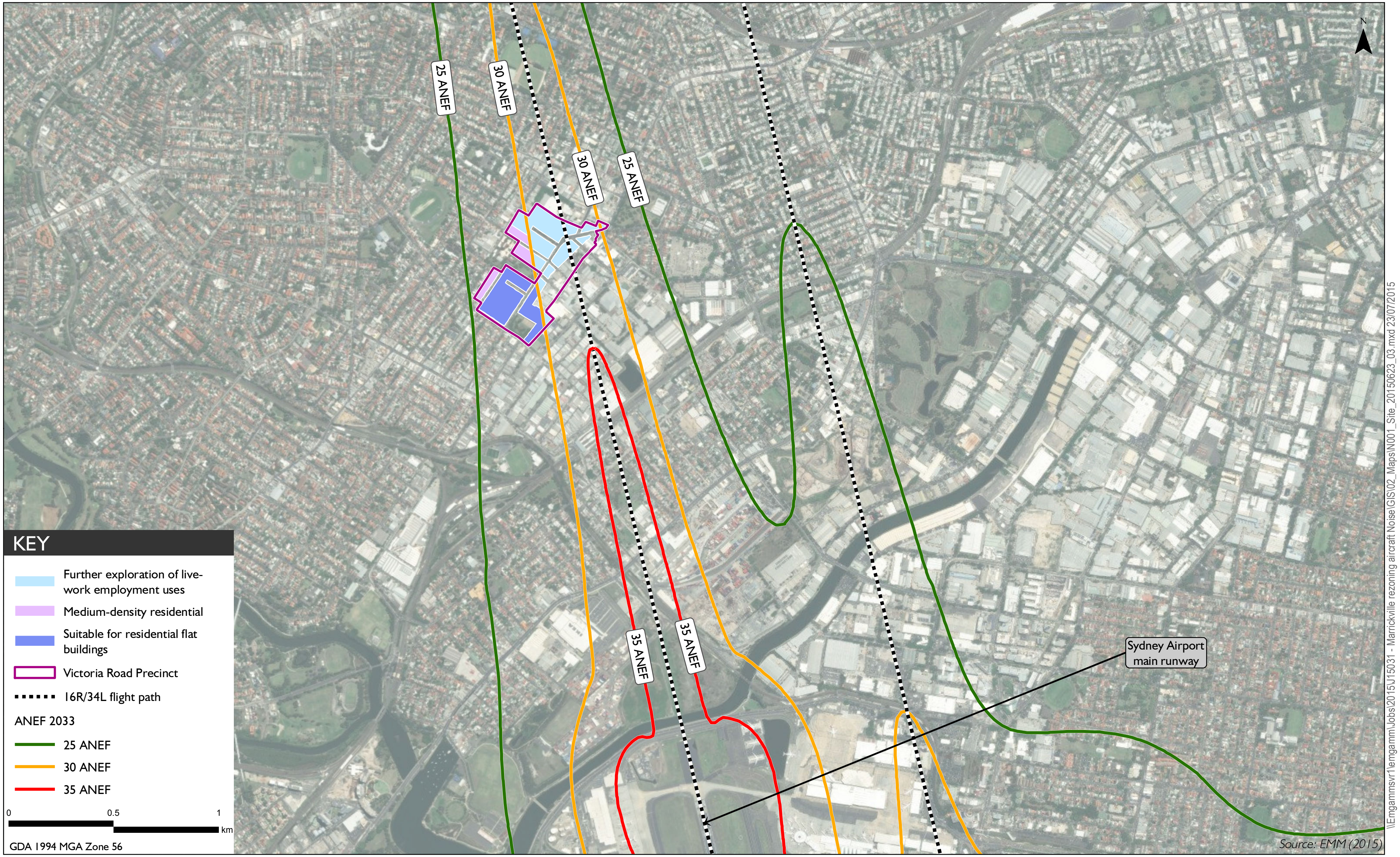
Examples of common noise levels are provided in Figure 1.1.



Source: RTA Environmental Noise Management Manual (RTA 2001)

Figure 1.1 Common noise levels

Refer to Figure 1.2 for the location of the site, overlaid on the ANEF 2033 for Sydney Airport and flight paths of interest.



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Site, ANEF 2033 and flight paths

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 1.2

1.4 Describing aircraft noise - Sydney Airport Master Plan 2033

It is important to describe aircraft noise exposure at a site in a manner that is useful to potential occupants of that site. The Sydney Airport Master Plan 2033 provides the most current airport operations and related noise information. A summary of relevant aircraft noise exposure information from this document is provided below.

1.4.1 Future operations and noise levels

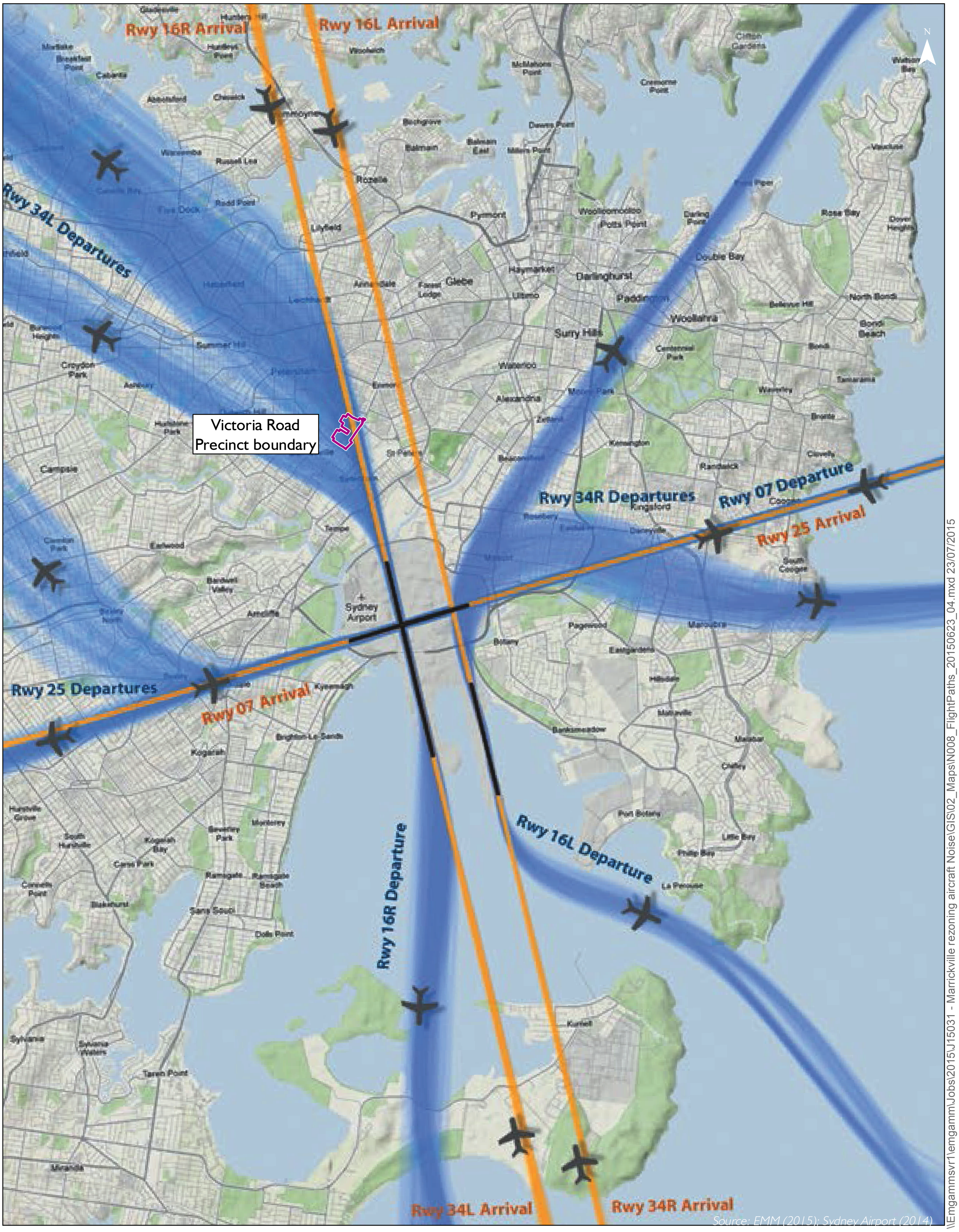
The Master Plan represents the vision for the operation of Sydney Airport and is to be used as a tool to forecast growth in air travel for tourism and trade to and beyond 2033. The Master Plan is stated to be based on the premise that there will be no changes to the curfew, aircraft movement cap, noise sharing arrangements, flight paths, runways and regional airline access arrangements. These factors are important for informing land use planning generally and the site in particular.

Chapter 14 'Noise Management' of the Master Plan includes actions and strategies for managing aircraft noise. It shows aircraft flight paths, how noise is measured, mapped and communicated and has information on ground-based noise. The key points in this chapter also include Sydney Airport's acknowledgment of the noise impacts it produces on the community and its commitment to working with the community, governments and the aviation industry to manage and mitigate these impacts. The Master Plan states that aircraft in Australian skies are some of the most modern in the world and with quieter aircraft replacing older ones, the impacts from aircraft will continue to reduce. This means that the published ANEF contours for 2033 cover a significantly smaller area than previous ANEF contours (eg 2029 and earlier).

This is also reflected in community announcements advertised by Sydney Airport Corporation in the local paper The Leader (Thursday 27 September 2012), which stated "*The fleet of aircraft flying into Sydney is one of the most modern in the world. Aircraft coming off the production line today are about 75% quieter than they were 40 years ago. The aviation industry is working to reduce this even more*. *With new generation quieter aircraft continuing to replace older noisier aircraft, noise impacts around Sydney Airport will continue to improve, helping to offset increased movements.*" The article goes on to explain the noise reduction in decibels for an Airbus A380 as compared to a Boeing 747 and the quieter Boeing 787 Dreamliner expected to use Sydney Airport in the future.

1.4.2 Flight paths

An important factor in determining aircraft noise impacts is site location relative to runways. For the subject site, the most relevant departure runway end is 34L on the main north-south runway, where take-offs occur towards but adjacent to the Marrickville site. This runway end is over 6 km from the site. Similarly, the arrival path of most interest is that for runway end 16R which passes adjacent the site and runway end 16R is approximately 2.4 km from the site. Arrival path 16L and departure path 34L (on the parallel north-south runway) are less relevant, however operations from these flight paths will be noticeable at the site. Refer to Figure 1.3 for flight paths associated with runways as published in the Master Plan 2033, showing the Victoria Road precinct boundary. The proximity of departure and arrival events are clear in relation to the site in this figure. Note that the residential component of the site (see Figure 1.2) is to the south west and therefore furthest from the aircraft events.



Site location and flight paths at Sydney Airport (jet aircraft)

Victoria Road, Marrickville

Design initiatives for aircraft noise

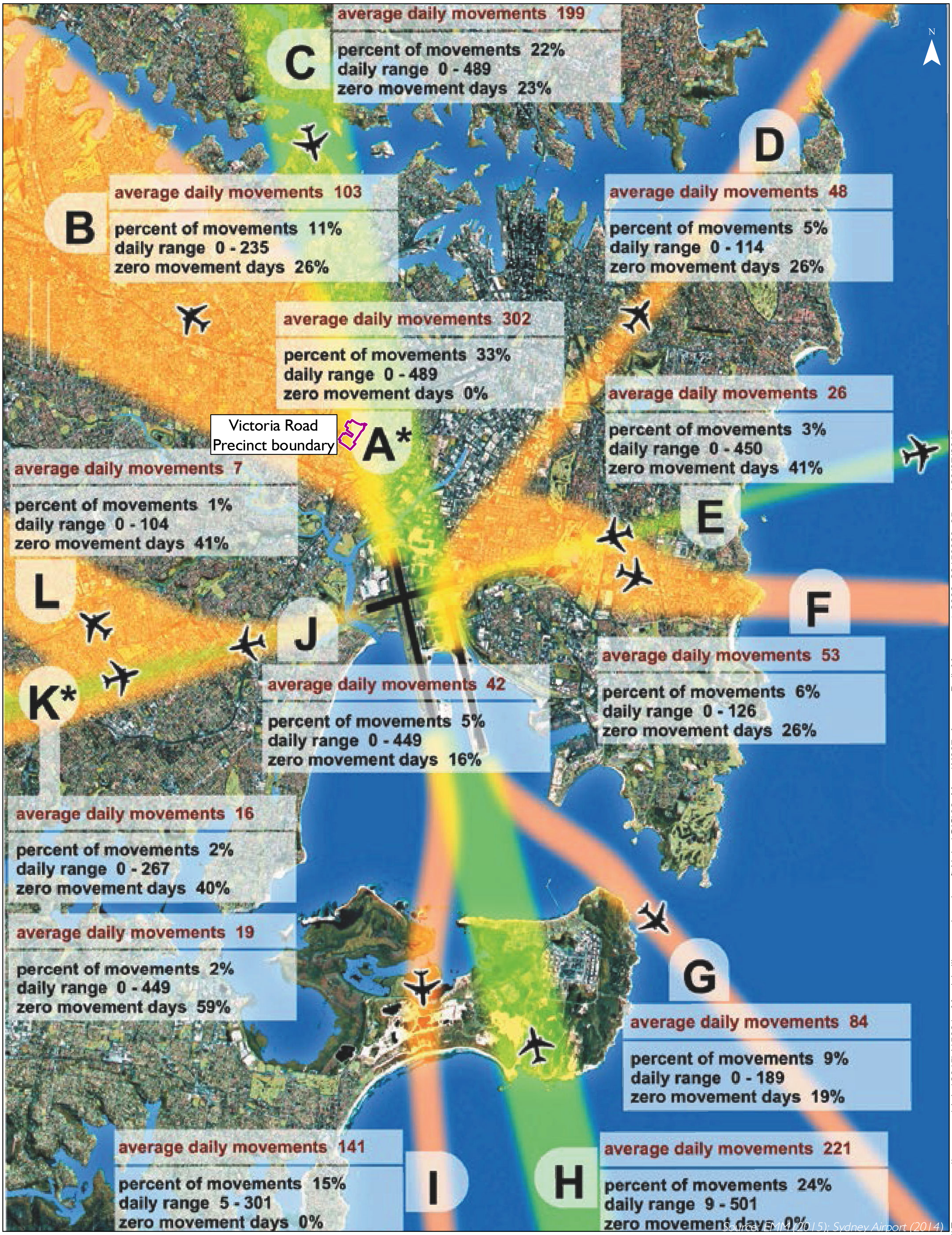
Figure 1.3

1.4.3 Movement and respite data

Other useful maps presented in the Master Plan include the average daily jet aircraft movements for 2033 as reproduced in Figure 1.4 and respite data as shown in Figure 1.5. The movement data shows 302 average daily movements on flight path A and this includes arrivals on both parallel runways and not just the closest to the site (however the main north south runway does accommodate the higher portion of these as shown in published ANEI reports from ASA. A subset of 103 movements from flight path A occurs on flight path B, with the latter being relatively closer to the proposed residential portion of the site (south west corner). Flight path B also indicates zero movements for 26 per cent of days on average. Given the proximity of the site to the runways, aircraft movements will be relatively high as the 302 events will be 'observed' at the site albeit at varying noise magnitude.

Similarly, total respite for flight path A is relatively low at 3%, however is 51% on average for path B as shown in Figure 1.5. The proximity of the proposed residential area of the site is such that little respite can be expected as indicated by flight path A data.

In summary, the proposed residential area of the site will be exposed to aircraft noise on a continual basis. The future occupants should be made fully aware of the impacts of the aircraft noise and the operations of Sydney Airport.



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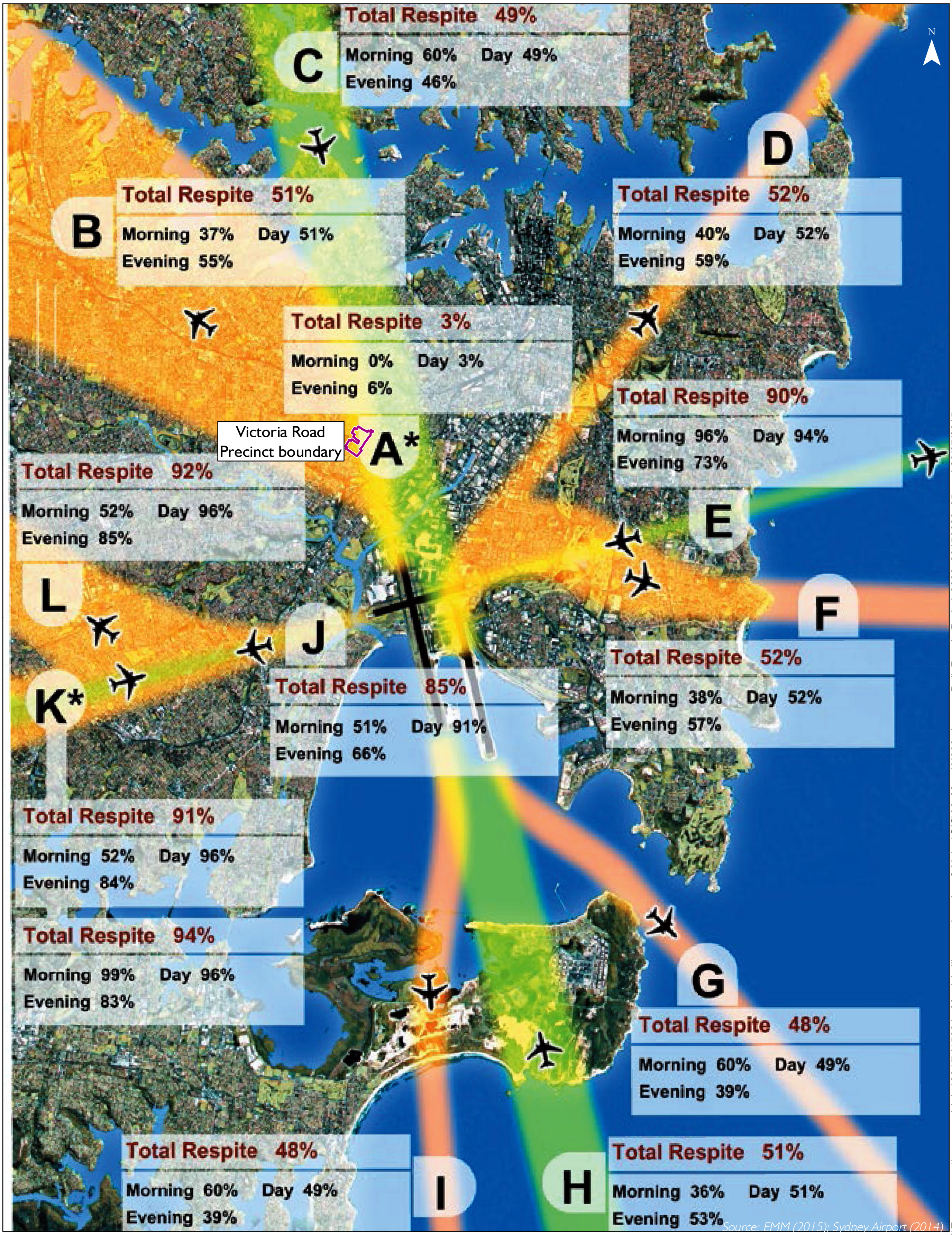
Site location and average daily jet aircraft movements 2033

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 1.4



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Site location and average daily jet aircraft respite periods 2033

Victoria Road, Marrickville
Design initiatives for aircraft noise

Figure 1.5

1.4.4 Other noise descriptors

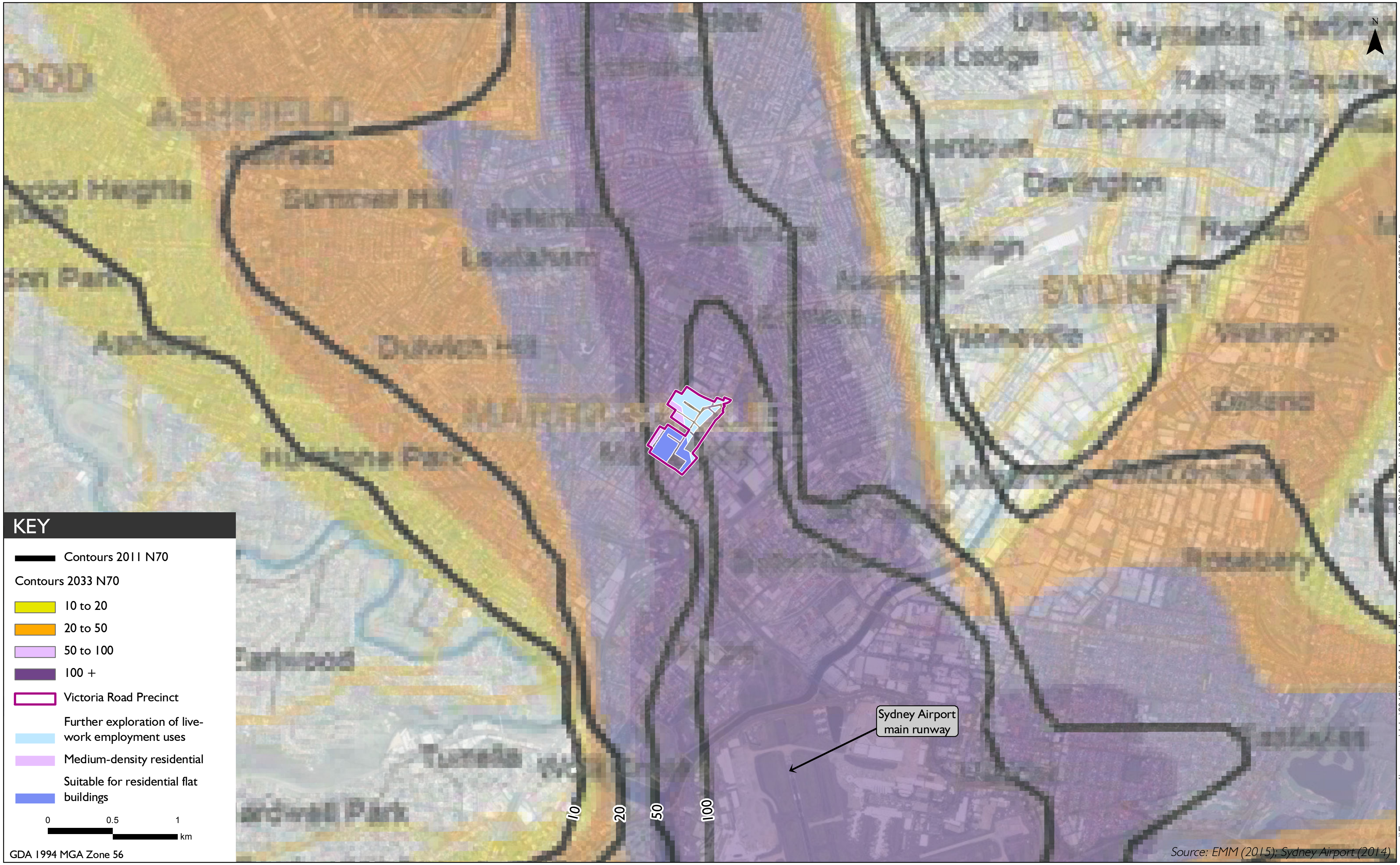
Other useful noise metrics that are often used and displayed in airport noise impact assessments are Number Above (NA) indices. Whilst there are no formal standards, policies or guidelines that adopt these indices for planning or impact assessment, they do provide useful indications of impacts. The Sydney Airport Master Plan document, for example, acknowledges that an internal noise level greater than L_{Smax} of 60 dB(A) is likely to interfere with conversation or with listening to radio or television (refer to Master Plan 2033 Appendix H Dictionary, for N70 contours). The equivalent outdoor noise level would be 70 dB(A) with windows or doors partially open, and therefore the Master Plan advocates use of N70 as another way of informing the community about aircraft noise.

