

Environmental Research and Consultancy Department



ERCD REPORT 1006

Measurement and Modelling of Aircraft Noise at Low Levels

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Summary

This report describes a study undertaken by ERCD on behalf of the Aircraft Noise Management Advisory Committee (ANMAC) to investigate and potentially improve the accuracy of aircraft noise monitoring at locations outside of the 54 dBA $L_{Aeq\ 16hr}$ contours, and to consider issues related to modelling at these lower contour levels. To take account of developments since the publication of the first edition of this report in 2010, including new government guidance on the environmental assessment of airspace change proposals, this second edition has been updated by ERCD to include new references and information on alternative noise event detection methods.

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Contents

	Revision History	iv
	Glossary of Terms	v
1	Introduction	1
2	Assessment of Historical NTK Data	2
3	Site Surveys of Potential New Monitoring Locations	7
4	Alternative Noise Monitoring Equipment	9
5	Theoretical Low Level Modelling	11
6	Conclusions	12
	References	13
Figure 1	Historical monitor locations around Heathrow with thresholds between 52 and 60 dBA	14
Figure 2	Historical monitor locations around Gatwick with thresholds between 52 and 60 dBA	15
Figure 3	Historical monitor locations around Stansted with thresholds between 52 and 60 dBA	16
Figure 4	Typical background sound levels at historical monitor locations	17
Figure 5	Average L_{90} against percentage of aircraft events with $L_{Amax} > \text{Threshold} + 10 \text{ dB}$	17
Figure 6	Noise time histories for a Stansted monitor with a threshold of 52 dBA	18
Figure 7	Distribution of L_{Amax} noise levels for a Heathrow monitor with a threshold of 55 dBA	18
Figure 8	Noise monitoring sites at Heathrow, summer 2017	19
Figure 9	Site survey locations near the Bovingdon hold	20
Figure 10	Site survey locations near Heathrow Airport westerly Brookmans Park and Wobun departures	21
Figure 11	Site survey locations near the Lambourne hold	22
Figure 12	Site survey locations near Gatwick Airport westerly arrivals	23
Figure 13	Site survey locations near Stansted Airport south-westerly arrivals	24
Figure 14	Site survey locations near Stansted Airport north-easterly departures	25
Figure 15	Summary of noise events recorded at the Gatwick Capel monitor between February and November 2009	26
Figure 16	Comparison of mean and dispersed tracks versus individual radar tracks	27
Figure 17	Comparison of contours generated (48 to 54 dBA $L_{Aeq 16hr}$)	28

Revision History

Edition 1

October 2010

Edition 2

July 2019

Updated with additional information, including differences between measured and modelled noise exposure. Updated references and minor editorial changes have also been incorporated.

Glossary of Terms

ANMAC	Aircraft Noise Management Advisory Committee. The committee is chaired by the Department for Transport and comprises representatives of the airlines, NATS, CAA, Heathrow, Gatwick and Stansted airports, and airport consultative and scheduling committees.
dB	Decibel units describing sound level or changes of sound level. It is used in this report to define differences measured on the dBA scale.
dBA	Units of sound level on the A-weighted scale, which incorporates a frequency weighting approximating the characteristics of human hearing.
kt	Knot(s), nautical mile(s) per hour
L ₉₀	The sound level exceeded for 90 percent of the measurement period, which is often used as an indicator of the background sound.
L _{Aeq}	Equivalent sound level of aircraft noise in dBA, often called 'equivalent continuous sound level'. For conventional historical contours this is based on the daily average movements that take place within the 16-hour period (0700-2300 local time) over the 92-day summer period from 16 June to 15 September inclusive.
L _{Amax}	The maximum sound level (in dBA) measured during an aircraft fly-by.
m/s	Metre(s) per second
NTK	Noise and Track Keeping monitoring system. The NTK system associates air traffic control radar data with related data from both fixed (permanent) and mobile noise monitors at prescribed positions on the ground.
SEL	The Sound Exposure Level generated by a single aircraft at the measurement point, measured in dBA. This accounts for the duration of the sound as well as its intensity.
SID	Standard Instrument Departure. A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated air traffic service route, at which the en-route phase of a flight commences.
VOR	Very high frequency omnidirectional radio range. A type of radio navigation aid for aircraft.