Similarly, Airservices Australia in its publication "Sydney Airport N477 Australian Noise Exposure Index 1 January to 31 March 2012", states the following:

"*'Number Above' (Nxx) noise maps are an approach which provides additional information on aircraft noise in a form that is more easily understood by the community. The contours provide a visual depiction that shows the number of noise events during a given period that are louder than a selected threshold level. The N70 Aircraft Noise Map for Sydney Airport shows for all areas around the airport how many aircraft noise events louder than 70 dB(A) there were, on a daily average, during the period from 1 January to 31 March 2012 ANEI (N477)*.

70 dB(A) is generally considered to be the external sound level below which no difficulty with reliable communication from radio, television or conversational speech in a typical room with windows open is expected. (Reference - Department of Transport and Regional Services, 2000, Expanding Ways to Describe and Assess Aircraft Noise, pp23-35)." This is due to the accepted and tested external to internal changes in noise with partially open windows being approximately 10 dB.

Figure 1.6 shows the site relative to the N70 noise contours as provided in the Master Plan 2033 and shows the site can expect more than 100 daily events above 70 dB(A) on average.



\\Emgammsvr1\emgamm\Jobs\2015\J15031 - Marrickville rezoning aircraft Noise\GIS\02_Maps\N005_N70_2011_2033_20150623_06.mxd 23/07/2015

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Site location and Sydney Airport N70 contours 2033 and N70 contours 2011

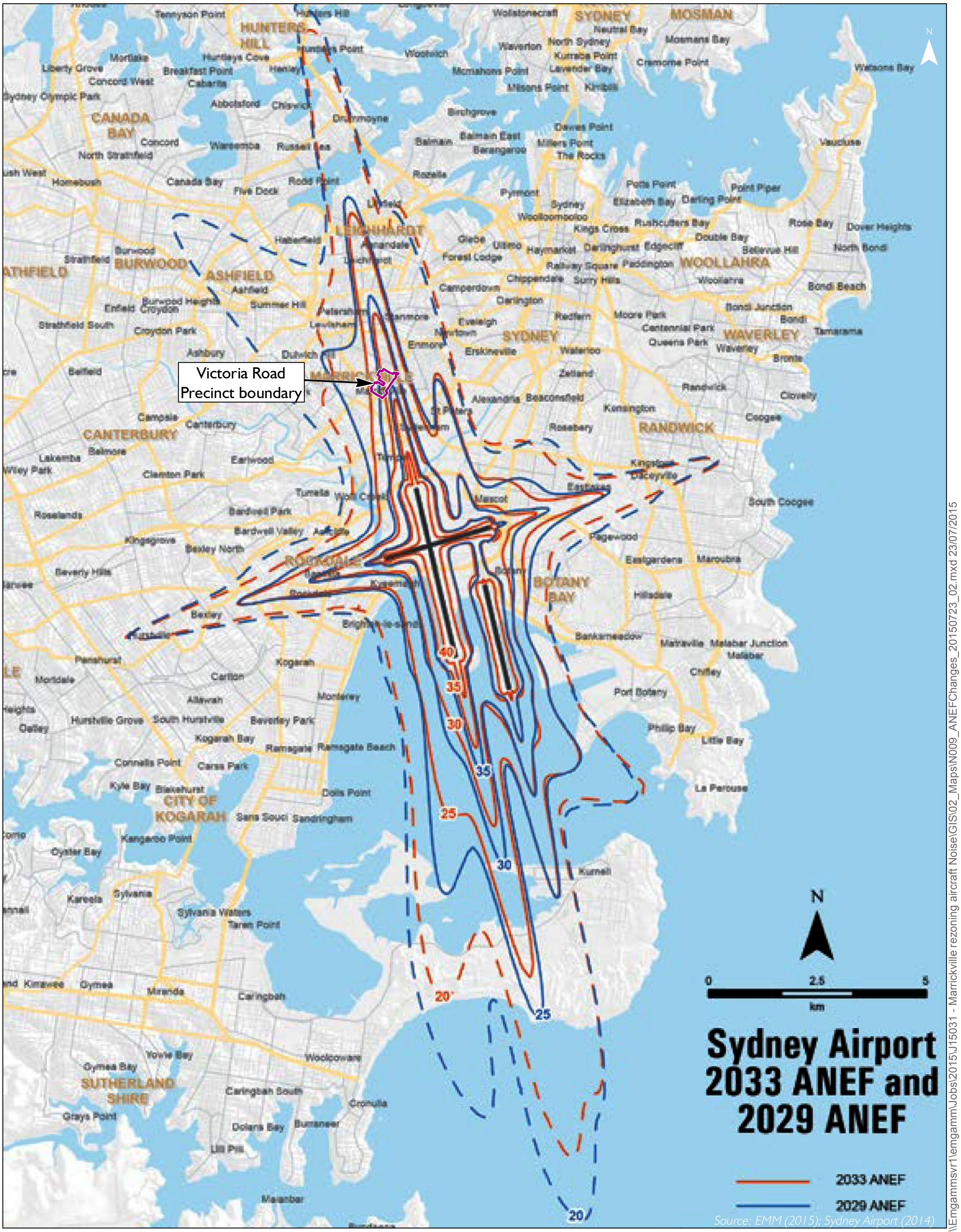
Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 1.6

1.4.5 ANEF comparisons

The Sydney Airport Master Plan 2033 provides a useful indication on what is anticipated with respect to aircraft noise exposure over time. For example, the ANEF 2029 and ANEF 2033 contours are provided on the one map (Figure 14.7 of the Master Plan 2033) and is reproduced as Figure 1.7 herein. This figure shows ANEF 2033 contours (red in colour) contract on those of ANEF 2029 (blue in colour) in all directions from the airport. This means operations are forecast to have a reduced noise exposure on the community on average, based on the latest forecasting information. The fundamental parameters that affect ANEF calculations and therefore this outcome includes the number of aircraft movement events and aircraft type. Given it is unlikely that the number of movements will decrease over time, the contraction in the contours therefore implies the operation of quieter aircraft through either phasing out of some models and introduction of newer aircraft with reduced emissions as compared to predecessors. Refer to Figure 1.7 indicating a contracting ANEF contour, including in the vicinity of the subject site at Marrickville.



Site, ANEF 2029 vs ANEF 2033

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 1.7

1.4.6 Other relevant information from Sydney Airport Master Plan 2033

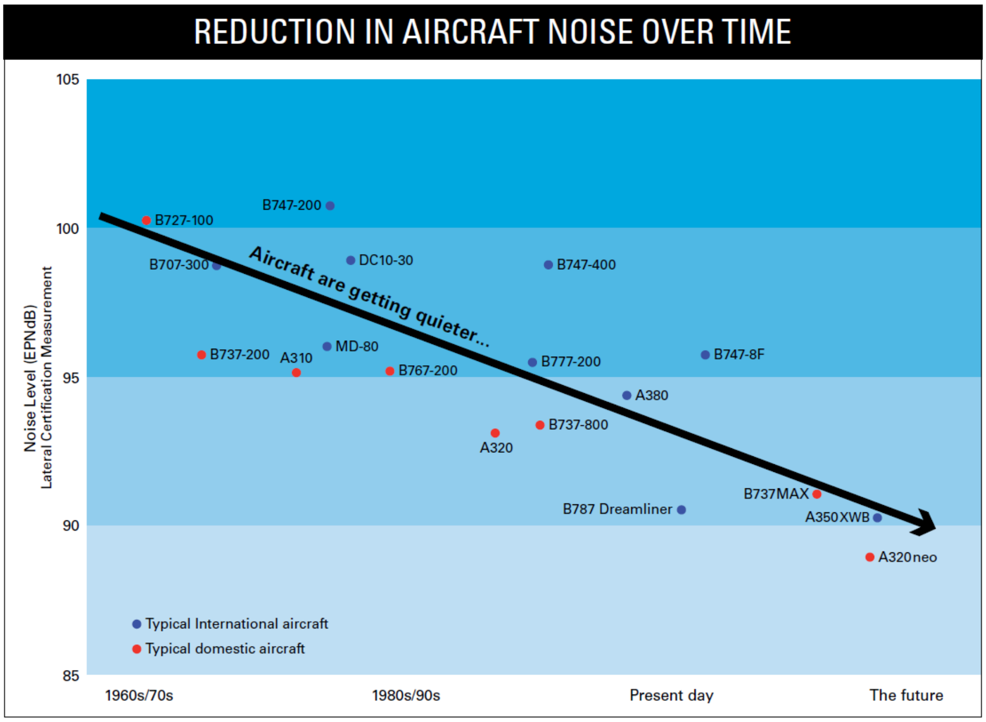
This report has highlighted a number of relevant references from the Sydney Airport Master Plan 2033 and the plan should be read in conjunction with this report to assist further in understanding the future operations and related changes in impacts from aircraft noise.

For example, it is stated that airlines expected to see continued increases in seating density across the industry. Further, Qantas "...intends to replace B767s with the 20-25% larger A330s".

At Section 14.2.1, page 179, the plan states:

> Sydney Airport welcomes the introduction of the new generation of quieter aircraft like the Airbus A380, Boeing B777, B787 Dreamliner and B747-8F. It is expected that other new generation quieter aircraft like the A350XWB, B737 MAX and A320neo will be introduced within the planning period of this Master Plan.
>
> Sydney Airport's past, present and future investment in infrastructure to accommodate these new generation aircraft is designed to ensure residents living close to the airport or under flight paths will continue to benefit from their introduction. For example, to accommodate the A380, which is both larger and much quieter than the older aircraft type it is replacing, Sydney Airport has invested significantly to upgrade infrastructure.

Figure 14.2 of the Master Plan 2033 demonstrates the above and depicts how improved technology has resulted in quieter aircraft (reproduced as Figure 1.8). The expectation as shown is to continue the trend of reduced aircraft noise emissions into the future.



Source: Sydney Airport Master Plan 2033 (2014)

Figure 1.8 Reduction in aircraft noise over time

At page 182, the Master Plan states:

> In 2008, Airservices Australia released a report showing that an Airbus A380 departing from or arriving at Sydney Airport is between 2.1 and 6.7 decibels quieter than the 747-400, the older aircraft type it typically replaces.
>
> Airservices Australia indicates in its report that “a three decibel reduction is regarded as a halving of an aircraft’s noise energy".

Refer to Figure 1.9, demonstrating the above via actual measured noise reductions from comparable aircraft, as reported in the Master Plan at Table 14.6. The A380 has a smaller noise footprint on take-off and landing and hence reduces the impact of aircraft on the community.

Location of NMT	Aircraft type	Arriving or departing	Average LA max [dB(A)]	Reduction in decibels	Reduction in noise energy
Sydenham	A380	Departing	87.7	- 4.4	- 64%
	B747-400	Departing	92.1		
	A380	Arriving	93.9	- 2.6	- 45%
	B747-400	Arriving	96.5		
Leichhardt	A380	Departing	81.7	- 3.9	- 59%
	B747-400	Departing	85.6		
	A380	Arriving	84.4	- 2.1	- 38%
	B747-400	Arriving	86.5		
Annandale	A380	Departing	71.5	- 5.5	- 72%
	B747-400	Departing	77.0		
St Peters	A380	Departing	73.6	- 6.7	- 79%
	B747-400	Departing	80.3		
Croydon	A380	Departing	76.7	- 2.3	- 41%
	B747-400	Departing	79.0		

Source: Airservices Australia

Source: Sydney Airport Master Plan 2033 (2014)

Figure 1.9 Noise monitoring around Sydney Airport

At page 182, the Master Plan states:

> In July 2012, Virgin Australia announced an agreement with Boeing to order 23 of its new generation 737 MAX aircraft, the first airline in Australia to do so. Boeing has said that the noise footprint of this aircraft is 40% smaller than today’s B737s."
>
> The B787 Dreamliner began flying to Sydney in August 2013. Qantas has selected the B787 Dreamliner as the cornerstone of its domestic and international fleet renewal program. Under the fleet plan, the Qantas Group has orders for 15 Boeing 787 aircraft, with the first aircraft having arrived in the second half of 2013. Qantas has options and purchase rights for a further 50, available for delivery from 2016. Powered by General Electric’s GEnx engines, Qantas indicates that it has a 50% smaller noise footprint. The B787 will, over time, replace older aircraft like the B767-300. Cathay Pacific already flies the new generation B747-8F freighter to Sydney and has said that its noise footprint is 30% smaller than the older freight aircraft type it replaced.

2 Relevant aircraft noise criteria

This section details the relevant current accepted land use planning tools for aircraft noise exposure.

2.1 Standard instrument LEP provisions

The Department of Planning and Environment (the Department) in developing the Standard Instrument LEP acknowledges the potential for airport activity to impact the quality of life of residents close to airports. To manage this potential the Department has prepared and requires NSW Councils to adopt a Standard clause where potential arises for aircraft noise to impact residential areas. The Department advises that the "...model provision is applicable to all civil and military airports for which noise forecast (ANEF) maps have been prepared." Expansion of airport runway facilities, change of flight paths or increased residential development in close proximity to existing airports where the Department considers it to increase the likelihood of aircraft noise impacts being experienced by the community unless aircraft noise is specifically taken into account in the planning process.

The Department advises that:

> "The model clause has been developed so that where residential development is proposed in areas of aircraft noise exposure forecast levels of greater than 20 ANEF, consent authorities must be satisfied that appropriate measures will be taken so that the interior noise levels in the development will meet Australian Standard AS2021-2000, Acoustics-Aircraft noise intrusion - building siting and construction."

The model clause is extracted below and has been applied in published comprehensive local environmental plans for local government areas surrounding the airport including but not limited to Marrickville (Clause 6.5), Randwick, Botany, Rockdale and the City of Sydney.

"**Development in areas subject to aircraft noise**

(1) The objectives of this clause are as follows:

(a) to prevent certain noise sensitive developments from being located near the Kingsford Smith Airport and its flight paths,

(b) to assist in minimising the impact of aircraft noise from that airport and its flight paths by requiring appropriate noise attenuation measures in noise sensitive buildings,

(c) to ensure that land use and development in the vicinity of that airport do not hinder or have any other adverse impacts on the ongoing, safe and efficient operation of that airport.

(2) This clause applies to development that:

(a) is on land that:

(i) is near the Kingsford Smith Airport, and

(ii) is in an ANEF contour of 20 or greater, and

(b) the consent authority considers is likely to be adversely affected by aircraft noise.

(3) Before determining a development application for development to which this clause applies, the consent authority:

(a) must consider whether the development will result in an increase in the number of dwellings or people affected by aircraft noise, and

(b) must consider the location of the development in relation to the criteria set out in Table 2.1 (Building Site Acceptability Based on ANEF Zones) in AS 2021—2000, and

(c) must be satisfied the development will meet the indoor design sound levels shown in Table 3.3 (Indoor Design Sound Levels for Determination of Aircraft Noise Reduction) in AS 2021—2000.

(4) In this clause:

***ANEF contour** means a noise exposure contour shown as an ANEF contour on the Noise Exposure Forecast Contour Map for the Sydney (Kingsford Smith) Airport prepared by the Department of the Commonwealth responsible for airports.*

***AS 2021—2000** means AS 2021—2000 Acoustics - Aircraft noise intrusion - Building siting and construction.*

2.2 AS 2021 - 2015 Acoustics - Aircraft noise intrusion - Building siting and construction

The fundamental tool used for building site planning purposes around aerodromes in respect of acoustics is Australian Standard *AS 2021 - 2015 Acoustics - Aircraft noise intrusion - Building siting and construction*. The standard works on the principle of whether a building site is considered to be 'acceptable', 'conditionally acceptable' or 'unacceptable'. To do this the Australian Noise Exposure Forecast (ANEF) noise contour map is needed, which is a reflection of the aerodrome's noise footprint on the surrounding environment. The ANEF map is a function of both the noise levels from various aircraft that are forecast to use the site as well as the quantity of aircraft movements.

Our approach to the assessment of aircraft noise for the site included adopting the guidelines in AS 2021. This was aided by the available existing ANEF contour map for Sydney Kingsford Smith Airport operations (ie ANEF 2033 as published in the Sydney Airport Master Plan of 2014).

This standard recommends a screening type of approach initially to determine the acceptability of a building site. This is defined as shown in Table 2.1, which is a reproduction of Table 2.1 in AS 2021 as are the associated notes that follow the table.

Table 2.1 Building site acceptability based on ANEF zones (AS 2021)

Building Type	ANEF Zone of site		
	Acceptable	Conditionally Acceptable	Unacceptable
House, home unit, flat, caravan park	Less than 20 ANEF	20 to 25 ANEF	Greater than 25 ANEF
Hotel, motel, hostel	Less than 25 ANEF	25 to 30 ANEF	Greater than 30 ANEF
School, university	Less than 20 ANEF	20 to 25 ANEF	Greater than 25 ANEF
Hospital, nursing home	Less than 20 ANEF	20 to 25 ANEF	Greater than 25 ANEF
Public building	Less than 20 ANEF	20 to 30 ANEF	Greater than 30 ANEF
Commercial building	Less than 25 ANEF	25 to 35 ANEF	Greater than 35 ANEF
Light industrial	Less than 30 ANEF	30 to 40 ANEF	Greater than 40 ANEF
Other industrial		Acceptable in all ANEF zones	

Notes: *1. The actual location of the 20 ANEF contour is difficult to define accurately, mainly because of variation in aircraft flight paths. Because of this, the procedure of Clause 2.3.2 may be followed for building sites outside but near to the 20 ANEF contour.*

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 (see also Figure A1 of Appendix A).

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 Table 2.1 should be used to determine site acceptability, but internal design noise levels within the specific spaces should be determined by Table 3.3.

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 ANR determined according to Clause 3.2. 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 green field sites deemed unacceptable because such development may impact airport operations.