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1 Introduction

- 1.1 The amount of aircraft noise experienced by people living around Heathrow, Gatwick and Stansted airports during the summer of each year is estimated by the Environmental Research and Consultancy Department (ERCD) of the Civil Aviation Authority. The noise exposure contours are generated by the UK civil aircraft noise contour model ANCON 2.4, which calculates the emissions and propagation of noise from arriving and departing air traffic according to ECAC.CEAC Doc 29 4th Edition Volume 2 (Ref 1). The output from ANCON is validated by comparing noise calculations at grid points with noise measurements made at equivalent distances from the airport.
- 1.2 Based on research the Government has, for many years, used 57 dBA $L_{Aeq\ 16hr}$ as the level of daytime noise marking the approximate onset of significant community annoyance¹. However, the Survey of Noise Attitudes 2014 found that the degree of annoyance (based on the percentage of respondents highly annoyed) previously occurring at 57 dBA now occurs at 54 dBA (Ref 2). As a result, standard practice is to now produce daytime noise contours down to 54 dBA.
- 1.3 For the production of the standard 54 dBA $L_{Aeq\ 16hr}$ noise contours, there is no requirement to have noise data at any great distance outside those contours, so generally noise measurements tend to be restricted to locations within and just beyond the 54 dBA contours (Ref 3).
- 1.4 Contours below 54 dBA $L_{Aeq\ 16hr}$ are not normally produced because it has been considered that the results (and any subsequent analysis) will not be sufficiently accurate. This is principally because at lower noise exposure levels aircraft are at higher altitudes and hence quieter, and their flight paths typically more scattered, making it more difficult and costly to collect large enough samples of data that will yield statistically reliable results. However, in its Air Navigation Guidance to the CAA published in 2017, the Government set a Lowest Observed Adverse Effect Level (LOAEL) of 51 dBA for the purpose of assessing airspace changes (Ref 4). The LOAEL is regarded as the point at which adverse effects begin to be seen on a community basis. The need to examine the feasibility of producing aircraft noise exposure contours at low levels has also risen in recent years due to the raised profile of noise in rural areas.
- 1.5 In 2008, ERCD was asked by the Aircraft Noise Management Advisory Committee (ANMAC) to investigate and potentially improve the accuracy of aircraft noise monitoring at locations outside of the 54 dBA $L_{Aeq\ 16hr}$ contours, and to consider issues related to modelling at these lower contour levels. The study was conducted and reported to ANMAC through a series of papers. This report provides a summary of that work.
- 1.6 Section 2 provides a review of historical noise data collected at some of the more distant mobile monitor locations around the three London airports, including an analysis of the differences between measured and modelled noise exposure. This serves as an introduction to the work undertaken by ERCD to investigate the possibility of routinely monitoring aircraft noise at low levels, which is described in Section 3. In Section 4, the possibility of using alternative event detection technology and other elaborate noise monitoring equipment to collect low level aircraft noise data

¹ The relationship between noise and annoyance is of course not an exact one, and varies according to individuals and locations.

is discussed. Section 5 considers issues related to modelling of aircraft noise at lower contour levels, and the study conclusions are summarised in Section 6.

- 1.7 It is recommended that this report be read in conjunction with ERCD Report 0406 (Ref 5), which describes the best practice monitoring techniques used by ERCD when carrying out aircraft noise studies. Readers may also wish to consult ERCD Report 0904, which provides an overview of current metrics used to measure aircraft noise (Ref 6).