The definitions of the terms in Table 2.1 are as follows:

Acceptable

"If from Table 2.1, the building site is classified as 'acceptable', there is usually no need for the building construction to provide protection specifically against aircraft noise. However, it should not be inferred that aircraft noise will be unnoticeable in areas outside the ANEF 20 contour. (See Notes 1, 2 and 3 of Table 2.1)."

Conditionally acceptable

"If from Table 2.1, the building site is classified as 'conditionally acceptable', the maximum aircraft noise levels for the relevant aircraft and the required noise reduction should be determined from the procedure of Clauses 3.1 and 3.2, and the aircraft noise attenuation to be expected from the proposed construction should be determined in accordance with Clause 3.3 (See Notes 1 and 3 of Table 2.1)."

Unacceptable

"If, from Table 2.1 the building site is classified as 'unacceptable', construction of the proposed building should not normally be considered. Where in the community interest redevelopment is to occur in such areas, e.g. a hotel in the immediate vicinity of an aerodrome, refer to the notes to Table 2.1."

2.2.1 L_{Smax} noise levels

If a building site is within a ‘conditionally acceptable’ ANEF zone, it is necessary to quantify the typical L_{Smax} noise level from aircraft passing over that site. The representativeness of noise data should reflect typical events at the aerodrome, which can be ambiguous in some cases, particularly when trying to estimate future operations and associated impacts. Fortunately for Sydney Airport this is relatively straightforward because of its well established flight path movements, runways and aircraft types. For the site, the main influencing events will be aircraft approaches on runway ends 16R and to a lesser extent 16L, as well as departure events on runway end 34L and to a lesser extent 34R. These are the two parallel north-south runways at Sydney Airport.

Almost all of the planes on these runway ends are jet aircraft and these runways carry the majority of the movements for Sydney Airport.

2.2.2 Internal design goals

Where a site is ‘conditionally acceptable’, AS 2021 recommends that buildings be designed to achieve internal noise levels no greater than identified maximum values when aircraft pass overhead.

Table 2.2 reproduces recommended internal maximum noise levels for various spaces found in AS 2021 Table 3.3. These are the L_{Smax} or maximum noise level inside habitable spaces, with residential buildings understandably attracting one of the strictest criterion. The only other spaces with a more onerous criterion are theatres, cinemas and recording studios, although these types of buildings are often designed and constructed with relatively superior building elements.

For residential buildings, it is only necessary to consider aircraft noise levels of greater than 60 dB(A)L_{Smax} as an external level of 60 dB(A) is reduced to 50 dB(A) inside with a partially open window or door. This is the strictest residential criterion which applies to sleeping areas and dedicated lounges.

Table 2.2 Indoor design sound levels

Building type and activity	Indoor L_{Smax} Design Sound Level, dB(A)
Houses, home units, flats, caravan parks	
Sleeping areas, dedicated lounges	50
Other habitable spaces	55
Bathroom, 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

AS 2021 defines the 'aircraft noise level' at Section 1.5.2 as:

"The arithmetic average of the maximum sound levels occurring during a series of flyovers by a specific aircraft type and load conditions measured in A-weighted decibels (dB(A))using the S time-weighting of a sound level meter."

In our review we adopt AS 2021's aircraft noise reduction (ANR) definition, which is:

"A calculated or measured value. For design purposes, the arithmetic difference between the aircraft noise level at a site and the indoor design level, as described in Clause 3.2.2. For measurement purposes, the difference between the exterior and indoor sound levels as determined in accordance with Appendix C."

The amount of noise reduction is the difference between the outside L_{Smax} aircraft noise level and the indoor L_{Smax} design level taken from Table 2.2.

The ANR sets building fabric acoustic performance requirements to confirm the viability of developing sites for their intended use. For example, if an ANR of 20 were needed for sleeping areas (ie a typical external L_{Smax} of 70 dB(A)), standard dwelling construction would suffice so long as BCA ventilation requirements were satisfied. If an ANR of 40 were needed, this would require considerable modifications to standard dwelling construction, while ANR 30 would be somewhere in between. This review has assessed the appropriateness of the site for residential land uses.

3 Calculated aircraft noise exposure of site

3.1 Airservices Australia (ASA) movement data - day vs. night/curfew operations

Aircraft movement data is published by Airservices Australia (ASA) and is available on their website. Refer to Appendix A for overall day and night arrival and departure movement information by runway end and aircraft type.

3.2 Representative noise event

From the ASA movement data (refer to Appendix A and Table 3.1) it is clear that B737-800 aircraft arrivals and departures at Sydney Airport present the most frequent events the site is currently exposed to. The data shows that typically these aircraft constitute 25% of all jet movements. The next prominent aircraft is the A320 (ie Airbus 320) and generally has approximately half the movements of the B737-800, and is a quieter aircraft in any case.

One of the noisier, but considerably less frequent aircraft is the B747-400, having approximately less than one-fifth of the arrival movements on runway end 16R compared to the B737-800.

Other aircraft of interest is the BA463 (British Aerospace 463) which uses the airport in the curfew hours (11pm to 6am).

Refer to Table 3.1 for a snapshot of aircraft movement data for the most recent quarter of operations (for September to December 2014, being the latest available as of May 2015). As described earlier, 16R arrivals and 34L departures are the most relevant to site, being runway ends associated with the closest flight path on one of the main north-south runways at Sydney Airport.

Because of the conservative nature of AS 2021, the design aircraft noise event will be dictated by the noisiest of all aircraft events considered to be typical of operations at Sydney Airport. This is the B747-400 even though movement numbers are relatively insignificant as shown in Table 3.1.

Table 3.1 Aircraft movement data Sydney Airport 1 July to 30 September 2014

Aircraft	Average daily movements by runway					
	Arrivals		Departures		Introduced (Sydney/Globally)	Likely phase out
	16L	16R	34L	34R		
B747-400	0	**3.59 (3%)**	**4.02 (4%)**	0	1992 (eight gates added at Sydney Airport to cater for it)	Post 2033 (relatively small movements in ANEF 2033)
B737-800	25.45 (32%)	**30.74 (26%)**	**13.93 (15%)**	41.08 (40%)	~1998	Not in foreseeable future
B767-300	2.47 (3%)	**6.44 (5%)**	**1.35 (1%)**	6.94 (7%)	~1986	Immanent for Sydney Airport
A320	16.88 (21%)	17.35 (15%)	8.15 (9%)	24.59 (24%)	~1988	Not in foreseeable future
BA463/BAE300	0.13 (<1%)	0.27 (<1%)	0.03 (<1%)	0.02 (<1%)	Unknown	Unknown
Total All aircraft	79.78	**117.65**	**94.43**	102.36		

Notes: *1. Movement numbers in the above table are daily, averaged over the quarter.*

2. The above movement numbers have been rounded to two significant figures, as a result minor discrepancies may occur between totals and the sums of component items.

3. Introduced dates and Likely phase out of aircraft are based on literature search as of 15 may 2015 and are subject to change.

3.3 Representative L_{Smax} noise level

The representative aircraft noise levels across the subject site have been calculated for the B737-800, B747-400 and BA463 aircraft.

AS 2021 provides extensive tabulated data for numerous aircraft types showing average maximum noise levels for departures and arrivals based on a matrix of runway and flight line offset distances to a site. This is done using a commercially available software package (the Integrated Noise Model, INM) which includes a database of measured data contained within it.

The latest revision of AS 2021 (released on March 2015) was used to provide such data for the aircraft of interest. The tabulated results of this exercise are shown in Appendix B. The distances shown are only those available and presented in the AS 2021 tables. It is important to note that long range departures for the B747-400 aircraft were adopted as these are noisier than the short range departures, adding a further level of conservatism to this project. Anecdotal information indicates an even share between long range and short range departures for this aircraft, and hence movement volumes for long range departures are typically half those quoted in Table 3.1.

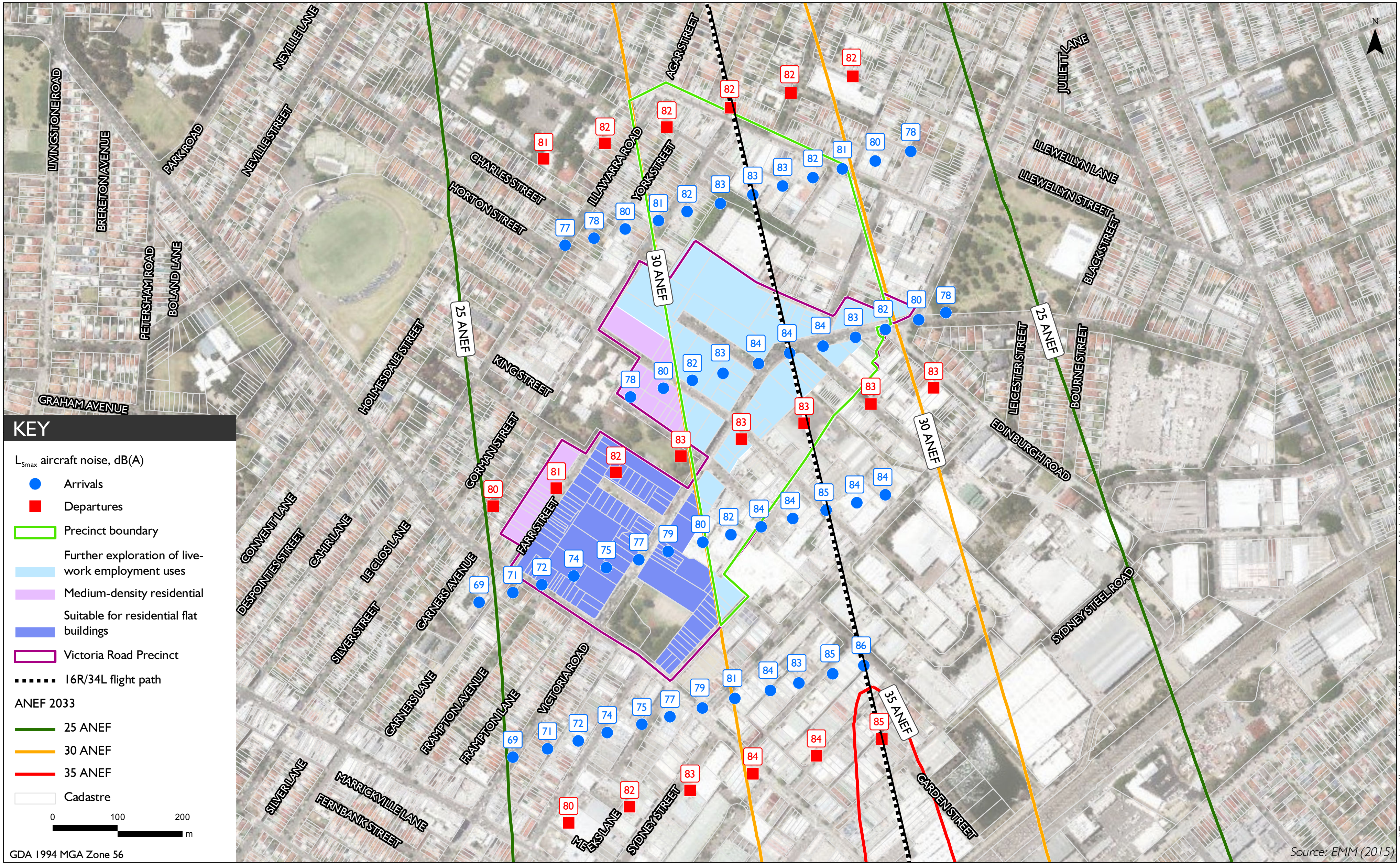
In summary, EMM found the following across the potential residential area of the site (as interpolated from the data presented in Figure 3.1 to Figure 3.3):

- B737-800 (typically 6am to 11pm)
  - Arrivals range between 72 dB(A) to 81 dB(A) L_{Smax}
  - Departures range between 81 dB(A) to 83 dB(A) L_{Smax}

- B747-400 (typically 6am to 11pm)
  - Arrivals range between 77 dB(A) to 86 dB(A) L_{Smax}
  - Departures (Long Range) range between 85 dB(A) to 90 dB(A) L_{Smax}
- BA463 (typically curfew 11pm to 6am)
  - Arrivals range between 69 dB(A) to 78 dB(A) L_{Smax}
  - Departures range between 76 dB(A) to 80 dB(A) L_{Smax}

As shown above, the upper end of the range of noise levels across the site is 78 dB(A) to 90 dB(A) for the three aircraft types. As expected, arrival events are less noisy than departures for the same aircraft. Although the noisier aircraft operate during the less sensitive daytime period, in the following sections we have adopted the upper limit of 90 dB(A) for sleep spaces and dedicated lounges (as per AS 2021) to develop the guideline noise mitigation strategy. Further, as stated earlier, the representative aircraft event, B747-400 long range departure (with a noise level at site of 85 dB(A) to 90 dB(A)), is a relatively infrequent event constituting between 1.5% to 2% of events on the runways relevant to the subject site (on the assumption that about half the reported B747-400 events are long range and half being short range as described earlier).

Refer to Figure 3.1 to Figure 3.3 for a graphic representation of aircraft noise levels across the site and to Appendix B for details and distances (DS, DL and DT) used to calculate noise levels as per AS 2021.



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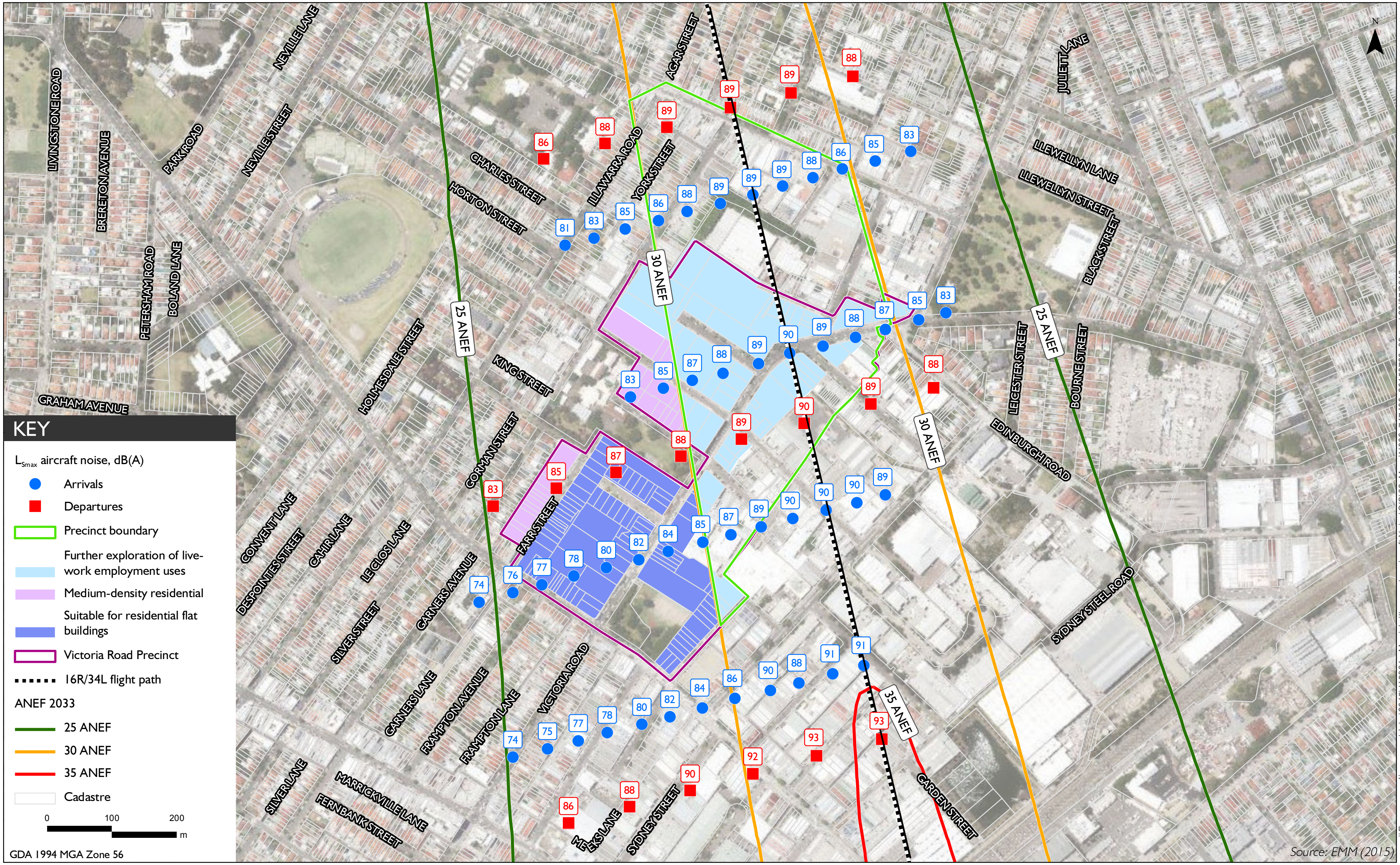
AS2021 L_{Smax} noise levels - B737-800 (arrivals and departures)

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 3.1

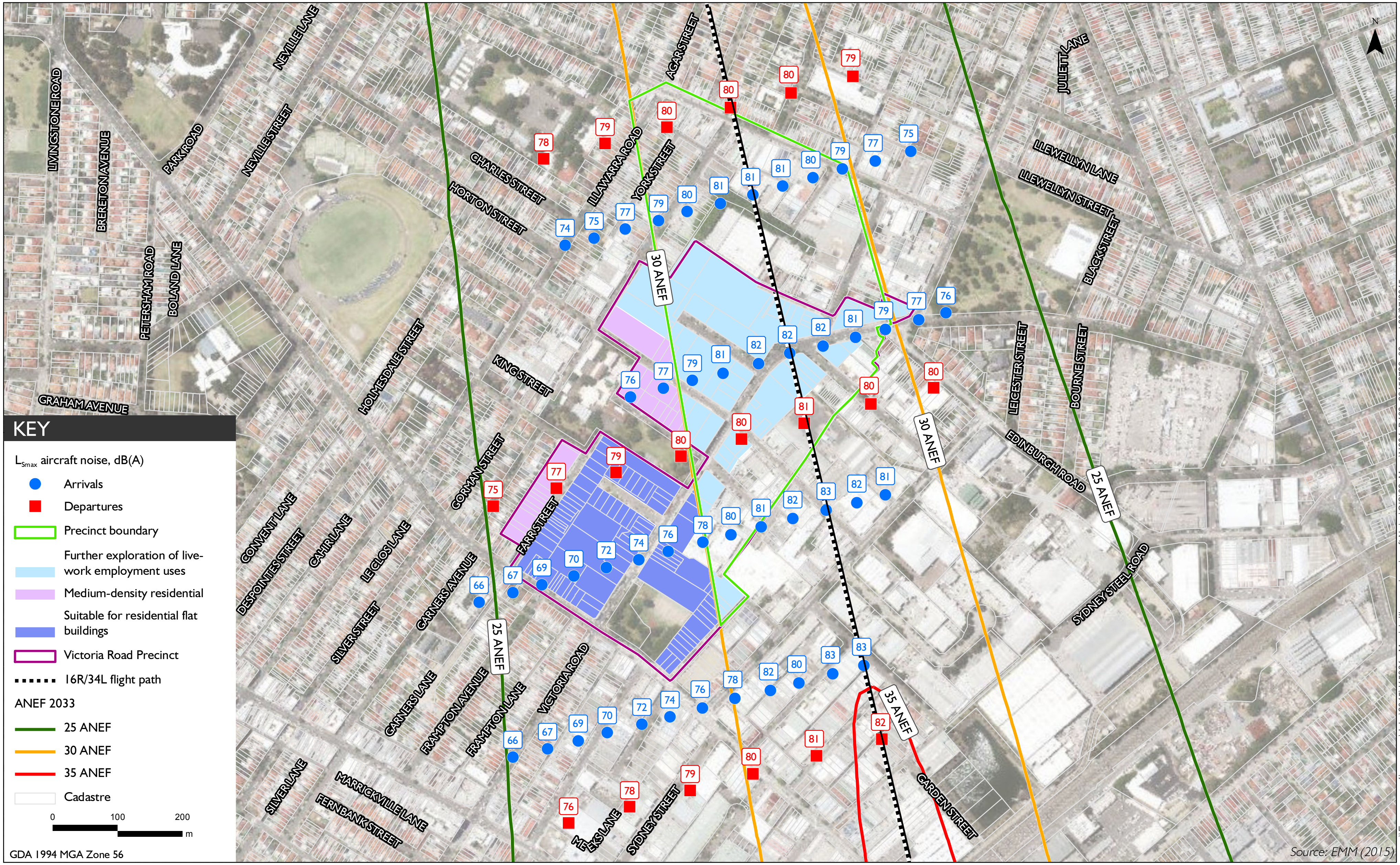


AS2021 L_{Smax} noise levels - B747-400 (arrivals and LR departures)

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 3.2



AS2021 L_{Smax} noise levels - BA146 (arrivals and departures)

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 3.3

4 Aircraft noise reduction (ANR) requirements for site

AS2021 provides the methodology adopted for calculating the aircraft noise reduction (ANR) values for building elements potentially constructed at the site.