2 Assessment of Historical NTK Data

- 2.1 Noise measurements can either be *attended* or *unattended*. With attended measurements, an observer is needed on site at the noise monitor to note down information relating to each noise event. This method is particularly useful where identification of the noise source might be difficult, but it is labour intensive and uneconomical especially when large numbers of measurements are required. For this reason, unattended measurements from the London airports' Noise and Track Keeping (NTK) noise monitors are normally used, since the equipment can be left alone for long periods after set-up to record aircraft noise events.
- 2.2 The NTK monitors are normally used with an event *threshold* level: to qualify as a noise event, the continuous time-varying sound level must exceed the threshold for a minimum user-specified time. For each measured noise event, the NTK system software then determines whether an aircraft passed within a defined zone around the noise monitor close to the time of L_{Amax} (the maximum sound level measured during the event). If an aircraft is found then the software correlates the noise event with that particular flight, otherwise the event is classed as community noise (non-aircraft).
- 2.3 If the threshold level is set too low, then the system can become overloaded with non-aircraft events which could make the identification of genuine aircraft events more difficult (e.g. if the aircraft event and non-aircraft event occur within a few seconds of each other). On the other hand, if the threshold is set too high then genuine quieter aircraft events can be missed.
- 2.4 The aim is therefore to install the monitor in a quiet enough location and to set the threshold level such that background sources do not routinely cause events to be detected, otherwise the NTK system becomes overloaded with non-aircraft events. By also using a minimum event duration, monitors are able to exclude loud but very short events, which could not be caused by aircraft.
- 2.5 Background sound (i.e. in this context non-aircraft) at any noise monitoring location can be composed of a variety of sources. Around an airport, road traffic noise is frequently a major contributor, unless a monitor can be located a significant distance away from any roads. Specific locations may also receive sound from railways, and in rural areas farm machinery and noise from animals might be important. For example, bird song can sometimes result in surprisingly high sound levels. In built-up areas, many everyday activities contribute to the background sound, including children playing, dogs barking, lawn mowing, sirens, alarms, building works and road repairs.
- 2.6 It should be noted that if aircraft noise measurements are contaminated by background sound, the resultant levels are increased relative to their true values, so contours based on such measurements would err on the conservative side. The average measured aircraft noise level can also be distorted if the threshold is set too

- high, such that it has the effect of eliminating a significant proportion of quieter aircraft events.
- 2.7 A set of historic data recorded at mobile NTK noise monitors between 2000 and 2008 was identified for this study, at locations estimated to be outside of the 54 dBA $L_{Aeq\ 16hr}$ contours for each airport, to determine whether such sites are suitable for collecting data for low level contour validation. **Figures 1 to 3** show the locations assessed around Heathrow, Gatwick and Stansted respectively. In each figure, the extent of the 2008 54 and 57 dBA $L_{Aeq\ 16hr}$ contours are shown for comparison. At all these selected locations the event threshold was set at values between 52 and 60 dBA². In many cases however, the data had been collected with an event threshold significantly higher than would be needed for this type of study, so it was found that much of this data has limited value.
- 2.8 **Figure 4** shows a plot of typical background L_{90} levels (hourly values averaged over the period 0700-2300) at these monitors against the event threshold³. Each point on the graph is for one location during one year, with some of the locations being used in more than one year⁴. In nearly all cases the difference between the threshold level and the average background level is more than 10 dB, and in a few cases more than 20 dB. **Figure 5** shows for the same data a plot of average L_{90} against the percentage of noise events that were determined to be aircraft *and* had an L_{Amax} value at least 10 dB greater than the threshold⁵ – i.e. valid events for the determination of aircraft SEL, which is the basic ‘building block’ of L_{Aeq} .
- 2.9 Most of the data points where the threshold was set lowest (52 or 55 dBA) gave percentages of valid aircraft SELs of less than 20 percent of all events measured, indicating the difficulty of using such measurements for low level aircraft noise exposure contours. One illustration of the cause of such difficulty is given in **Figure 6**, which shows the noise time histories for four aircraft flyovers at a monitor with a threshold of 52 dBA. This was at a remote rural location 16 km north east of Stansted. The first three events are quite distinct, although only one of them has an L_{Amax} more than 10 dB above the threshold. The fourth event is clearly corrupted by another source of noise, in this case bird song (the dawn chorus).
- 2.10 Similar examples could be shown where aircraft events are affected by wind-generated noise, road traffic noise, and many other extraneous sources. Locations for this study would normally be selected as far as possible away from roads, railways and built-up areas, but wind-generated noise can be a potentially serious issue anywhere in the absence of any man-made noise (see Section 3).
- 2.11 To provide an indication of the threshold value that would be required to obtain valid aircraft SEL measurements at a location just outside the 54 dBA $L_{Aeq\ 16hr}$ contour, **Figure 7** shows the distribution of L_{Amax} noise levels measured at one of the historic Heathrow sites located near Chertsey in Surrey. In this instance the monitor threshold was set at 55 dBA, which appeared to be low enough to capture almost the entire distribution of L_{Amax} levels. Assuming the noise levels to be (approximately) normally distributed as indicated in **Figure 7**, it is likely that only a very small

² It should be remembered that L_{Aeq} is an equivalent (average) noise level, which cannot be compared directly with an event threshold value or, for that matter, a single event noise metric such as L_{Amax} .

³ The calculation of L_{90} is independent of the monitor threshold.

⁴ It was found that some of the monitors had not been set up to record L_{90} levels, which meant the data could not be used for this analysis.

⁵ To obtain an accurate SEL measurement, it is necessary to know the noise time history for the full 10 dB below the L_{Amax} value.

proportion of aircraft events, with L_{Amax} levels lower than the threshold value, were not detected. However, many sites cannot accommodate thresholds as low as 55 dB and as aircraft have become quieter greater proportions of aircraft overflights are not being recorded as noise events, causing measurement bias. **Table 1** for example shows the percentages of overflights with noise measurements at a recent departure noise monitor approximately 14 km from start of take-off roll at Heathrow⁶.

Table 1 Percentage of overflights with L_{Amax} noise measurements for a departure noise monitor 14 km from start of take-off roll (Summer 2018)

ANCON Type	Number of valid measurements	Total overflights	Percentage
B738	19	21	90%
B744R	19	19	100%
B763R	61	63	97%
B772G	145	145	100%
B772R	100	102	98%
B773G	333	337	99%
B788	86	110	78%
B789	154	160	96%
EA30	17	27	63%
EA318	17	20	85%
EA319C	74	142	52%
EA319V	129	479	27%
EA320C	176	288	61%
EA320NEO	48	164	29%
EA320V	286	500	57%
EA321C	59	59	100%
EA321V	227	265	86%
EA33	102	103	99%
EA3510	13	13	100%
EA359	76	81	94%
EA38GP	201	201	100%
EA38RR	50	50	100%

2.12 However, since the L_{Amax} value has to be at least 10 dB greater than the threshold in order to determine a valid aircraft SEL, a threshold at least as low as 45 dBA would actually be required in order to collect suitable SEL data for all the measured events at the Chertsey monitoring site highlighted previously (**Figure 7**), which was located just outside the 54 dBA $L_{Aeq 16hr}$ contour. At lower noise exposure levels, the threshold level would need to be lower still. Practical experience has shown that unattended monitoring with such low thresholds is not feasible in all but the most exceptional locations.

2.13 It follows that to measure a sound level of 45 dBA accurately in this example (i.e. 10 dB below the lowest expected L_{Amax} value of 55 dBA), it must be several decibels above the background sound level to avoid interference between the aircraft and the background sound. The International Standard ISO 20906 on airport noise

⁶ Data recorded at monitor 142 in Richmond Park. The threshold level for this monitor was set at 58 dB.

monitoring recommends installing noise monitors only at sites where the difference between the level of the background sound and the sound level at the onset of a measurement is at least 5 dB (Ref 7). Continuing with the example above for a location close to the 54 dBA $L_{Aeq, 16hr}$ contour, the background level would have to be no more than 40 dBA in order to determine valid aircraft SELs for all the measured events. By comparison, the typical daytime background L_{90} level at this particular site was 47 dBA.

- 2.14 To illustrate the current level of agreement between noise measurements and noise contour calculations at Heathrow, a comparison has been made between the average measured and predicted noise levels across a number of monitor locations during the summer 2017 period. **Figure 8** shows the location of the noise monitoring sites, and for context, the 51 and 54 dBA $L_{Aeq, 16hr}$ contours and representative flight tracks are also shown.
- 2.15 Since most noise monitors at Heathrow are positioned primarily to measure aircraft operating in a particular runway direction, the results of the validation exercise have been reported separately for easterly and westerly operations, see **Table 2**. Across all monitors the results show a generally good agreement between the measured and predicted noise levels. In most cases the differences are less than 1 dB and are considered to be negligible⁷. However, larger differences of 1 to 2 dB are reported in some cases, which, as expected, are generally at the more distant locations where it can be more difficult to accurately measure lower level aircraft noise. It is also worth noting that most of the differences are positive, which indicates that the Heathrow noise model predictions for that year were marginally conservative overall.
- 2.16 For reference, a 1 dB change in the predicted noise contour level would correspond approximately to a 20 percent change in contour area. Therefore, if the exposed population was uniformly distributed within those contours, a 1 dB uncertainty in the noise contour level would correspond to a 20 percent uncertainty in the population exposed, 40 percent uncertainty for 2 dB, and so on. This uncertainty would also propagate through to any subsequent analysis that was based on those population estimates.