The spectral component of aircraft noise is important in the determination of ANR for each building element, particularly when an ANR of 30 or more is required. We have adopted spectral data from EMM's database of attended noise measurements of B747-400 aircraft for reference in the calculations that follow.

The overall ANR of a building is simply the external aircraft noise level (eg 90 dB(A) in this case) less the AS 2021 internal noise goal (eg 50 dB(A) for sleep areas and dedicated lounges). A maximum ANR of 40 dB(A) is applicable to the subject site.

The aircraft noise attenuation required of each component is determined from the equation:

$ANA\mathrm{c} = ANR + 10 \log10 [(S\mathrm{c}/S\mathrm{f})\ ´\ (3/h)\ ´\ 8TN] - K\mathrm{c}$

where:

Sc/Sf is the surface area ratio of the component (c) element to that of the floor (f)

h is the room height

T is the room's reverberation time

N is the number of components present in the external envelope of the room or space

Kc is the orientation effect (as defined in AS 2021)

5 Design measures and initiatives - a guideline

The following section provides a guideline to be used to define requirements and options for buildings exposed to aircraft noise. The fundamental principle is that almost any location exposed to aircraft noise can be made to achieve an internal noise amenity that satisfies AS2021 internal criteria irrespective of a building site's location with respect to an aerodrome's ANEF contours. For example, buildings in the acceptable (less than 20 ANEF) or conditionally acceptable (20 to 25 ANEF) zones according to AS 2021, are not necessarily free from the need to upgrade building elements. So too the subject site, being in the 25 to 30 ANEF zone, can be designed to ensure an internal environment equivalent to other aforementioned zones.

This guideline is analogous to the "Development near rail corridors and busy roads - Interim guideline", NSW Department of Planning, December 2008. The idea is to extend the methodology of this interim guideline to the other main mode of transport - flight.

5.1 Building design orientation and room layout

Objective:

To place less sensitive service areas on noise affected facades and hence providing greater opportunity to buffer more sensitive spaces.

This concept works well for road and rail traffic sources, and for the more enveloping type sound of aircraft noise environments requires additional thought. However, there will be some opportunity to achieve similar benefits since the east facing facade of proposed residential apartments will be relatively more exposed to aircraft noise (albeit marginally) than west facing facades. This will be particularly so for lower levels (eg ground and first floor) in an eight story block for example. The greater the number of stories above a particular apartment the greater the benefits achieved through the building itself acting as a barrier to aircraft noise for west facing facades. Hence, bedrooms and lounges would benefit if orientated on western facades of proposed buildings.

Furthermore, the aforementioned ANAc formulae includes an orientation effect factor, Kc as defined in AS 2021. Kc of a building component represents the attenuation of aircraft noise reaching the component due to its orientation with respect to the aircraft. This parameter varies from 0 dB for components directly facing the aircraft to approximately 8 dB for components which are well shielded.

5.2 Building treatments

Objective:

Ensure building fabric is of a material that will appropriately insulate against aircraft noise.

Table 5.1 lists construction acoustic performance ratings (or weighted sound reduction index, Rw) for building elements. These are minimum requirements and were derived for low density type dwellings and corresponding room, facade and window dimensions. They provide a basis starting point for the possible developments at the subject site. The options are divided into five categories of acoustic performance, with category 1 being the least onerous and category 5 the most onerous. The calculations provided later are for specific dimensions suited to possible development at the subject site as shown.

Table 5.1 Acoustic performance of building elements

Category of Noise control treatment	Rw of building elements (minimum assumed)				
	Windows/Sliding Doors	Facade	Roof	External Door	Floor
Category 1	24	38	40	28	29
Category 2	27	45	43	30	29
Category 3	32	52	48	33	50
Category 4	35	55	52	33	50
Category 5	43 to 47	55	55	40	50

Notes: 1. Floor Rw only apply to ground floor.

Source: "Development near rail corridors and busy roads - Interim guideline", NSW Department of Planning, December 2008.

The five categories can be characterised in general terms with respect to an everyday familiar situation (eg house 10m from a 60/70km/h street) as follows:

- Category 1 - road with a daily average traffic volume of 800-2,500 vehicles, typically a minor collector road serving less than 100 houses with no through traffic (this is a relatively standard light weight clad dwelling construction with standard glazing);
- Category 2 - road with a daily average traffic volume of 2,500-7,500 vehicles, typically a collector/distributor road serving 200 to 250 dwellings with some through traffic, eg Victoria Road Bellevue Hill;
- Category 3 - road with a daily average traffic volume of 7,500-18,000 vehicles, eg King Street Newtown (this dwelling is 'middle' of the categories having brick veneer facades, laminated glazing and roof insulation);
- Category 4 - road with a daily average traffic volume of 18,000-30,000 vehicles, eg Beecroft Road Cheltenham; and
- Category 5 - road with a daily average traffic volume of 30,000-60,000 vehicles, eg Princess Highway Tempe (this is a well constructed double masonry dwelling with double glazing, acoustic seals, double ceiling lining and insulation).

Source: Volume ranges adopted from "Development near rail corridors and busy roads - Interim guideline", NSW Department of Planning, December 2008.

The following sections provide five categories of building element options consistent with the Interim guideline (Department of Planning, 2008). The three main elements (windows, facade and roof) are provided only as these constitute the most relevant for the proposal (eg medium to high density apartment type buildings). Note that doors in apartments would typically lead to balconies and are therefore categorised with 'windows/sliding doors'.

5.2.1 Windows/Sliding doors

Table 5.2 provides construction examples for windows and sliding doors to achieve desired minimum Rw values as shown. It should be noted that these are minimum values and that other construction options may exist that achieve the same or higher ratings.

Table 5.2 Windows/Sliding doors

Category	Min Rw	Construction
1	24	Openable with minimum 4mm monolithic glass and standard weather seals
2	27	Openable with minimum 6mm monolithic glass and full perimeter acoustic seals
3	32	Openable with minimum 6.38mm laminated glass and full perimeter acoustic seals
4	35	Openable with minimum 10.38mm laminated glass and full perimeter acoustic seals
5	43	Openable Double Glazing with separate panes: 5mm monolithic glass, 100mm air gap, 5mm monolithic glass with full perimeter acoustic seals.
	46	Openable Double Glazing with separate panes: 6mm monolithic glass, 100mm air gap, 4mm monolithic glass with full perimeter acoustic seals.
	47	Openable Double Glazing with separate panes: 6mm monolithic glass, 150mm air gap, 4mm monolithic glass with full perimeter acoustic seals.

Source: 1. "Development near rail corridors and busy roads - Interim guideline", NSW Department of Planning, December 2008, and EMM database.

5.2.2 Facade

Table 5.3 provides construction examples for facades to achieve desired minimum Rw values as shown. It should be noted that these are minimum values and that other construction options may exist that achieve the same or higher ratings. For example, brick veneer is found in many of the categories listed.

Table 5.3 Facade

Category	Min Rw	Construction
1	38	**Timber Frame or Cladding:** 6mm fibre cement sheeting or weatherboards or plank cladding externally, 90mm deep timber stud or 92mm metal stud, 13mm standard plasterboard internally.
		Brick Veneer: 110mm brick, 90mm timber stud or 92mm metal stud, minimum 50mm clearance between masonry and stud frame, 10mm standard plasterboard internally.
		Double Brick Cavity: 2 leaves of 110mm brickwork separated by 50mm gap.
2	45	**Timber Frame or Cladding:** 6mm fibre cement sheeting or weatherboards or plank cladding externally, 90mm deep timber stud or 92mm metal stud, 13mm standard plasterboard internally with R2 insulation in wall cavity.
		Brick Veneer: 110mm brick, 90mm timber stud frame or 92mm metal stud, minimum 50mm clearance between masonry and stud frame, 10mm standard plasterboard internally.
		Double Brick Cavity: 2 leaves of 110mm brickwork separated by 50mm gap.
3	52	**Brick Veneer:** 110mm brick, 90mm timber stud or 92mm metal stud, minimum 50mm clearance between masonry and stud frame, 10mm standard plasterboard internally.
		Double Brick Cavity: 2 leaves of 110mm brickwork separated by 50mm gap.

Table 5.3 Facade

Category	Min Rw	Construction
4	55	**Brick Veneer:** 110mm brick, 90mm timber stud or 92mm metal stud, minimum 50mm clearance between masonry and stud frame, R2 insulation batts in wall cavity, 10mm standard plasterboard internally.
		Double Brick Cavity: 2 leaves of 110mm brickwork separated by 50mm gap with cement render to the external face of the wall and cement render or 13mm plasterboard direct fixed to internal faces of the wall.
5	55	**Double Brick Cavity:** 2 leaves of 110mm brickwork separated by 50mm gap with cement render to the external face of the wall and cement render or 13mm plasterboard direct fixed to internal faces of the wall.

Source: 1. "Development near rail corridors and busy roads - Interim guideline", NSW Department of Planning, December 2008.

5.2.3 Roof/ceiling

Table 5.4 provides construction examples for roof/ceilings to achieve desired minimum Rw values as shown. It should be noted that these are minimum values and that other construction options may exist that achieve the same or higher ratings.

Table 5.4 Roof

Category	Min Rw	Construction
1	40	Pitched concrete or terracotta tile or metal sheet roof with sarking, 10mm plasterboard ceiling fixed to ceiling joists, R1.5 insulation batts in roof cavity.
2	43	Pitched concrete or terracotta tile or metal sheet roof with sarking, 10mm plasterboard ceiling fixed to ceiling joists, R2 insulation batts in roof cavity.
		Low slope metal roof, timber or steel purlins, furring channels, 2 x 16mm Gyprock Fyrchek plasterboard, R2.5 insulation batts in roof cavity.
3	48	Pitched concrete or terracotta tile or sheet metal roof with sarking, 1 layer of 13mm sound-rated plasterboard fixed to ceiling joists, R2 insulation batts in roof cavity.
4	52	Pitched concrete or terracotta tile or sheet metal roof with sarking, 2 layers of 10mm sound-rated plasterboard fixed to ceiling joists, R2 insulation batts in roof cavity.
5	55	Pitched concrete or terracotta tile or sheet metal roof with sarking, 2 layers of 10mm sound-rated plasterboard fixed to ceiling joist using resilient mounts, R2 insulation batts in roof cavity

Source: 1. "Development near rail corridors and busy roads - Interim guideline", NSW Department of Planning, December 2008 OR 'The red Book' CSR 2004.

5.2.4 Top floor alternative uses

The top floor of residential buildings is the most susceptible to aircraft noise as it includes another major element that requires acoustic treatment (the ceiling/roof system) which also adds to the performance requirements of other elements. For this reason, and depending on the performance needs, it may be more practical to avoid residential occupancies on top floor apartments.

In lieu of a residence on the top floor, the space can be considered for recreational, commercial or retail use, providing a buffer to residences below from aircraft noise.

5.3 Podiums, balconies and courtyards

Objective:

To provide useable outdoor spaces with some level of noise amenity and to use these areas as additional buffers to more sensitive spaces.

A prime example of this is balconies that are fully glazed using operable windows or louvers. With such glazing closed, this provides a buffer to aircraft noise such that lounges serviced by such balconies can have acoustic performance needs of their glazing elements relaxed.

5.4 Worked example (mock up floor plan and design)

An example apartment layout was provided and assessed to provide a typical solution. The floor plan provided for this example is shown in Figure 5.1 and Figure 5.2. It is important to note that a combination of building materials and treatments could be used to achieve internal noise criteria and therefore there is no 'one size fits all' solution. Note that calculations herein are only indicative and used to demonstrate that solutions are feasible, and detailed design must be completed for future development applications for example.

As described earlier, the maximum external noise level for the site is 90 dB(A) based on the current noisiest aircraft (B747-400), requiring an ANR 40 or ANR 30 for sleeping (and dedicated lounges) or other habitable spaces to satisfy AS2021 internal targets of 50 dB(A) and 60 dB(A) respectively.

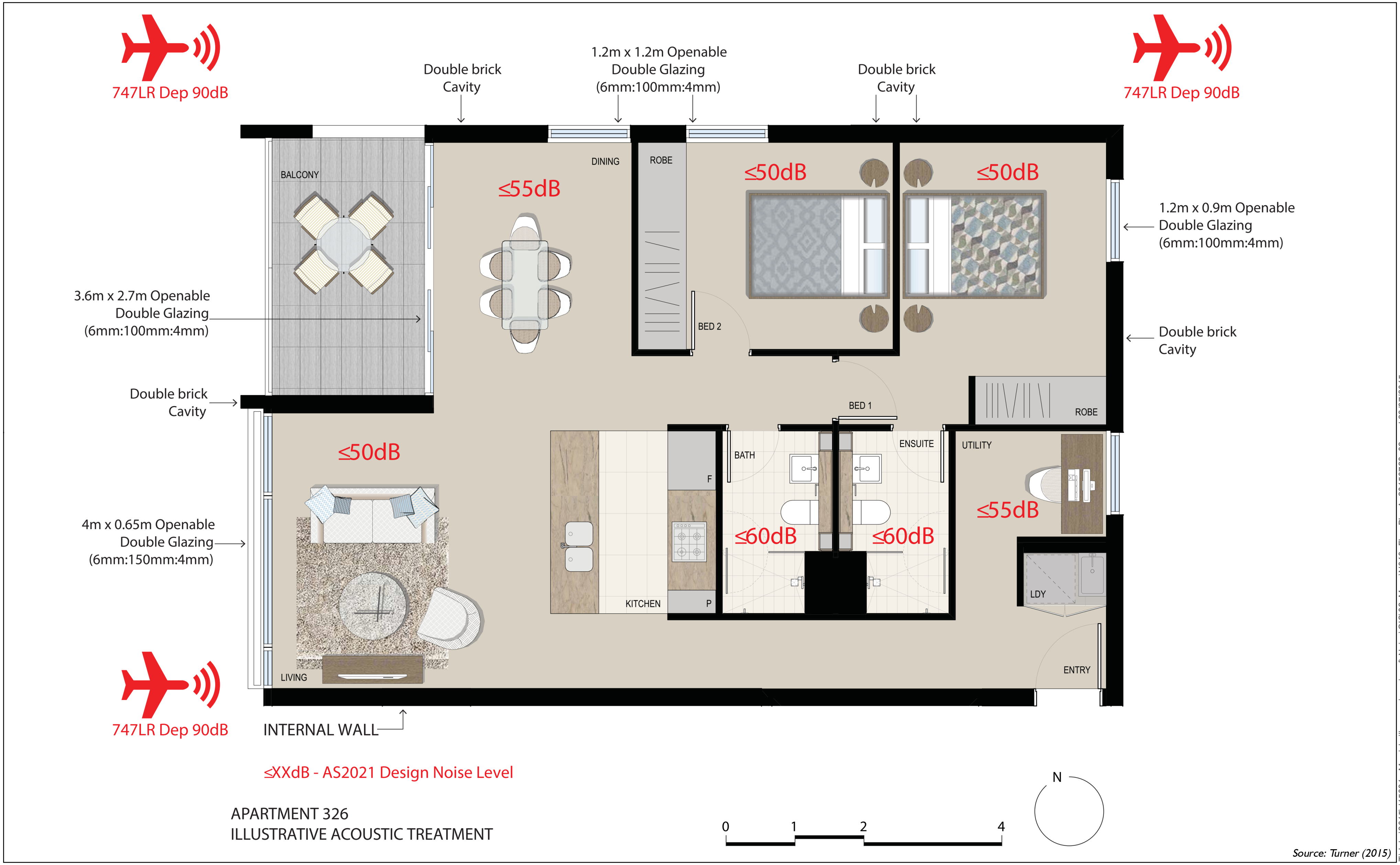
Table 5.5 provides a worked example showing:

- A typical room type and dimension (bedroom and living room);
- A top level and mid level apartment to show effects of the roof;
- Three glazing size options for each to demonstrate the quantity of glazing possible in square meters; and
- The categories (as per Table 5.1) for each of the three main building elements that are needed to achieve AS 2021 internal design noise targets.

It should be noted that lower categories can be adopted for glazing if the area of glass is reduced. In practice this may not be desirable or possible due to other limitations (eg natural light design criteria). Hence, it is most probable that glazing category five is unavoidable (ie double glazing) to achieve the desired balance of glazing area to facade area. The required adopted roof/ceiling (Category 5) is also unlikely to be avoidable as this element is the largest by area.

Table 5.5 Worked example for 90 dB L_{ASmax} external aircraft noise level

Room type (internal goal, dB)	Unit level	Category			Dimensions of wall, m		Total Wall surface area (m^2)	Total allowable glazing (m^2)
Overall dimensions		**Wall**	**Ceiling**	**Window (Cat5)**	**W**	**H**		**Glazing**
Refer Figure 5.1								
Bedroom 2: 3.1m(w)x3.7m(l)	Top level	5	5	6mm x 100mm x 4mm	3.1	2.7	8.37	4
(50)	Mid-level	5	n/a	6mm x 100mm x 4mm	3.1	2.7	8.37	6.9
Bedroom 1: 3.1m(w)x3.7m(l)	Top level	5	5	6mm x 100mm x 4mm	6.8 (3.7x2.7 and 3.1x2.7)	2.7	18.36	1.1
(50)	Mid-level	5	n/a	6mm x 100mm x 4mm	6.8 (3.7x2.7 and 3.1x2.7)	2.7	18.36	3.1
Dedicated lounge (Living): 2.2m(w)x4m(l)	Top level	5	5	6mm x 150mm x 4mm	6.2 (2.2x2.7 and 4x2.7)	2.7	16.74	2.6
(50)	Mid-level	5	n/a	6mm x 150mm x 4mm	6.2 (2.2x2.7 and 4x2.7)	2.7	16.74	4.9
Other habitable room (Dining): 4m(l)x3m(w)	Top level	5	5	6mm x 100mm x 4mm	7 (3x2.7 and 4x2.7)	2.7	18.9	Full glazing
(55)	Mid-level	5	n/a	6mm x 100mm x 4mm	7 (3x2.7 and 4x2.7)	2.7	18.9	Full glazing
Refer to Figure 5.2								
Bedroom: 3.1m(w)x3.7m(l)	Top level	5	5	6mm x 150mm x 4mm	6.8 (3.7x2.7 and 3.1x2.7)	2.7	18.36	1.5
(50)	Mid-level	5	n/a	6mm x 150mm x 4mm	6.8 (3.7x2.7 and 3.1x2.7)	2.7	18.36	4.5



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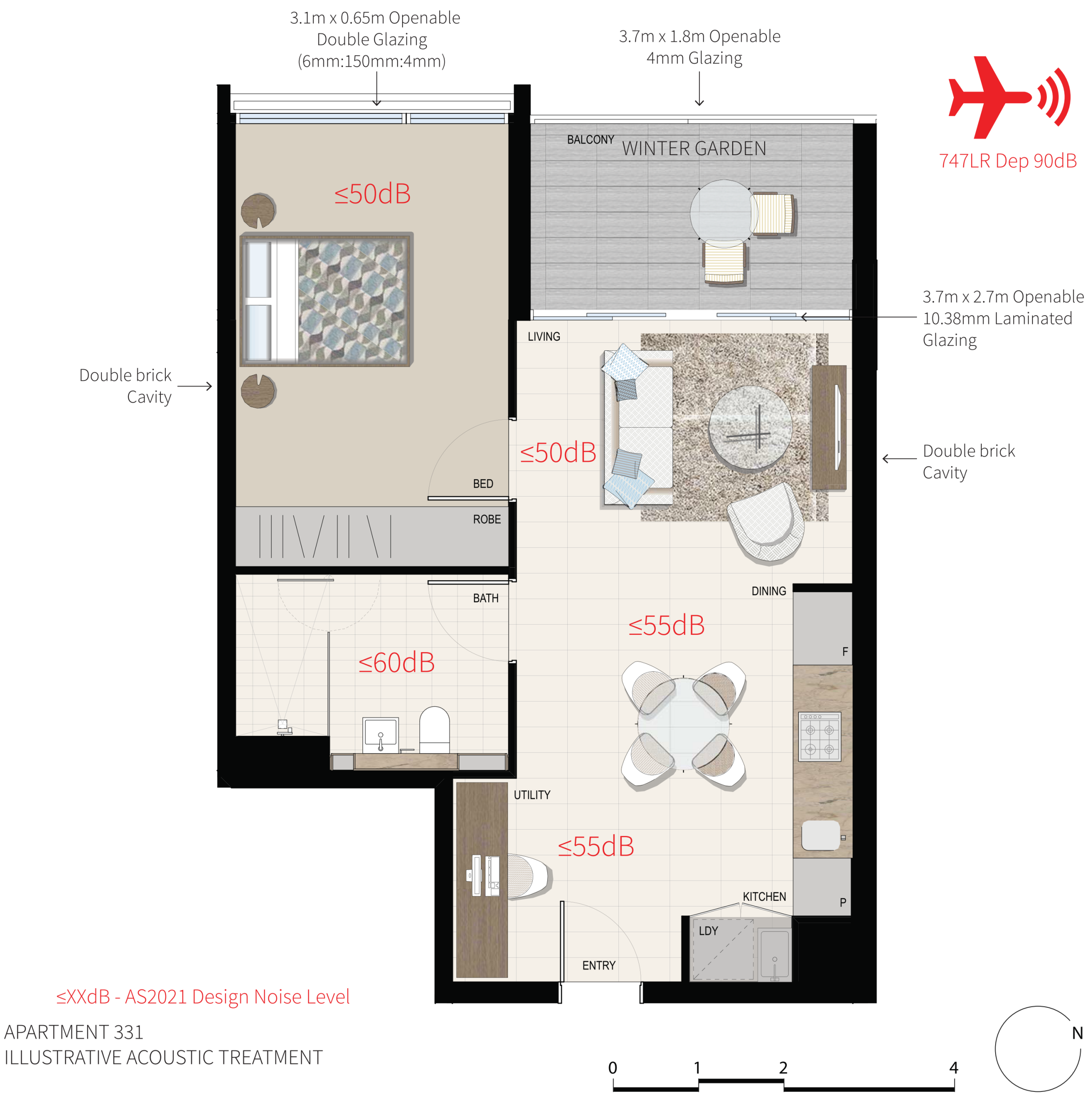
Indicative floor plan A

Victoria Road, Marrickville
Design initiatives for aircraft noise

Figure 5.1



Source: Turner (2015)

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Indicative floor plan B

Victoria Road, Marrickville

Design initiatives for aircraft noise

Figure 5.2

6 Conclusion

EMM has completed an aircraft noise study of the Victoria Road, Marrickville site, to determine its suitability to accommodate residential land use. The study adopted the noise data contained in AS 2021, used to produce grid points across or in the vicinity of the site and assigned a representative aircraft noise level to each. A worst case 90 dB L_{ASmax} noise level was established for the most exposed part of the site, based on the relatively noisier but very infrequent B747-400 aircraft long range departure events (representing approximately 1.5% to 2% of movements on average, and likely reducing in the future). From this, performance requirements for facade, roof/ceiling and glazing were developed to ensure AS 2021 internal design goals are achieved. Numerous construction options are provided to satisfy minimum building element sound ratings (Rw), however, internal noise criteria can be achieved using multiple design scenarios. The principles in the NSW government's guideline for residences near busy roads or rail corridors were used as a basis for and extended to develop the same for the third mode of transport - flight.