⁷ In aircraft noise modelling, a generally accepted margin of error is ± 1 dB. In terms of noise measurements, the error margin even on high specification noise measurement devices is likely to be of a similar level.

Table 2 Comparison of measured and predicted noise levels at Heathrow, Summer 2017

Monitor ID (see Fig 8)	Average $L_{Aeq, 16hr}$ summer daytime noise level, dB					
	Easterly Mode Operations			Westerly Mode Operations		
	Measured	Predicted	Difference	Measured	Predicted	Difference
6	56.5	56.7	+0.2	66.1	66.4	+0.3
10	66.9	68.2	+1.3	-	-	-
11	65.7	66.2	+0.5	-	-	-
12	65.9	66.4	+0.5	-	-	-
13	66.1	66.4	+0.3	-	-	-
14	-	-	-	62.0	62.9	+0.9
15	-	-	-	65.5	65.8	+0.3
17	-	-	-	66.7	66.7	0.0
18	70.7	71.1	+0.4	68.7	68.4	-0.3
19	-	-	-	64.0	64.3	+0.3
20	66.2	66.2	0.0	-	-	-
21	68.2	69.0	+0.8	-	-	-
56	58.6	59.9	+1.3	-	-	-
129	-	-	-	62.2	62.1	-0.1
130	-	-	-	60.4	60.7	+0.3
131	-	-	-	55.5	56.9	+1.4
132	57.3	57.9	+0.6	-	-	-
133	51.4	53.0	+1.6	-	-	-
135	56.3	57.5	+1.2	-	-	-
136	53.5	55.6	+2.1	-	-	-
137	73.6	73.5	-0.1	71.5	70.8	-0.7
138	63.0	64.0	+1.0	-	-	-
139	63.5	64.3	+0.8	-	-	-
140	59.9	60.8	+0.9	-	-	-
141	55.2	54.5	-0.7	-	-	-
142	54.3	55.5	+1.2	-	-	-
143	52.0	52.8	+0.8	-	-	-
144	60.0	60.2	+0.2	-	-	-
145	59.7	59.9	+0.2	-	-	-
146	53.2	53.9	+0.7	-	-	-
500 ⁸	-	-	-	49.2	51.1	+1.9
501 ⁹	-	-	-	52.1	53.5	+1.4

⁸ NMTs 500 and 501 were only operational for 24 days during the 92-day summer period and are therefore subject to additional uncertainty.

3 Site Surveys of Potential New Monitoring Locations

3.1 General

- 3.1.1 The analysis of existing data in Section 2 shows that in general, aircraft noise measurements would need to be obtained with significantly lower thresholds than have typically been used in the past in order to collect suitable data for low-level contour validation. However this is not possible if, as at many locations, the background sound level is not low enough to provide an adequate margin below the aircraft levels. In order to give an indication whether it is possible to achieve suitably low background noise levels for routine monitoring of aircraft noise at low levels, several areas around Heathrow, Gatwick and Stansted airports were investigated.
- 3.1.2 Locations with the required low background levels are typically found in rural areas such as farm fields, open access public footpath areas, and generally land away from any other noise source which could distort any subsequent aircraft noise monitoring. Locations such as these tend to be in the vicinity of trees and/or areas with long grass or other vegetation (natural or crops). On a still day with no wind, such locations could potentially provide a suitable monitoring location, but this initial assessment as well as previous experience has shown that with even a light wind, the noise generated from trees/crops/long grass etc. could raise background noise levels by up to 10 dB (or more in some cases), making a location unsuitable.
- 3.1.3 Sound levels can also be affected by meteorological conditions particularly when the noise propagation distance is large. Atmospheric variations in temperature and relative humidity will produce different rates of sound absorption and hence result in different measured noise levels for the same source emission. Wind speed and direction can also affect the noise propagation path quite significantly due to refraction/turbulence effects, which will affect the noise on the ground. Wind-induced noise at the microphone is also an important factor when measuring low sound levels. Although microphones are equipped with windshields, the latest guidance (Ref 7) is that measurements should be flagged (for likely rejection) when wind speeds are greater than 10 m/s (19 kt), and ERCD's practice generally is to eliminate measurements for contour data when the wind speed is greater than this.
- 3.1.4 It was also found that other local man-made sources of noise in rural locations caused a rise in the background noise level above that which would be suitable for low-level aircraft noise measurements. These included farm machinery, noise from animals, cars on nearby roads, distant motorways, bird song, and noise from walkers/ramblers when passing near the monitoring equipment. General Aviation (GA) aircraft and helicopters operating at lower altitudes can also be a source of aircraft noise independent to the one under investigation. This is covered in more detail below.
- 3.1.5 Another important consideration for a suitable measurement location is the security of any monitoring equipment which will be left at the site over an extended period of time. As explained above, the type of site required to achieve a suitably low background noise level will most likely be rural. This would mean that a noise monitor would typically be in an open field, where anyone could potentially have access to it, increasing the risk of vandalism or theft. This would need to be taken into consideration when deciding whether to undertake unattended monitoring at a given site. In addition, the typically broader spread of aircraft tracks at these more distant locations means that obtaining valid aircraft events in sufficient numbers through attended monitoring would require a significant investment of time.
- 3.1.6 Finally, whilst every effort was made to ensure the survey measurements for this study were taken under representative operational conditions, it should be recognised that they are only short-term 'snapshots' of the particular situation at each site, such

that sample measurements made at the same locations on different days could produce significantly different results.

3.2 Heathrow site surveys

- 3.2.1 **Figures 9 to 11** provide a summary of the site surveys undertaken in July and September 2008 at Heathrow. Each site was visited by ERCD staff during daytime hours, typically for between 30 to 60 minutes, and the noise levels measured. On each figure, details of valid aircraft events are given, where the aircraft was close to overhead of the monitoring position. At some locations, these events were the only valid aircraft events captured during the survey period; this is indicative of the difficulty in obtaining sufficient aircraft events at many of the locations surveyed.
- 3.2.2 **Figure 9** shows several locations where site surveys were undertaken near the Bovingdon hold⁹. This area was selected due to the concentration of aircraft flight tracks inbound to Heathrow. A location next to the VOR beacon was found to have a low background noise level of around 35 dBA in the absence of wind or other noise sources. The location is however, unsuitable due to the proximity of a local airfield with near constant helicopter noise observed during the survey period and also GA aircraft routing via the beacon, which masked any Heathrow bound traffic.
- 3.2.3 **Figure 9** also shows that other survey locations in the area suffered from similarly unwanted noise from helicopters, GA aircraft and other man-made sources. Additionally, on the day of the survey there was a light wind, up to 7 m/s (14 kt), that resulted in the background levels increasing to the high 40s dBA, although during short periods when there was little or no wind the background level would drop below 40 dBA in most locations. Thus, it could be possible to find locations for low-level monitoring in the Bovingdon area but due to the reasons mentioned above, attended monitoring would be required in order to disregard any contaminated aircraft events.
- 3.2.4 **Figure 10** shows the results of a site survey undertaken in the Wooburn area (underneath the westerly Heathrow Brookmans Park and Wobun SIDs). Similar results were found to those mentioned above for Bovingdon but with higher background levels due to distant road traffic noise from the M4 and M40 motorways (approximately 3 km away from the nearest sites). Other potentially quieter locations were found but again due to the rural nature of these, wind/tree noise raised the background levels into the high 40s dBA and above sometimes.
- 3.2.5 **Figure 11** shows the results of a site survey undertaken near the Lambourne hold. Again, this area was selected due to the concentration of aircraft flight tracks inbound to Heathrow. Locations surveyed in this area suffered from noise from the nearby M11 and M25 motorways. With a light wind the background level could reach 50 dBA in several of the locations surveyed. Locations near to the VOR beacon were found to be unsuitable due to GA aircraft using Stapleford Aerodrome¹⁰. It was found that in most locations in the Lambourne area, aircraft events were rarely more than 10 dB above the background level. From the results of the site survey, areas around the Lambourne hold would probably not be suitable to measure low level aircraft noise, due to the high background levels found in many locations.

⁹ Aircraft arriving at Heathrow are normally directed under Air Traffic Control (ATC) instructions to one of four holding stacks positioned around Heathrow. These holds are based on VOR ground beacons at Biggin Hill, Ockham, Lambourne and Bovingdon. During less busy times these holds may not be utilised but, when they are active, aircraft will be directed by ATC from the holds to their final approach. The VOR ground beacons are used by GA aircraft operating beneath the lowest level of the holding stack.