Design guidelines and their objectives are provided to contribute to the overall aircraft noise strategy to accompany the proposal.

The findings demonstrate that current building materials can be reasonably applied to achieve internal noise goals set by AS 2021 such that the occupant's amenity is not compromised. This shows that although the subject site is in an ANEF zone which is susceptible to higher levels of aircraft noise, buildings can be designed to ensure internal levels are insulated appropriately. The noise result internally for potential residences at the subject site, which is located in 25 to 30 ANEF zone, could be the same as that for a site in a 20 to 25 ANEF. The difference being the building fabric requirements.

In summary, the proposed high and medium residential developments can be supported in terms of residential amenity provided the accompanying design guidelines, and their objectives, are achieved.

Appendix A

ASA Data - Sydney Airport N489 Australian Noise Exposure Index 1 July to 30 September 2014

Sydney Airport

N489 Australian Noise Exposure Index

1 July to 30 September 2014

December 2014

DISCLAIMER

The aircraft noise contours on this chart have been calculated using the best currently available modelling process. The data input to that process are derived from external sources, and Airservices cannot warrant their accuracy. Airservices accepts no liabilities for any reliance placed on any data on this chart by any third party. Airservices accepts no responsibility for any interpretation of this data by third parties.

CONDITIONS OF SUPPLY OF REPORT N489, Dated December 2014

Airservices Australia

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Contents

List of Tables

List of Figures

Sydney Airport
N489 Australian Noise Exposure Index
1 July 2014 to 30 September 2014

1. Introduction

1.1 Background

In accordance with recommendation 21 of the Proponent's Statement for the Long Term Operating Plan (LTOP) at Sydney Airport, Airservices has prepared an Australian Noise Exposure Index (ANEI) for the period 1 July 2014 to 30 September 2014 inclusive (Reference Number N489).

1.2 Airport Layout

Sydney Airport has three runways. Runway 07/25 (2529m long and 45m wide), Runway 16R/34L (3962m long and 45m wide) and Runway 16L/34R (2438m long and 45m wide). The runway end coordinates and elevations, Aerodrome Reference Point coordinates, elevation data and displaced threshold information for Sydney Airport were obtained from airport data held by Airservices and are shown in Table 1.1.

Table 1.1 Sydney Airport Runway Data

Location	Latitude (WGS84)	Longitude (WGS84)	Elevation AHD (m)	Displaced Landing Threshold (m)
Aerodrome Reference Point	33 56 45.6S	151 10 37.6E	6.4	
Runway End 07	33 56 37.5S	151 09 49.1E	5.3	0m
Runway End 25	33 56 15.1S	151 11 23.8E	6.0	340m
Runway End 16R	33 55 45.7S	151 10 17.8E	2.1	85m
Runway End 34L	33 57 51.4S	151 10 50.4E	4.1	0m
Runway End 16L	33 56 58.6S	151 11 17.9E	4.5	230m
Runway End 34R	33 58 19.0S	151 11 38.1E	3.1	38m
Helipad	33 56 20.4S	151 11 27.2E	6.0	

The airport average temperature and humidity were obtained from Bureau of Meteorology (BOM) data. The temperature and humidity shown in Table 1.2 are taken from the BOM data over the study period.

Table 1.2 Sydney Airport Meteorological Data

Airport Average Temperature	14.7°C
Airport Average Humidity	56.0%

2. The Integrated Noise Model (INM)

The Integrated Noise Model version 7.0d (INM 7.0d) developed by the US Federal Aviation Administration (FAA) as a means of evaluating the impact of aircraft noise was used to model the noise contours. Further information regarding INM can be found at:

http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/inm_model/

INM Version 7.0d is the most recent release of INM. It includes database updates and correction of minor software issues, but no new functionality added relative to INM Version 7.0c. Details of the database updates and changes can be found in the link above.

2.1 Development of INM Model

The flight tracks used in the model were determined from the NFPMS. Flight track plots from the NFPMS were used to identify the major flight paths associated with aircraft movements to and from the airport.

A nominal backbone track for all the major flight paths was identified by means of geographic coordinates along the length of the track and from NFPMS track plots. The corresponding spread for each track was also determined from the NFPMS plots. These tracks were entered into the INM as 'point type' tracks. Each 'nominal backbone track' was prepared with subsidiary tracks that provided a realistic lateral spread of traffic along the nominal tracks.

Including terrain information around the airport improves the accuracy of the contour and was taken into account. Terrain data for the Sydney region was compiled in accordance with the INM User's Guide into a format suitable to be read by INM. The terrain data was aligned to the Aerodrome Reference Point (ARP) and incorporated by INM when calculating the ANEI contours.

The use of terrain data changes the shape of the ANEI contours when compared to a flat ground model. Variances in ground elevation change the distance between the aircraft and the ground, hence the calculated aircraft noise levels at each grid point on the ground.

3. Methodology Used in the Development of the ANEI

3.1 Introduction

The ANEI contour is based on the data collected by Airservices Noise and Flight Path Monitoring System (NFPMS).

The development of the ANEI consisted of the following stages:

i) collection and verification of the required NFPMS data;

ii) preparation of the data as INM input files;

iii) running of the model; and,

iv) preparation and verification of model's output.

3.2 Collection and verification of the required NFPMS data

Aircraft movement data was obtained from Airservices NFPMS. The total number of movement records from the NFPMS data for the study period is shown in Table 3.1.

Table 3.1 NFPMS Aircraft Movements

Operation	Movements
Arrivals – Fixed Wing	40564
Departures – Fixed Wing	40556
Touch and Go - Fixed Wing	15
Arrivals – Helicopter	278
Departures – Helicopter	270
Touch and Go - Helicopter	885
Total	**83,468**

Note that the touch and go movements above have been doubled in the total movement count.

Other sources of data exist within Airservices, (Avcharges data for example) however NFPMS data has been used for this ANEI. NFPMS data at Sydney airport is groomed daily for a high level of data integrity.

There were 36 unknown aircraft movements within the study period. The NFPMS movement numbers were adjusted to account for these. This was achieved by increasing either the arrival or departure number to ensure arrivals equals departures by aircraft type. Touch and Go operations were split into arrivals and departures evenly.

3.3 Preparation of INM input file

The aircraft movement data extracted from the NFPMS were organised into:

- track flown;
- aircraft types and the associated operation (departure or arrival);
- the runway used; and,
- the time of day or night.

For the purposes of modelling and using the Australian Noise Exposure Forecast (ANEF) metric, night is considered to be between the hours of 7:00pm and 7:00am and carries a weighting of 4.

The types of aircraft that operated at Sydney Airport were assigned to 42 representative aircraft types that are contained within the INM database and are shown in Table 3.3. Where possible, the actual aircraft type was matched to its INM counterpart. However, in cases where a particular aircraft type had a small number of movements, it was grouped with a major INM type or INM substitute.

To allocate aircraft operations to flight tracks within the INM study, the geographical track location from the NFPMS was used.

In this study, helicopters were modelled using actual helicopter profiles within INM. Representative helicopter types from INM7.0d were used to assign helicopter movements where possible. Not all helicopter types that operated at Sydney Airport are available for use in INM7.0d. Where it was not possible to use actual helicopter types, representatives were used based on aircraft size. Helicopter types that were unknown were assigned to the representative helicopter type that contained the highest percentage of operations, namely the R44. All helicopters were modelled as arriving to or departing from the Helipad that is located south of the threshold of Runway 25.

Table 3.3 Aircraft Types Used by INM for ANEI N489

INM Type	Aircraft
737300	Boeing B737-300 aircraft
737400	Boeing B737-400 aircraft
737700	Boeing B737-700 aircraft
737800	Boeing B737-800 aircraft
747400	Represents B747-400 aircraft
7478	Represents B747-800 aircraft
757PW	Boeing B757-200 aircraft
757RR	Represents T204 (twin engine medium jet) aircraft
767300	Boeing B767-300 aircraft
777200	Boeing B777-200 aircraft, A359 - Airbus A350-900 aircraft
777300	Boeing B777-300 aircraft
7878R	Boeing B787-800 aircraft, B789 - Boeing B787-900 aircraft
A319-131	Airbus Industries A319 aircraft
A320-232	Airbus Industries A320 aircraft
A330-301	Airbus Industries A330 aircraft
A340-211	Airbus Industries A340-200 and A340-400 aircraft
A340-642	Airbus Industries A340-500 and 600 aircraft
A380-841	Airbus Industries A380 aircraft fitted with RR Trent engines
A380-861	Airbus Industries A380 aircraft fitted with Engine Alliance engines
BAE300	Represents BAe146 aircraft

BEC58P	Represents GA twin piston-engine aircraft
CL601	Represents Canadair CL601 Challenger aircraft
CNA208	Represents Pilatus PC-12 and other single engine turbo-prop aircraft
CNA441	Represents GA twin turbine-engine aircraft
DHC6	Represents Twin Otter and similar aircraft
DHC830	Represents Dash 8, FK50 type aircraft
EMB145	Represents Embraer 135 and 145 type aircraft
EMB170	Represents Embraer 170 type aircraft
EMB190	Represents Embraer 190 type aircraft
GASEPF	Represents GA single engine fixed pitch propeller aircraft
GASEPV	Represents GA single engine variable pitch propeller and/or turbine aircraft
F10062	Represents F100 and F70 aircraft
HS748A	Represent AT75 and ATR 72-212 A aircraft
LEAR35	Represents other small business type jet aircraft, including the G280 – Gulfstream G280 aircraft
MD11GE	Represents DC10 and MD11 type aircraft
SF340	Saab 340 aircraft
B206B3	Bell 206 helicopter aircraft
B407	Bell 407 helicopter
B430	Bell 430 helicopter
EC130	Eurocopter EC130 helicopter representing large-medium helicopter types
R22	Robinson R22 helicopter representing small helicopter types
R44	Robinson R44 helicopter, also representing unknown helicopter types

The average daily movements for each aircraft type by runway, time of day and type of operation are shown in Attachment A.

3.4 Running of the Model

The INM was run using standard noise profile data for each of the aircraft types. The parameters used for the ANEF metric were:

Day multiplier	1.0
Night multiplier	4.0

A derivation for the ANEF metric can be found in Australian Standard 2021:2000 *Acoustics, Aircraft Noise Intrusion – Building Siting and Construction.* In accordance with the standard, the evening multiplier is included as part of the night period (7:00pm to 7:00am) and is not modelled.

3.5 Preparation and verification of the model output

The ANEI contours produced by INM were plotted using a GIS software package onto a base map. The contours produced for the 1 Jul - 30 Sep 2014 ANEI (N489) are consistent with flight tracks and the aircraft operations for the period and the use of terrain data.

Table 3.4 shows the average daily aircraft movements for ANEI N489 is 2.2 movements higher than for the same period for the previous year.

Table 3.4 Comparison of Average Daily Movements

ANEI Study	Period	Average Daily Aircraft Movements
N484	1 Jul – 30 Sep 2013	**915.9**
N489	1 Jul – 30 Sep 2014	**918.1**

4. Comparison of the 2014 ANEI (N489) with the 2013 ANEI (N484)

The 1 July 2014 to 30 September 2014 ANEI (N489) contours for Sydney Airport are shown in Attachment D. For comparison purposes, the 1 July to 30 September 2013 ANEI (N484) for Sydney Airport has been included as Attachment E. Both contours were produced using INM 7.0d software.

4.1 Comparison of Movement Numbers

The changes evident in the contours for ANEI N489, when compared with the contours for ANEI N484, are consistent with the changes in aircraft types, movement numbers, runway usage, night movements and aircraft flight path use during the two periods.

Table 4.2 shows a comparison of average daily arrival and departure movements by runway for ANEI N489 and ANEI N484. Note that this comparison provides the basis for evaluation of the ANEI N489 contours. When INM disperses the movements assigned for each aircraft type from the nominated ‘nominal backbone track’ to its subsidiary tracks, there are sometimes slight differences between the reported number of arrivals and departures for that aircraft type, runway or INM study due to rounding.

Table 4.1 Comparison of Average Daily Runway Movement

Runway	ANEI N489 (1 July 2014 to 30 September 2014)			ANEI N484 (1 July 2013 to 30 September 2013)		
	Arrivals	Departures	Totals	Arrivals	Departures	Totals
07	5.4	0.0	5.4	3.7	0.2	3.9
16L	79.8	89.5	169.3	39.2	49.4	88.6
16R	117.6	145.4	263.0	50.3	76.8	127.1
25	23.4	14.4	37.8	22.0	21.5	43.5
34L	145.3	94.4	239.7	214.4	148.2	362.7
34R	74.7	102.4	177.0	115.8	149.2	265.1
Helipad	12.9	12.9	25.8	12.5	12.5	25.0
Total	**459.0**	**459.0**	**918.1**	**458.0**	**458.0**	**915.9**

Table 4.2 Difference of Average Daily Runway Movement

	Difference N489 - N484		
Runway	**Arrivals**	**Departures**	**Totals**
7	1.7	-0.2	1.5
16L	40.6	40.1	80.7
16R	67.3	68.6	135.9
25	1.4	-7.1	-5.7
34L	-69.1	-53.8	-123.0
34R	-41.1	-46.8	-88.1
Helipad	0.4	0.4	0.8
Total	1.0	1.0	2.2

Long-haul jet aircraft departing from Runway 34L for destinations in the USA were allocated to a backbone track based on their actual departure track. Table 4.3 shows a comparison of departures that maintained runway heading and those that tracked via the Richmond Two SID and South West Jet SID.

Table 4.3 Comparison of Average Daily Long Haul Departures from Runway 34L

Runway 34L US Departures	ANEI N489 (1 July 2014 to 30 September 2014)		ANEI N484 (1 July 2013 to 30 September 2013)	
	Movements	% of USA Departures	Movements	% of USA Departures
Maintain Runway Heading	2.6	64.1%	3.7	55%
RICHMOND TWO SID / Rwy 34L SOUTH WEST SID	1.5	35.9%	3.1	45%
Total	**4.1**		**6.8**	

4.2 Comparison of Runway Use

Table 4.4 shows a comparison of runway usage in the 1 July 2014 to 30 September 2014 ANEI (N489) to the 1 July 2013 to 30 September 2013 ANEI (N484).

Table 4.4 Runway Use Comparison

Runway	ANEI N489		ANEI N484	
	1 July 2014 to 30 September 2014		1 July 2013 to 30 September 2013	
	N489 Arrivals %	N489 Departures %	N484 Arrivals %	N484 Departures %
07	0.6	0.0	0.4	0.0
16L	8.7	9.7	4.3	5.4
16R	12.8	15.8	5.5	8.4
25	2.5	1.6	2.4	2.4
34L	15.8	10.3	23.4	16.2
34R	8.1	11.1	12.6	16.3
Helipad	1.4	1.4	1.4	1.4

Note: Numbers represent percentage of total movements for the respective period of the ANEI and have been rounded to one decimal place.

Figures 4.1a and 4.1b depict this comparison for arrivals and departures respectively.

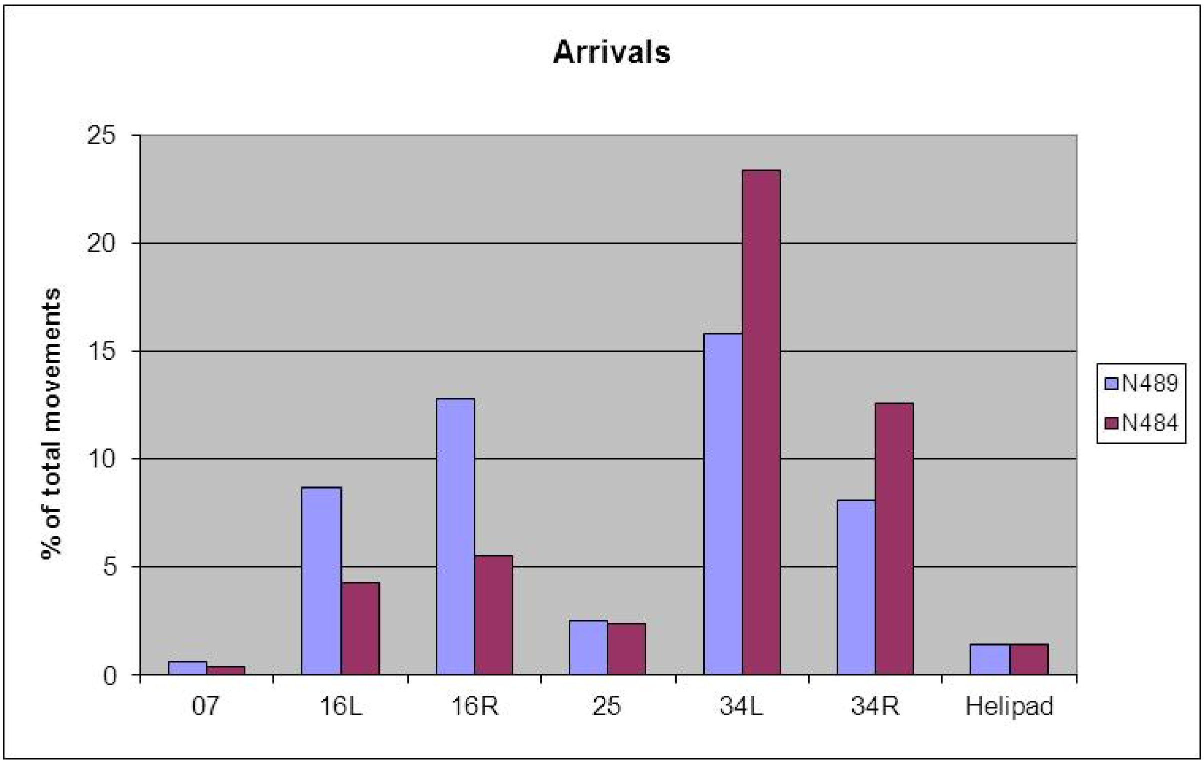


Figure 4.1a Runway Use Comparison – Arrivals

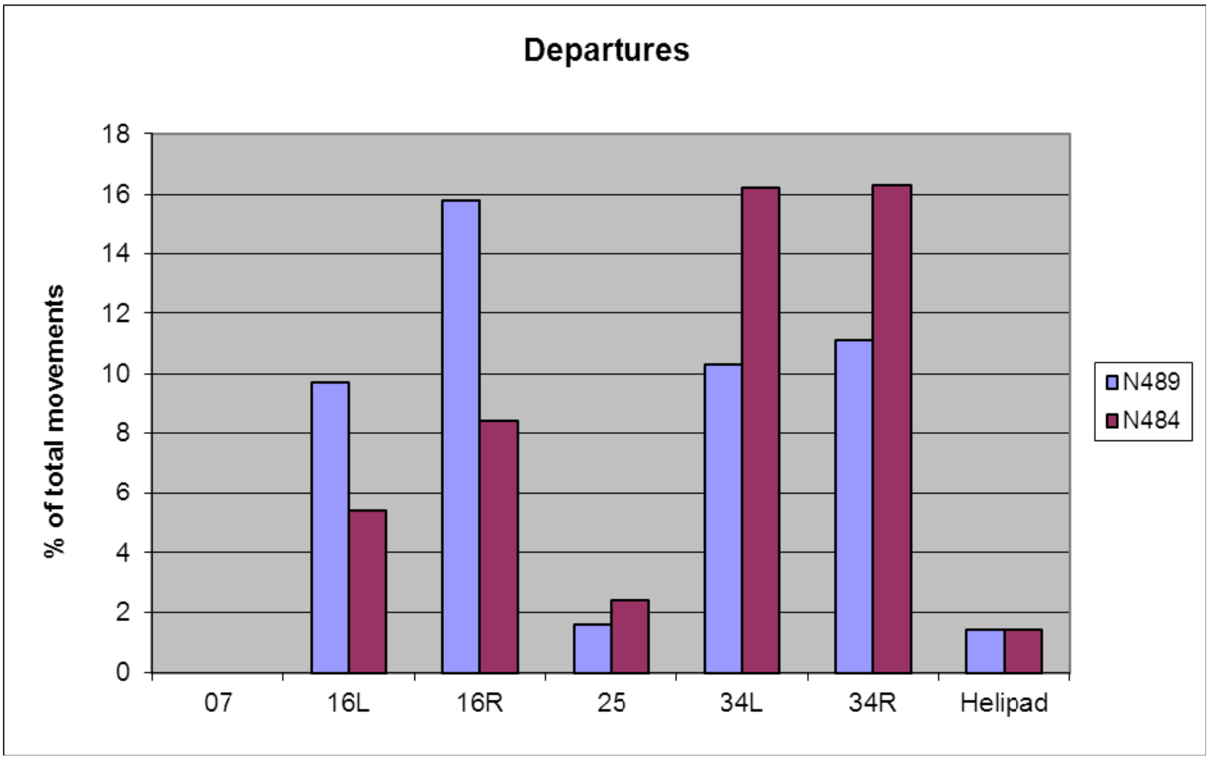


Figure 4.1b Runway Use Comparison - Departures

Table 4.5 details the proportion of aircraft movements to the north, south, east and west of Sydney Airport for ANEI N489 compared with ANEI N484. In calculating the proportion of aircraft movements, helicopter operations were not included. Further information regarding runway end usage should be obtained from the Sydney Operational Statistics Report, http://www.airservicesaustralia.com/publications/reports-and-statistics/sydney-airport-operational-statistics.

Table 4.5 Runway End Impact Comparison

Direction	Operation		ANEI N489	ANEI N484
	Arrival Runway	Departure Runway	%	%
North	16L and 16R	34L	31.8	26.0
South	34L and 34R	16L and 16R	49.5	49.8
East	25	07 and 34R	13.7	18.7
West	07	25	2.2	2.8

4.3 Comparison of Population Counts

To estimate the population beneath the current ANEI contours, the latest available Census 2011 Mesh Block data and Suburb Boundary information has been used. Mesh Blocks are the smallest geographic region in the Australian Statistical Geography Standard (ASGS), and the smallest geographical unit for which Census data are available. Details of Mesh Block data can be found here:

http://www.abs.gov.au/websitedbs/censushome.nsf/home/meshblockcounts

Previous contour population counts were generated using 2006 Census District information. These included much larger blocks which required some editing of CD boundaries and populations to accurately reflect population distribution in critical areas (close to the airport or flight paths). This editing was not required for the current count due to the improved accuracy of the much smaller Mesh Block data.

The section below compares total population within ANEI contours for the Q3 2014 (N489), Q3 2013 (N484) and the previous annual contour for 2013 (N486).

Table 4.6 Comparison of Total Population Estimates within each ANEI Contour

ANEI	Period	>=20	>=25	>=30	>=35	>=40
N484	1 July 2013 to 30 September 2013	101100	22100	1900	50	0
N486	1 January 2013 to 31 December 2013	100850	21500	2650	150	0
N489	1 July 2014 to 30 September 2014	**101650**	**19450**	**2850**	**150**	**0**

Notes:

- 2011 Mesh Block information and has been rounded to the nearest 50. The size of a Mesh Block is much smaller than the size of a suburb.

A more detailed listing of the number of people within the current ANEI contour is shown by suburb in Attachment B. The Census Mesh Block data captured indicates suburb information. In the latest Census data, various suburbs have been grouped together. This grouping can be seen within the tables of Attachment B.

5. Number of Aircraft Noise Events Above 70dB(A) Noise Map

5.1 Introduction

'Number Above' (Nxx) noise maps are an approach which provides additional information on aircraft noise in a form that is more easily understood by the community. The contours provide a visual depiction that shows the number of noise events during a given period that are louder than a selected threshold level. The N70 Aircraft Noise Map for Sydney Airport shows for all areas around the airport how many aircraft noise events louder than 70 dB(A) there were, on a daily average, during the period from 1 July 2014 to 30 September 2014.

70 dB(A) is generally considered to be the external sound level below which no difficulty with reliable communication from radio, television or conversational speech in a typical room with windows open is expected. (Reference - Department of Transport and Regional Services, 2000, *Expanding Ways to Describe and Assess Aircraft Noise,* pp23-35).

5.2 Methodology used in the Development of the N70 Aircraft Noise Map

The N70 aircraft noise map was prepared using the same input files as those for the ANEI contours and was prepared by running the Time-Above (TA) metric, which is a standard metric within INM 7.0d, to produce a detailed grid output file. It is important to note that the TA metric, unlike the ANEF metric, does not use any night weighting in the calculations.

The detailed grid output file was then modified using propriety software and then imported into a GIS software package for plotting onto a base map.

5.3 Analysis of the N70 Aircraft Noise Map

The N70 map prepared for Sydney Airport is shown in Attachment F – Sydney Airport N489 N70 Aircraft Noise Map - 1 July 2014 to 30 September 2014.

The map output is consistent with the patterns that would be expected given the position of the flight paths and the number and types of aircraft using the flight paths modelled in the ANEI (N489).

The N70 aircraft noise map provides information on the total number of aircraft noise events that exceeded 70 dB(A) in a grid area that were likely to have interfered with conversation, sleeping and listening to the radio or television inside a house with the windows open. However, it is important to note the limitations with the N70 aircraft noise maps.

The INM does not provide users with a direct way of computing a 'Number Above' chart, unlike the ANEI and TA contours. It is only possible to derive 'Number Above' values on a rectangular grid, which is then processed for importing into the GIS software package. The accuracy of the N70 contours shown in Attachment F is therefore at best plus or minus 500 metres, the distance between grid points used by INM in the calculations. In addition, the superimposed contours may have incurred errors in the transformation from INM coordinates to the map coordinates that were used in the preparation of the N70 chart.

Attachment A

ANEI N489 Average Daily Aircraft Movements by Runway

Table A1 Average Daily Movements by Runway

Runway	Aircraft Type	Arrivals			Departure			Total
		Day	Night	Total	Day	Night	Total	
07	717200	0.03	0.00	0.03	0.00	0.00	0.00	0.03
07	737300	0.00	0.02	0.02	0.00	0.00	0.00	0.02
07	737700	0.03	0.00	0.03	0.00	0.00	0.00	0.03
07	737800	0.88	0.82	1.70	0.00	0.00	0.00	1.70
07	747400	0.00	0.02	0.02	0.00	0.00	0.00	0.02
07	767300	0.07	0.10	0.16	0.00	0.00	0.00	0.16
07	777200	0.03	0.00	0.03	0.00	0.00	0.00	0.03
07	777300	0.02	0.00	0.02	0.00	0.00	0.00	0.02
07	7878R	0.01	0.00	0.01	0.00	0.00	0.00	0.01
07	A320-232	0.71	0.75	1.46	0.01	0.00	0.01	1.47
07	A330-301	0.04	0.13	0.18	0.02	0.00	0.02	0.20
07	A380-861	0.00	0.01	0.01	0.00	0.00	0.00	0.01
07	BAE300	0.00	0.02	0.02	0.00	0.00	0.00	0.02
07	CL601	0.02	0.00	0.02	0.00	0.00	0.00	0.02
07	DHC6	0.24	0.31	0.55	0.00	0.00	0.00	0.55
07	DHC830	0.31	0.10	0.41	0.00	0.00	0.00	0.41
07	EMB145	0.01	0.00	0.01	0.00	0.00	0.00	0.01
07	EMB190	0.14	0.15	0.30	0.00	0.00	0.00	0.30
07	HS748A	0.09	0.01	0.10	0.00	0.00	0.00	0.10
07	LEAR35	0.09	0.03	0.12	0.00	0.00	0.00	0.12
07	SF340	0.14	0.00	0.14	0.00	0.00	0.00	0.14
07		**2.88**	**2.48**	**5.36**	**0.03**	**0.00**	**0.03**	**5.40**

Runway	Aircraft Type	Arrivals			Departure			Total
		Day	Night	Total	Day	Night	Total	
16L	717200	0.36	0.08	0.44	0.78	0.21	0.99	1.43
16L	737300	0.00	0.04	0.04	0.00	0.09	0.09	0.13
16L	737400	0.00	0.09	0.09	0.00	0.05	0.05	0.14
16L	737700	0.65	0.03	0.68	0.46	0.19	0.65	1.33
16L	737800	19.21	6.24	25.45	27.13	6.18	33.31	58.76
16L	747400				0.00	0.04	0.04	0.04
16L	757PW	0.03	0.04	0.08	0.13	0.07	0.20	0.27
16L	767300	2.12	0.35	2.47	2.66	1.31	3.97	6.44
16L	777200	0.01	0.00	0.01	0.01	0.00	0.01	0.02
16L	7878R	0.15	0.02	0.18	0.16	0.01	0.18	0.35
16L	A320-232	14.19	2.69	16.88	17.86	4.24	22.10	38.98
16L	A330-301	0.71	0.87	1.58	0.60	0.12	0.73	2.31
16L	BAE300	0.00	0.13	0.13	0.01	0.00	0.01	0.14
16L	BEC58P	0.02	0.01	0.03	0.02	0.01	0.03	0.07
16L	CL601	0.15	0.00	0.15	0.16	0.03	0.20	0.35
16L	CNA208	0.03	0.00	0.03	0.02	0.00	0.02	0.05
16L	CNA441	0.05	0.01	0.07	0.00	0.01	0.01	0.08
16L	DHC6	1.13	0.33	1.46	1.52	0.30	1.81	3.27
16L	DHC830	12.67	0.89	13.56	9.91	1.74	11.65	25.21
16L	EMB145	0.04	0.01	0.05	0.01	0.00	0.01	0.07
16L	EMB190	3.71	0.38	4.10	4.25	1.20	5.45	9.55
16L	F10062	0.01	0.00	0.01	0.01	0.00	0.01	0.02
16L	GASEPV	0.01	0.00	0.01	0.00	0.00	0.00	0.01
16L	HS748A	2.16	0.21	2.37	1.04	0.01	1.05	3.43
16L	LEAR35	0.59	0.12	0.71	0.64	0.13	0.77	1.48
16L	MD11GE	0.00	0.00	0.00	0.00	0.01	0.01	0.01
16L	SF340	8.20	0.98	9.18	5.26	0.89	6.15	15.33
16L		**66.24**	**13.54**	**79.78**	**72.67**	**16.83**	**89.50**	**169.28**

Runway	Aircraft Type	Arrivals			Departure			Total
		Day	Night	Total	Day	Night	Total	
16R	717200	2.16	0.32	2.48	1.79	0.47	2.26	4.75
16R	737300	0.00	0.31	0.31	0.00	0.70	0.70	1.01
16R	737400	0.00	0.04	0.04	0.00	0.21	0.21	0.25
16R	737700	0.75	0.07	0.81	1.08	0.05	1.13	1.94
16R	737800	24.08	6.66	30.74	25.13	6.52	31.65	62.38
16R	74720B	0.08	0.01	0.09	0.02	0.08	0.10	0.19
16R	747400	2.55	1.04	3.59	3.31	1.07	4.37	7.97
16R	7478	0.10	0.00	0.10	0.13	0.00	0.13	0.23
16R	757PW	0.05	0.14	0.20	0.01	0.27	0.29	0.48
16R	767300	5.10	1.34	6.44	4.59	2.20	6.79	13.23
16R	777200	2.62	1.13	3.75	4.65	0.21	4.86	8.60
16R	777300	2.27	0.80	3.08	2.67	1.25	3.92	7.00
16R	7878R	0.77	0.24	1.01	1.40	0.03	1.43	2.44
16R	A310-304	0.00	0.01	0.01	0.01	0.00	0.01	0.02
16R	A319-131	0.02	0.00	0.02	0.01	0.01	0.02	0.04
16R	A320-232	13.40	3.96	17.35	14.37	5.10	19.47	36.82
16R	A330-301	8.79	4.78	13.57	13.27	4.15	17.43	31.00
16R	A340-211	0.51	0.10	0.60	0.77	0.02	0.79	1.40
16R	A340-642	0.18	0.08	0.25	0.32	0.04	0.36	0.62
16R	A380-841	0.35	0.56	0.91	2.12	0.04	2.16	3.08
16R	A380-861	0.15	1.22	1.37	0.36	0.81	1.18	2.55
16R	BAE300	0.00	0.27	0.27	0.03	2.82	2.86	3.13
16R	CL601	0.26	0.02	0.29	0.24	0.02	0.26	0.55
16R	CNA208	0.01	0.00	0.01	0.02	0.00	0.02	0.03
16R	CNA441	0.01	0.00	0.01	0.04	0.01	0.05	0.07
16R	DHC6	1.42	0.90	2.32	2.20	1.23	3.43	5.75
16R	DHC830	7.78	0.81	8.59	11.49	1.56	13.05	21.65
16R	EMB145	0.04	0.00	0.04	0.07	0.02	0.09	0.13
16R	EMB190	2.30	0.68	2.98	2.35	0.52	2.87	5.85
16R	F10062	0.01	0.00	0.01	0.00	0.00	0.00	0.01
16R	GASEPV	0.00	0.00	0.00	0.01	0.00	0.01	0.01
16R	HS748A	2.90	0.58	3.48	4.13	1.05	5.19	8.67
16R	LEAR35	0.78	0.13	0.91	1.23	0.22	1.45	2.36
16R	MD11GE	0.96	0.13	1.09	0.87	0.34	1.21	2.30
16R	SF340	9.81	1.09	10.90	11.82	3.79	15.62	26.52
16R		**90.21**	**27.44**	**117.65**	**110.54**	**34.85**	**145.38**	**263.03**

Runway	Aircraft Type	Arrivals			Departure			Total
		Day	Night	Total	Day	Night	Total	
25	717200	0.25	0.02	0.27	0.13	0.05	0.19	0.46
25	737300	0.00	0.24	0.24	0.00	0.20	0.20	0.44
25	737400	0.00	0.05	0.05	0.00	0.04	0.04	0.10
25	737700	0.12	0.01	0.13	0.07	0.03	0.10	0.23
25	737800	4.32	3.22	7.54	2.87	1.18	4.04	11.58
25	747400	0.14	0.01	0.15	0.12	0.04	0.16	0.32
25	757PW	0.01	0.10	0.11	0.02	0.10	0.12	0.23
25	767300	0.69	0.44	1.13	0.59	0.49	1.09	2.22
25	777200	0.21	0.00	0.21	0.09	0.00	0.09	0.30
25	777300	0.08	0.01	0.09	0.11	0.01	0.12	0.21
25	7878R	0.09	0.00	0.09	0.09	0.00	0.09	0.18
25	A320-232	3.10	2.26	5.36	2.11	1.02	3.13	8.49
25	A330-301	0.57	0.57	1.14	0.51	0.09	0.59	1.74
25	A380-861	0.00	0.05	0.05	0.00	0.00	0.00	0.05
25	BAE300	0.00	0.14	0.14	0.00	0.00	0.00	0.14
25	BEC58P	0.00	0.0	0.00	0.01	0.00	0.01	0.01
25	CL601	0.03	0.02	0.05	0.04	0.00	0.04	0.10
25	DHC6	0.46	0.32	0.78	0.44	0.18	0.62	1.40
25	DHC830	2.09	0.41	2.49	1.34	0.09	1.43	3.92
25	EMB190	0.66	0.34	1.00	0.38	0.09	0.47	1.47
25	HS748A	0.53	0.04	0.57	0.36	0.10	0.46	1.03
25	LEAR35	0.11	0.08	0.19	0.11	0.09	0.20	0.38
25	MD11GE	0.15	0.00	0.15	0.05	0.01	0.07	0.22
25	SF340	1.34	0.07	1.41	1.02	0.12	1.14	2.55
25		**14.96**	**8.42**	**23.37**	**10.47**	**3.93**	**14.41**	**37.78**

Runway	Aircraft Type	Arrivals			Departure			Total
		Day	Night	Total	Day	Night	Total	
34L	717200	2.49	0.33	2.82	0.33	0.00	0.33	3.15
34L	737300	0.00	0.63	0.63	0.02	0.12	0.14	0.77
34L	737400	0.00	0.18	0.18	0.00	0.07	0.07	0.24
34L	737700	0.71	0.04	0.76	0.58	0.08	0.66	1.42
34L	737800	25.57	10.38	35.96	11.59	2.34	13.93	49.89
34L	74720B	0.02	0.00	0.02	0.00	0.01	0.01	0.03
34L	747400	3.38	1.45	4.84	3.08	0.95	4.02	8.86
34L	7478	0.20	0.00	0.20	0.16	0.00	0.16	0.36
34L	757PW	0.01	0.24	0.25	0.00	0.00	0.00	0.25
34L	767300	5.31	1.90	7.21	0.86	0.49	1.35	8.56
34L	777200	2.75	2.73	5.47	4.38	0.13	4.52	9.99
34L	777300	2.34	2.02	4.36	2.19	1.32	3.51	7.87
34L	7878R	1.01	0.65	1.66	1.23	0.01	1.24	2.90
34L	A319-131	0.01	0.00	0.01	0.00	0.00	0.00	0.01
34L	A320-232	14.12	6.43	20.55	5.62	2.54	8.15	28.70
34L	A330-301	10.64	7.23	17.87	12.51	3.92	16.43	34.30
34L	A340-211	1.01	0.20	1.21	1.02	0.00	1.02	2.23
34L	A340-642	0.15	0.20	0.35	0.22	0.02	0.24	0.59
34L	A380-841	0.48	2.47	2.96	1.69	0.01	1.70	4.66
34L	A380-861	0.15	1.44	1.59	0.66	1.20	1.86	3.45
34L	BAE300	0.01	2.20	2.21	0.02	0.01	0.03	2.24
34L	BEC58P	0.02	0.00	0.02	0.03	0.00	0.03	0.05
34L	CL601	0.27	0.07	0.34	0.12	0.01	0.13	0.47
34L	CNA208	0.02	0.00	0.02	0.04	0.00	0.04	0.07
34L	CNA441	0.01	0.02	0.03	0.00	0.01	0.01	0.04
34L	DHC6	1.33	1.92	3.25	2.32	0.21	2.53	5.78
34L	DHC830	8.47	1.29	9.76	10.03	1.38	11.42	21.18
34L	EMB145	0.04	0.01	0.05	0.03	0.02	0.05	0.11
34L	EMB190	2.69	0.64	3.33	0.67	0.10	0.77	4.10
34L	HS748A	2.88	0.70	3.58	3.73	0.69	4.42	8.00
34L	LEAR35	0.84	0.40	1.23	0.56	0.04	0.60	1.84
34L	MD11GE	0.58	0.20	0.78	0.55	0.19	0.74	1.52
34L	SF340	10.73	1.07	11.79	11.44	2.86	14.30	26.09
34L		**98.27**	**47.02**	**145.30**	**75.69**	**18.74**	**94.43**	**239.72**

Runway	Aircraft Type	Arrivals			Departure			Total
		Day	Night	Total	Day	Night	Total	
34R	717200	0.30	0.01	0.31	2.29	0.31	2.59	2.90
34R	737300	0.02	0.05	0.08	0.00	0.19	0.19	0.26
34R	737400	0.00	0.08	0.08	0.00	0.07	0.07	0.14
34R	737700	0.70	0.01	0.71	0.54	0.05	0.59	1.31
34R	737800	18.22	4.41	22.63	34.78	6.30	41.08	63.70
34R	757PW	0.02	0.07	0.09	0.01	0.11	0.12	0.21
34R	767300	2.47	0.25	2.73	5.56	1.38	6.94	9.67
34R	7878R	0.04	0.02	0.07	0.08	0.00	0.08	0.14
34R	A319-131	0.00	0.00	0.00	0.01	0.00	0.01	0.01
34R	A320-232	12.74	3.12	15.86	20.57	4.02	24.59	40.45
34R	A330-301	0.88	1.62	2.49	1.53	0.11	1.64	4.13
34R	BAE300	0.00	0.14	0.14	0.02	0.00	0.02	0.16
34R	BEC58P	0.03	0.01	0.04	0.02	0.00	0.02	0.07
34R	CL601	0.09	0.00	0.09	0.29	0.02	0.31	0.40
34R	CNA208	0.05	0.00	0.05	0.03	0.00	0.03	0.09
34R	CNA441	0.01	0.00	0.01	0.03	0.01	0.04	0.05
34R	DHC6	1.02	0.36	1.38	1.33	0.03	1.36	2.75
34R	DHC830	11.90	0.75	12.65	8.74	1.18	9.91	22.56
34R	EMB145	0.00	0.00	0.00	0.00	0.01	0.01	0.01
34R	EMB190	3.18	0.25	3.43	4.70	0.87	5.57	9.00
34R	F10062	0.01	0.00	0.01	0.01	0.01	0.02	0.03
34R	HS748A	1.81	0.22	2.03	1.01	0.01	1.02	3.05
34R	LEAR35	0.63	0.16	0.79	0.81	0.12	0.93	1.73
34R	SF340	8.53	0.46	8.99	4.63	0.57	5.20	14.19
34R		**62.66**	**12.00**	**74.66**	**86.99**	**15.37**	**102.36**	**177.02**
H	B206B3	1.60	0.00	1.60	1.60	0.00	1.60	3.21
H	B407	0.12	0.00	0.12	0.12	0.00	0.12	0.24
H	B430	0.07	0.00	0.07	0.07	0.00	0.07	0.13
H	EC130	2.77	0.10	2.87	2.77	0.10	2.87	5.74
H	R22	0.02	0.00	0.02	0.02	0.00	0.02	0.04
H	R44	8.19	0.04	8.23	8.18	0.05	8.23	16.46
H		**12.77**	**0.14**	**12.91**	**12.76**	**0.15**	**12.91**	**25.82**
Grand Total		**347.99**	**111.04**	**459.03**	**369.15**	**89.88**	**459.03**	**918.06**

<u>Note</u>

1. Movement numbers in the above table are daily, averaged over the quarter.

2. The above movement numbers have been rounded to two significant figures, as a result minor discrepancies may occur between totals and the sums of component items.