¹⁰ The Lambourne VOR is on Stapleford Airfield, so the background sound is only at suitably low levels when the airfield is not operating (before 0730 and after sunset) and during periods between flights.

3.3 Gatwick site surveys

- 3.3.1 **Figure 12** summarises the results of a site survey undertaken in October 2008 near Gatwick airport, at several locations where aircraft are turning to join the extended runway centre line on westerly arrivals. These include locations suggested by ANMAC members such as Ashdown Forest and Hartfield. Again, details of valid aircraft events are provided where the event was close to overhead of the monitoring position. As **Figure 12** indicates, the results of the Gatwick site surveys were generally more favourable than those for Heathrow.
- 3.3.2 In general, lower background noise levels were observed near Gatwick with aircraft event L_{Amax} values 20 dB or more above the background level in some locations. This was particularly true at the Ashdown Forest location where the background level was briefly as low as 31 dBA. At this location however, there is a broad spread of aircraft tracks such that obtaining a suitable number of valid aircraft events would require a significant investment of time.

3.4 Stansted site surveys

- 3.4.1 **Figures 13 and 14** summarise the results of the site surveys that were undertaken at locations around Stansted in July and September 2009. For arrivals noise, several locations at distances greater than 20 km from touchdown on runway 22 were visited (see **Figure 13**). For departures in **Figure 14**, distances greater than 20 km from start-of-takeoff-roll on runway 04 were visited. Measurements were taken at two locations under the Buzad SID and one location under the Clacton SID. Note on the days planned for the departure site surveys, aircraft were operating in a north-easterly direction (note also that at some of the locations, data for both arrivals and departures were measured).
- 3.4.2 The results illustrate that some of these locations could sometimes have background noise levels as low as 30 to 40 dBA. However, due to the presence of wind-generated noise and/or intermittent road traffic noise, background levels were closer to 50 dBA or more on occasion. Without an observer at the location to note the cause of a noise event, a non-aircraft event might easily be mistaken for an aircraft. Other sources of contamination observed at some of these locations included bird song and GA aircraft.

4 Alternative Noise Monitoring Equipment

4.1 Alternatives to fixed threshold technology

- 4.1.1 As explained in Section 2, to ensure as far as possible that non-aircraft noise events are not recorded during unattended monitoring, the NTK noise monitors are set up to only record noise events above a pre-determined threshold level. Typically, a threshold of between 55 and 65 dBA is used at NTK monitoring sites around the London airports, depending on the general level of background noise. However, at locations where the background noise level is frequently varying (for example, due to local road traffic, bird song or wind noise), it becomes difficult to select an appropriate threshold level that is low enough to capture a suitable number of valid low-level aircraft noise events, but high enough to ensure that extraneous noise events are not recorded.
- 4.1.2 To get around this problem, some airport noise monitors also have the facility to use a dynamic or 'floating' threshold, rather than a fixed threshold, in order to trigger the measurement event. When set to a floating threshold, the noise monitor effectively tracks the general background noise level and only starts to record a noise event if the level rises rapidly. Some brief testing of the floating threshold facility was

undertaken for this study at all three airports during 2009. At Heathrow, a mobile monitor with a floating threshold was placed alongside a permanent noise monitor in Hounslow Heath for side-by-side testing. At Gatwick, an existing noise monitor in Capel was temporarily switched from a fixed to a floating threshold for several months. At Stansted, a mobile monitor was installed with a floating threshold in Great Sampford over the summer period.

- 4.1.3 Results were generally favourable, with the floating threshold typically allowing for a greater proportion of aircraft noise events that have an L_{Amax} value more than the required 10 dB above threshold. One potential issue however is that using a floating threshold appears to significantly increase the proportion of non-aircraft events in the NTK system (events that might otherwise have been at too low a level to trigger a fixed-threshold noise monitor), thus causing data storage issues.
- 4.1.4 The effect of switching between floating and fixed thresholds is illustrated for example in **Figure 15**, which summarises the proportion of valid aircraft events and non-aircraft events recorded at the Gatwick Capel¹¹ monitor over a ten month period in 2009. In this case the NTK monitor was switched to a floating threshold towards the end of January 2009 and then back to a fixed threshold (of 61 dBA) towards the end of June 2009. Another issue is that events recorded using a floating threshold are typically much longer in duration (due to the lower threshold), lasting for more than 90 seconds in some instances, and the NTK systems automatically classify very long measurements as non-aircraft events.
- 4.1.5 In addition to floating thresholds, the latest generation of NTK noise monitors and software also provide the optional capability to change the event detection parameters *after* measurements have been recorded to try and improve the detection rates of aircraft noise events. Technology also exists to extract aircraft noise events from a continuous stream of noise measurements without the reliance of a threshold level. The process makes use of modelled estimates of aircraft noise to determine whether the measured levels at that location are plausible for the particular aircraft type (Ref 8). Such a system could not be used to identify aircraft noise events for model calculation validation, since the measurements would no longer be independent of the calculation model. Overall, whilst developments are occurring, alternative event detection systems such as these are practically some years away from deployment to airport monitoring systems and may incur an additional cost to the airport.