Attachment B

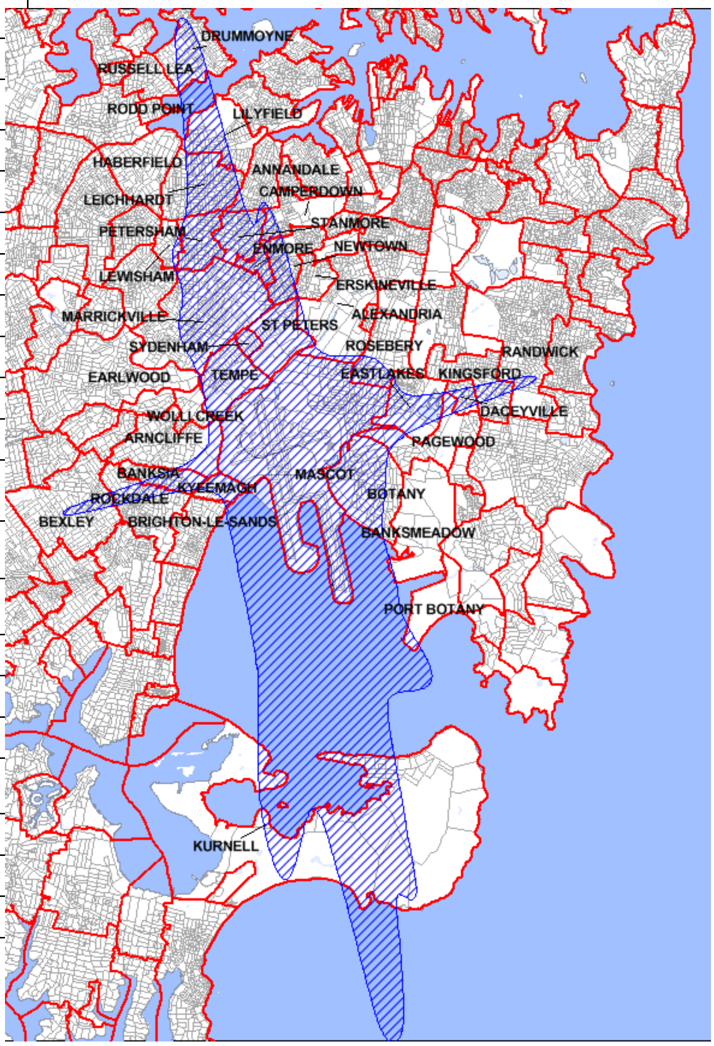
ANEI N489 Estimated Population within each ANEI Contour by Suburb

Table B1 Estimated Population within each ANEI Contour by Suburb

Suburb information is derived directly from the latest Census Mesh Block data. As a result certain suburbs have been grouped together. The Census data has not been altered. The above chart displays the Annual Contour for 2013 (N486) for display purposes. The table shows how the population within the current contour (N489) compares to the counts from the Annual Contour.

ANEI 20 Contour

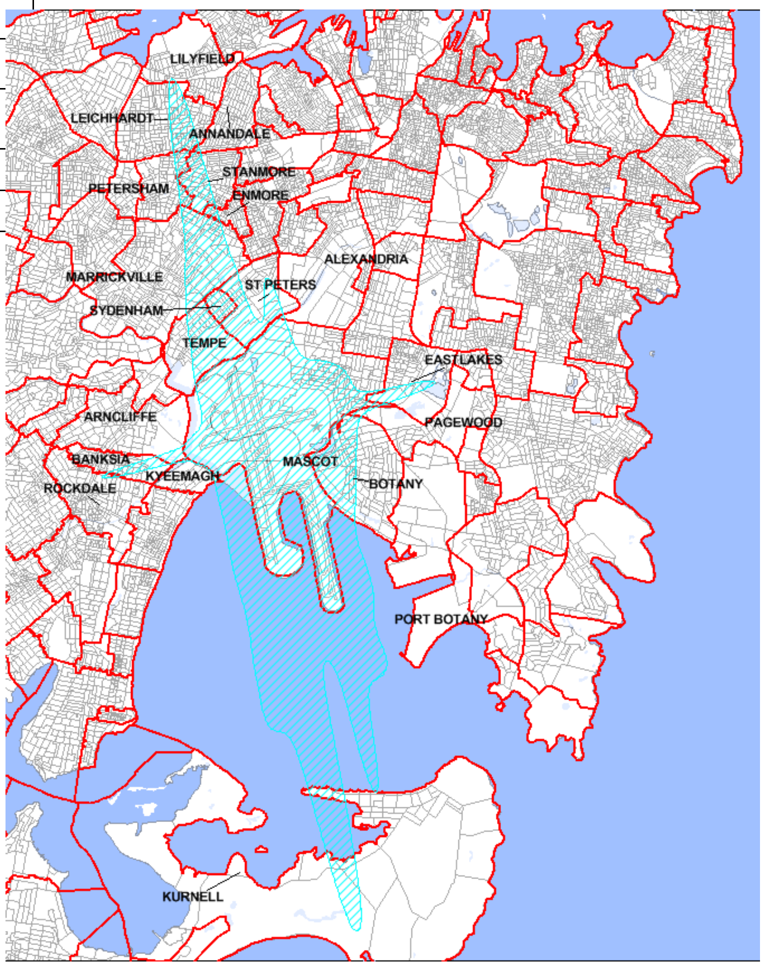
Suburb	2013 Annual Sum of Residents (N486)	2014 Q3 Sum of Residents (N489)
Arncliffe - Bardwell Valley	3	489
Banksmeadow	0	0
Bexley	1830	519
Botany	6071	6071
Coogee - Clovelly	0	81
Cronulla - Kurnell - Bundeena	1309	1309
Drummoyne - Rodd Point	4351	6087
Dulwich Hill - Lewisham	597	0
Erskineville - Alexandria	201	29
Kensington - Kingsford	1897	2026
Leichhardt - Annandale	10953	11549
Lilyfield - Rozelle	2751	2996
Marrickville	15050	15450
Mascot - Eastlakes	15459	14467
Monterey - Brighton-le-Sands - Kyeemagh	708	926
Newtown - Camperdown - Darlington	8852	8869
Pagewood - Hillsdale - Daceyville	608	723
Petersham - Stanmore	18155	17338
Randwick	645	1410
Rockdale - Banksia	3938	4095
Sydenham - Tempe - St Peters	7204	7204
Sydney Airport	3	3
Waterloo - Beaconsfield	240	0
Grand Total	**100825**	**101641**



ANEI 25 Contour

Suburb information is derived directly from the latest Census Mesh Block data. As a result certain suburbs have been grouped together. The Census data has not been altered. The above chart displays the Annual Contour for 2013 (N486) for display purposes. The table shows how the population within the current contour (N489) compares to the counts from the Annual Contour.

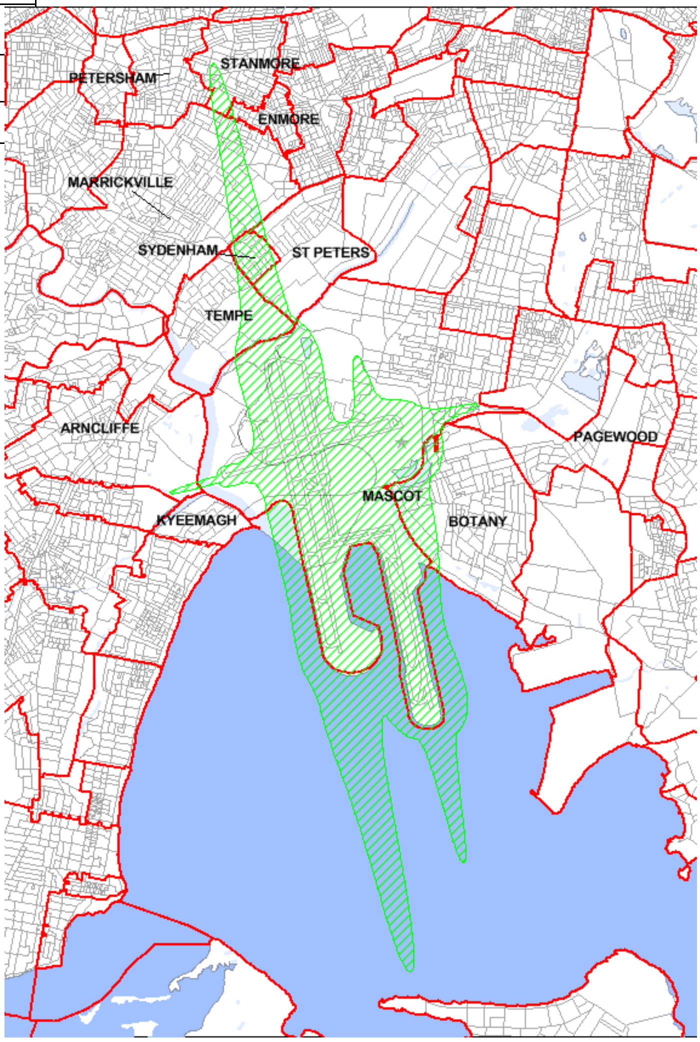
Suburb Names	2013 Annual Sum of Residents (N486)	2014 Q3 Sum of Residents (N489)
Botany	2127	1821
Cronulla - Kurnell - Bundeena	0	0
Leichhardt - Annandale	2831	2967
Lilyfield - Rozelle	0	217
Marrickville	3664	2864
Mascot - Eastlakes	3626	3063
Monterey - Brighton-le-Sands - Kyeemagh	0	0
Petersham - Stanmore	4923	4551
Rockdale - Banksia	656	429
Sydenham - Tempe - St Peters	3653	3517
Sydney Airport	3	3
Grand Total	**21483**	**19432**



ANEI 30 Contour

Suburb information is derived directly from the latest Census Mesh Block data. As a result certain suburbs have been grouped together. The Census data has not been altered. The above chart displays the Annual Contour for 2013 (N486) for display purposes. The table shows how the population within the current contour (N489) compares to the counts from the Annual Contour.

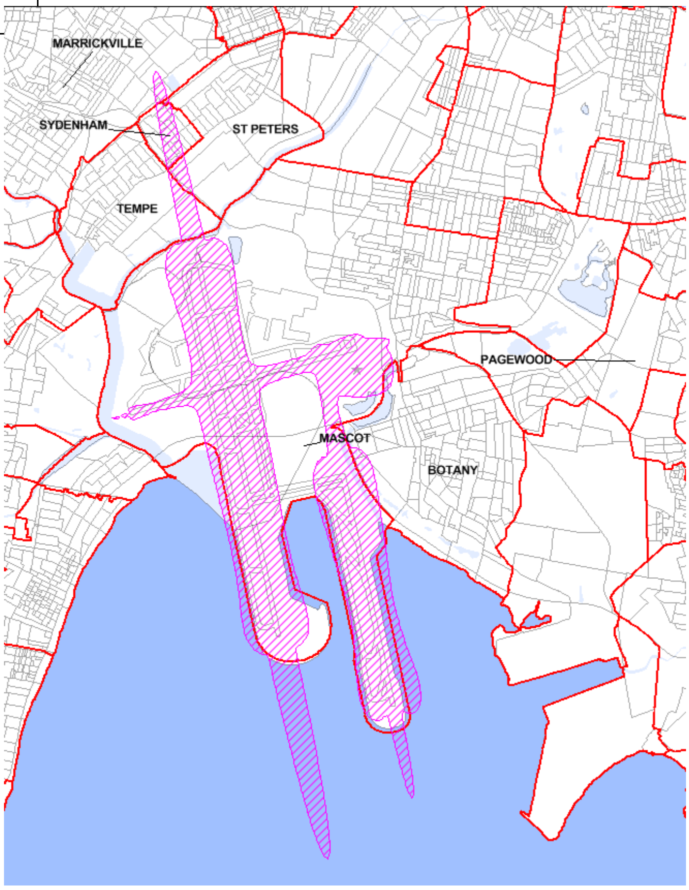
Suburb Names	2013 Annual Sum of Residents (N486)	2014 Q3 Sum of Residents (N489)
Botany	196	146
Marrickville	716	803
Mascot - Eastlakes	378	378
Petersham - Stanmore	223	532
Sydenham - Tempe - St Peters	1134	986
Sydney Airport	0	0
Grand Total	**2647**	**2845**



ANEI 35 Contour

Suburb information is derived directly from the latest Census Mesh Block data. As a result certain suburbs have been grouped together. The Census data has not been altered. The above chart displays the Annual Contour for 2013 (N486) for display purposes. The table shows how the population within the current contour (N489) compares to the counts from the Annual Contour.

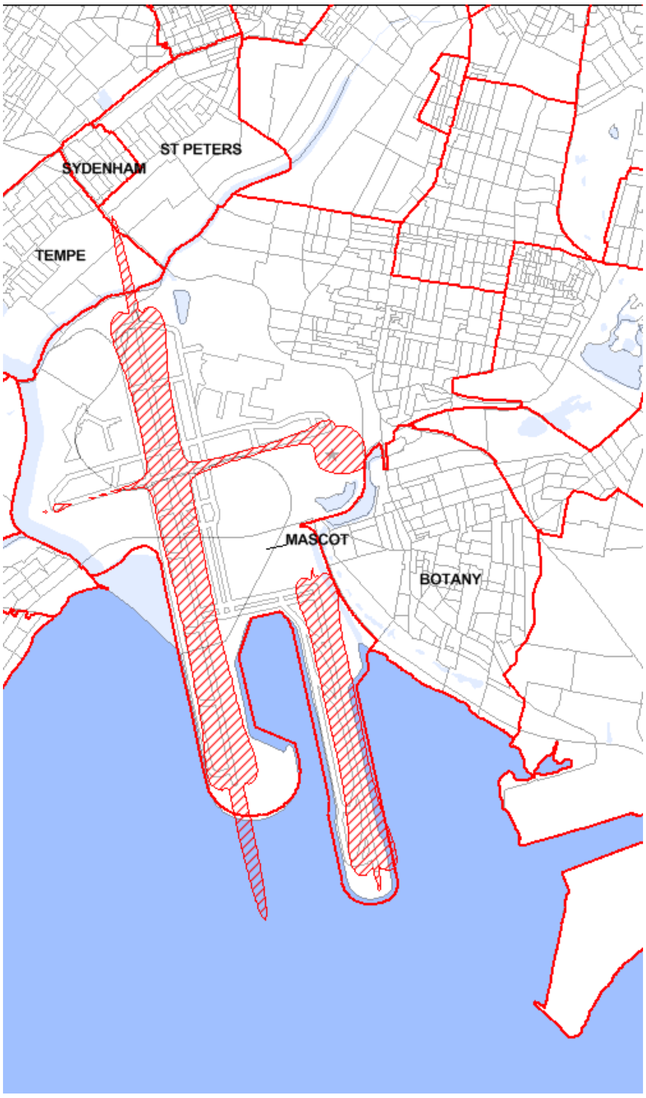
Suburb Names	2013 Annual Sum of Residents (N486)	2014 Q3 Sum of Residents (N489)
Marrickville	4	8
Sydenham - Tempe - St Peters	136	136
Sydney Airport	0	0
Grand Total	**140**	**144**



ANEI 40 Contour

Suburb information is derived directly from the latest Census Mesh Block data. As a result certain suburbs have been grouped together. The Census data has not been altered. The above chart displays the Annual Contour for 2013 (N486) for display purposes. The table shows how the population within the current contour (N489) compares to the counts from the Annual Contour.

Suburb Name	2013 Annual Sum of Residents (N486)	2014 Q3 Sum of Residents (N489)
Sydenham - Tempe - St Peters	0	0
Sydney Airport	0	0
Grand Total	**0**	**0**



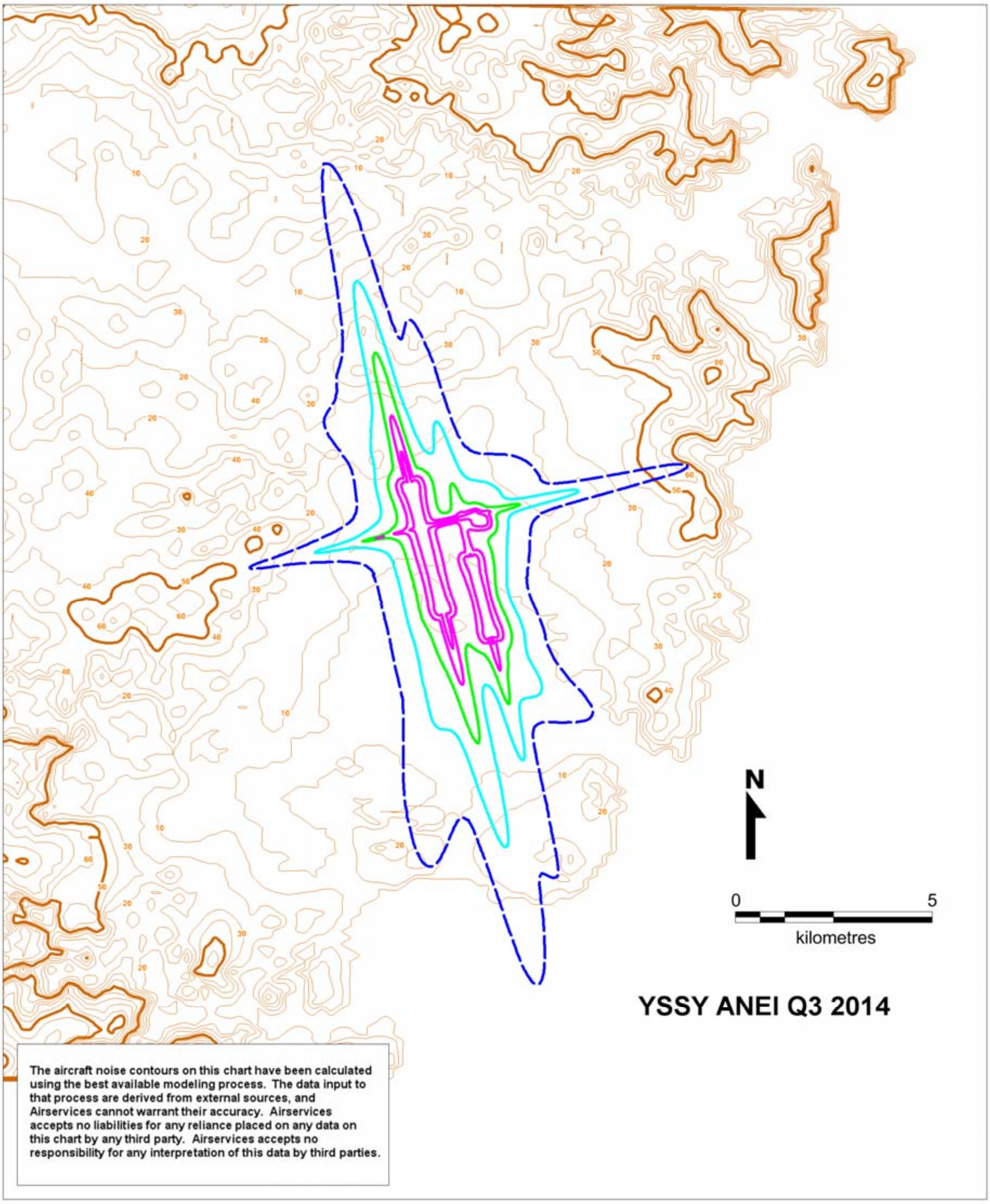
Attachment C

ANEI N489 Contours with INM Terrain Contours

Sydney Airport

1 July 2014 to 30 September 2014

Sydney Airport N489 (1 July 2014 to 30 September 2014) ANEI Contours with Terrain Data



Terrain contour height shown in metres.

Attachment D

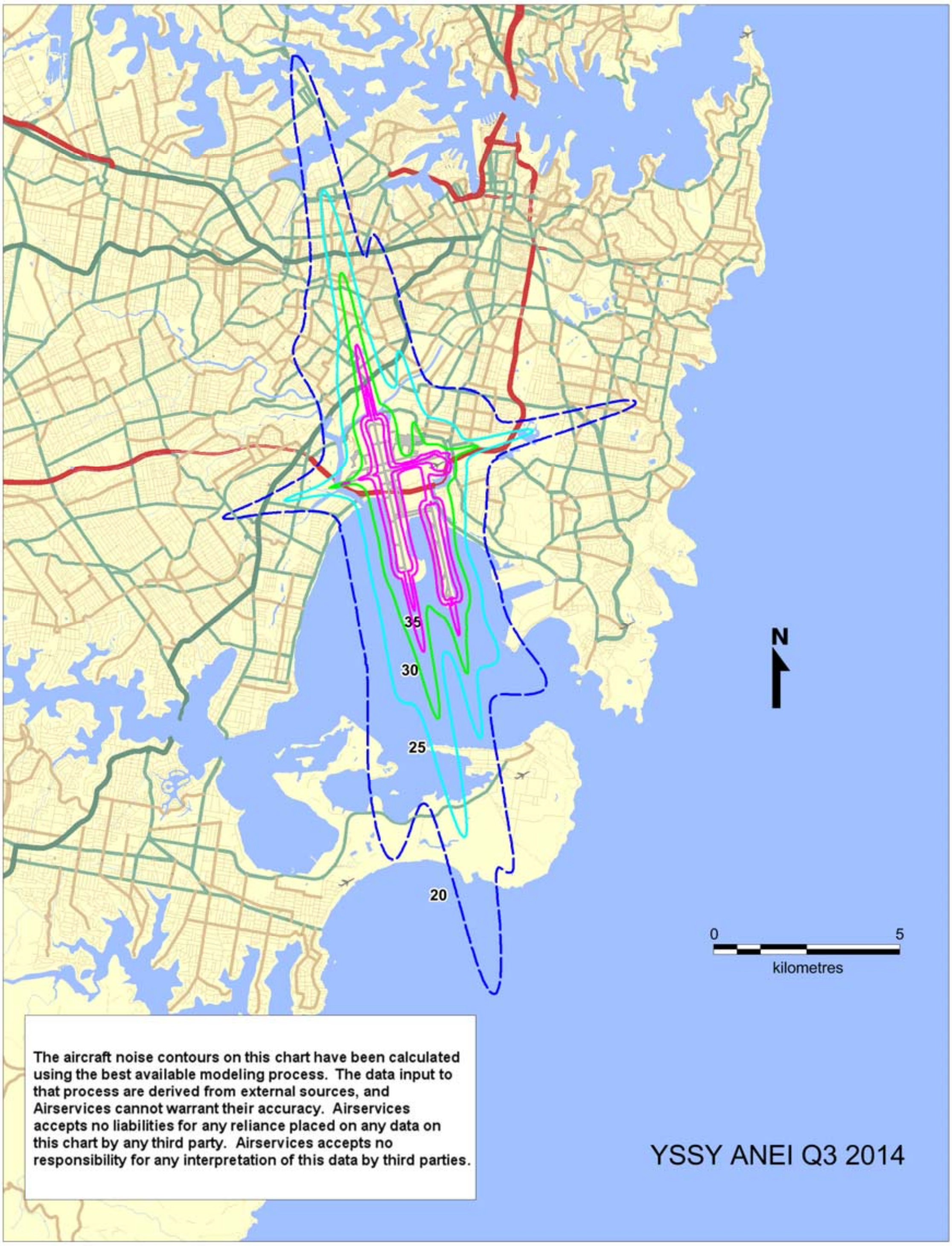
ANEI N489 Contours

Sydney Airport

1 July 2014 to 30 September 2014

The contours for ANEI N489 have been prepared using terrain data.

Sydney Airport N489 (1 July 2014 to 30 September 2014) ANEI Contours



ANEI contours modelled by INM 7.0d incorporating terrain data.

Attachment E

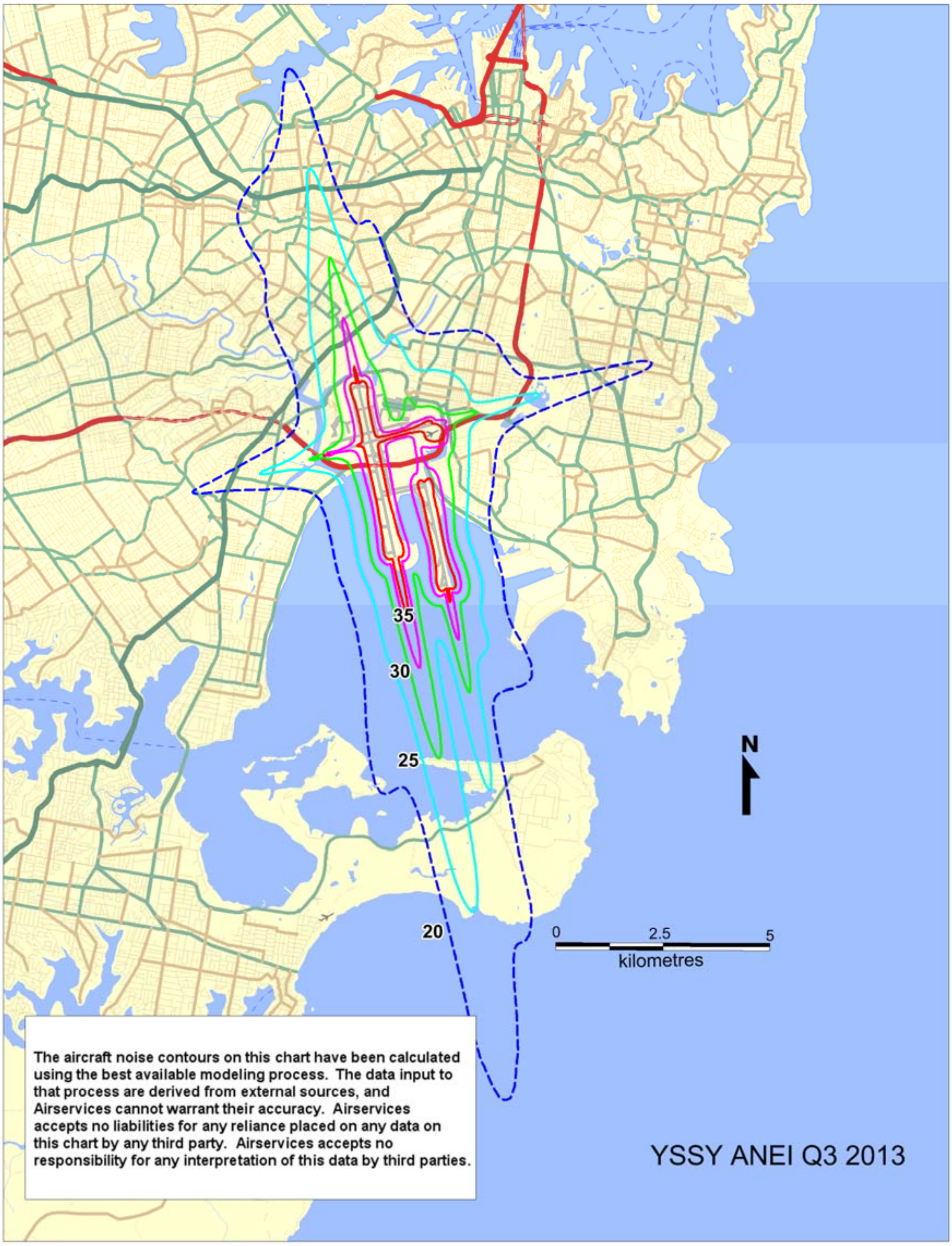
ANEI N484 Contours

Sydney Airport

1 July 2013 to 30 September 2013

The contours for ANEI N484 have been prepared using terrain data.

Sydney Airport N484 (1 July 2013 to 30 September 2013) ANEI Contours



ANEI contours modelled by INM 7.0d incorporating terrain data.

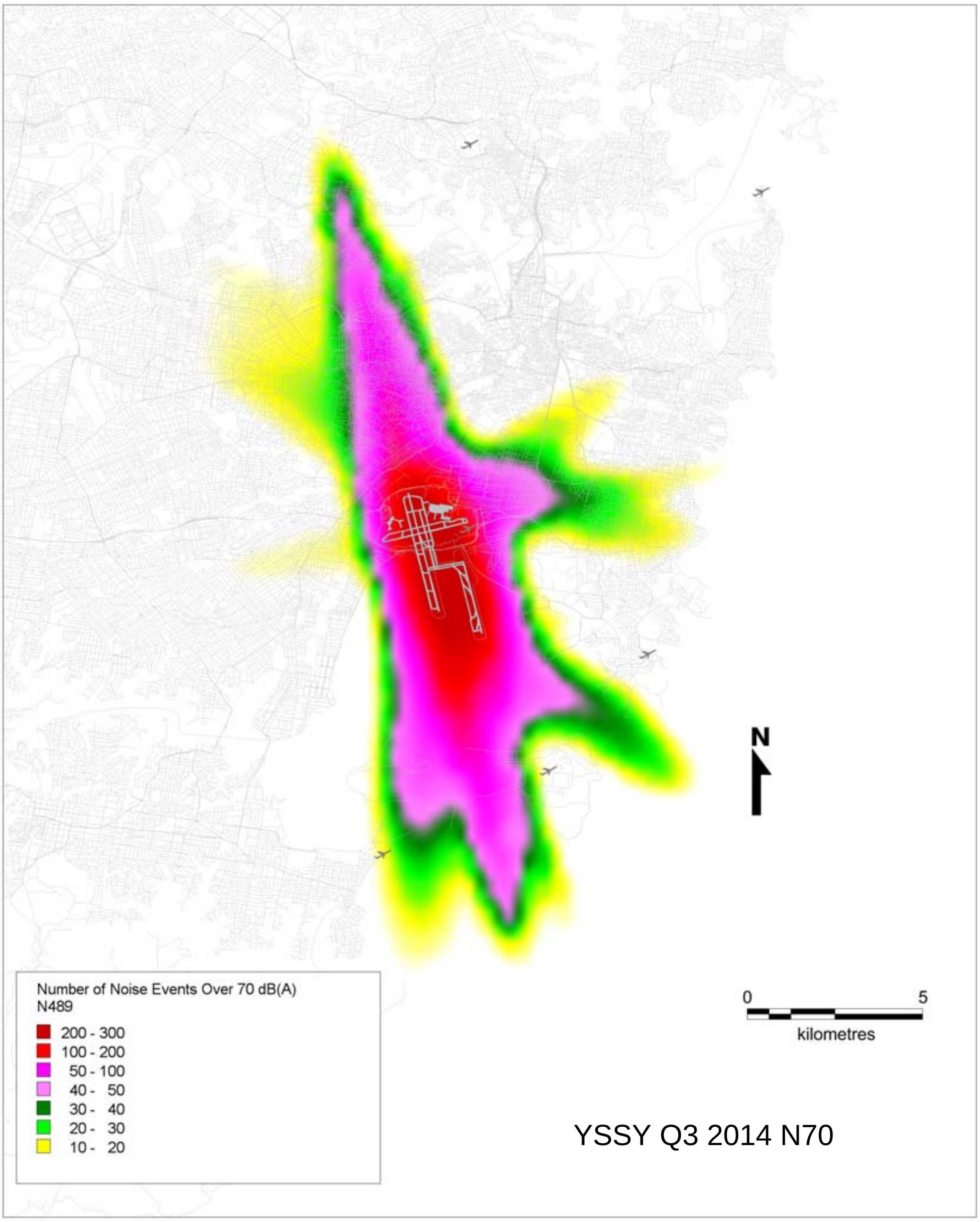
Attachment F

N489 N70 Chart

Sydney Airport

1 July 2014 to 30 September 2014

Sydney Airport N489 (1 July 2014 to 30 September 2014) N70 Chart



Daily average number of aircraft noise events louder than 70 dB(A).

Appendix B

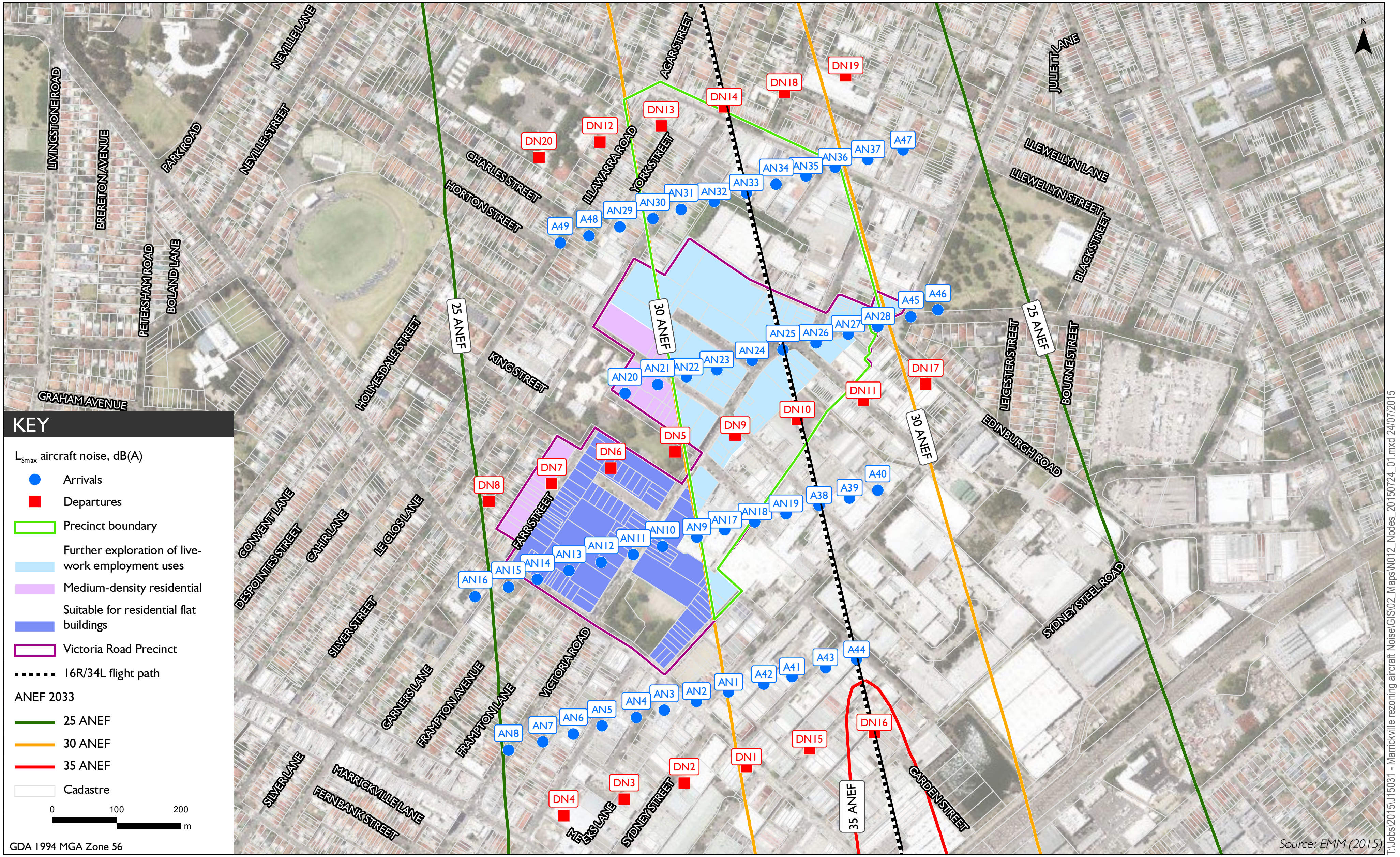
AS 2021 Calculated aircraft noise levels at site

Table B.1 AS 2021 calculated aircraft noise levels at site (Refer to Figure B.1)

Node	Distance			Departures	Arrivals	Departures (LR)	Arrivals	Departures	Arrivals
	DS	DL	DT	737-800	737-800	747-400	747-400	B463	B463
A38	0	2500			85		90		83
A39	50	2500			84		90		82
A40	100	2500			84		89		81
A41	150	2250			83		88		80
A42	100	2250			84		90		82
A43	50	2250			85		91		83
A44	0	2250			86		91		83
A45	200	2750			80		85		77
A46	250	2750			78		83		76
A47	250	3000			78		83		75
A48	250	3000			78		83		75
A49	300	3000			77		81		74
AN1	200	2250			81		86		78
AN10	250	2500			79		84		76
AN11	300	2500			77		82		74
AN12	350	2500			75		80		72
AN13	400	2500			74		78		70
AN14	450	2500			72		77		69
AN15	500	2500			71		76		67
AN16	550	2500			69		74		66
AN17	150	2500			82		87		80
AN18	100	2500			84		89		81
AN19	50	2500			84		90		82
AN2	250	2250			79		84		76
AN20	250	2750			78		83		76
AN21	200	2750			80		85		77
AN22	150	2750			82		87		79
AN23	100	2750			83		88		81
AN24	50	2750			84		89		82
AN25	0	2750			84		90		82
AN26	50	2750			84		89		82
AN27	100	2750			83		88		81
AN28	150	2750			82		87		79
AN29	200	3000			80		85		77
AN3	300	2250			77		82		74
AN30	150	3000			81		86		79
AN31	100	3000			82		88		80
AN32	50	3000			83		89		81
AN33	0	3000			83		89		81

Table B.1 AS 2021 calculated aircraft noise levels at site (Refer to Figure B.1)

Node	Distance			Departures	Arrivals	Departures (LR)	Arrivals	Departures	Arrivals
	DS	DL	DT	737-800	737-800	747-400	747-400	B463	B463
AN34	50	3000			83		89		81
AN35	100	3000			82		88		80
AN36	150	3000			81		86		79
AN37	200	3000			80		85		77
AN4	350	2250			75		80		72
AN5	400	2250			74		78		70
AN6	450	2250			72		77		69
AN7	500	2250			71		75		67
AN8	550	2250			69		74		66
AN9	200	2500			80		85		78
DN1	200		6000	84		92		80	
DN10	0		6500	83		90		81	
DN11	100		6500	83		89		80	
DN12	200		7000	82		88		79	
DN13	100		7000	82		89		80	
DN14	0		7000	82		89		80	
DN15	100		6000	84		93		81	
DN16	0		6000	85		93		82	
DN17	200		6500	83		88		80	
DN18	100		7000	82		89		80	
DN19	200		7000	82		88		79	
DN2	300		6000	83		90		79	
DN20	300		7000	81		86		78	
DN3	400		6000	82		88		78	
DN4	500		6000	80		86		76	
DN5	200		6500	83		88		80	
DN6	300		6500	82		87		79	
DN7	400		6500	81		85		77	
DN8	500		6500	80		83		75	
DN9	100		6500	83		89		80	



AS2021 nodes

Victoria Road, Marrickville
Design initiatives for aircraft noise

Figure B.1

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