4.2 Automatic aircraft noise identification systems

- 4.2.1 One of the major problems of using unattended monitors for low-level sound measurements is that the current NTK monitors cannot differentiate between aircraft and non-aircraft events. More advanced monitoring equipment is available commercially, which can automatically identify aircraft noise based on the sound arrival direction using an additional array of four microphones mounted next to the main signal microphone.
- 4.2.2 However, whilst the unit cost for such a system is higher than for a conventional NTK noise monitor, the key issue is its relatively high power consumption. This means that the system is currently not suited for temporary or mobile installations where mains power is unavailable (particularly likely at rural locations). For example, using batteries that can be lifted by one person would necessitate daily battery changes. By comparison, an existing battery-powered NTK mobile monitor can typically operate for a week or more before the battery needs changing. Whilst battery technology has improved over the last decade, noise monitor power requirements have also

¹¹ Capel is over flown by north-turning departures when the airport is operating in a westerly direction.

increased, with the more routine analysis of multiple noise indicators, including frequency analysis with filters other than 'A-weighting'. Thus, there is a trade-off between providing processing power for improved detection systems versus additional measurement analysis.

- 4.2.3 Modern airport noise monitoring systems also have the capability to record and store an audio file for each measured noise event, which can then be played back by airport staff for later analysis or source identification. However, whilst this allows an airport to identify potentially erroneous or contaminated noise events on an ad-hoc basis, it would be impractical for someone to listen to every event. Nonetheless, given advancements in technology the opportunity exists for the automatic 'pattern recognition' of aircraft events through the analysis and processing of the audio signal. Again though, such a system, if feasible, would likely incur an additional cost to the airport and the associated practical problems with processing large amounts of audio data.

5 Theoretical Low Level Modelling

- 5.1 Whilst the modelling of aircraft noise at low levels is highly dependent on the availability of noise measurement data, other aspects of the aircraft noise modelling process become more important. It is not normally practical to model the flight path (i.e. the ground track and vertical profile) of all individual aircraft movements. Therefore some statistical averaging of the variation in flight tracks and profiles is undertaken to make the analysis more manageable. Two key components of the statistical averaging currently applied were considered:
- (a) assessing the uncertainty due to the lateral dispersion of aircraft flight tracks, and
 - (b) assessing the uncertainty due to the vertical dispersion of aircraft height/speed profiles.
- 5.2 A single day's worth of radar data from Heathrow was chosen for this analysis. To determine the uncertainty due to the lateral dispersion of flight tracks, traffic on the runway 27L Detling SID was modelled using both a mean track derived from all aircraft departing on that route and individual radar tracks for each flight. The differences between these two modelling approaches can be seen in **Figures 16 and 17**.
- 5.3 Current international best practice noise modelling recommends that, for all aircraft types, a spread of individual flight tracks is modelled with a nominal mean track and a minimum of six symmetric dispersed sub-tracks either side of the central mean track according to a normal (Gaussian) distribution (Ref 1). As **Figure 16** shows, the use of individual radar tracks however, for this sample of traffic, results in a skewed or asymmetric distribution with more traffic found towards the outside of the swathe than the inside.
- 5.4 Because of the asymmetric distribution of traffic, the resulting shape of the noise contours generated using individual tracks differs from contours created using a mean track and symmetrically distributed sub-tracks – see **Figure 17**. This offset becomes more pronounced as the contours extend to lower noise levels and overall track dispersion increases.
- 5.5 Modelling all flight tracks individually would be prohibitively time-consuming in preparation, but also lead to long calculation run-times, from one to two days currently to several weeks where average summer day contours are typically based on 120,000 movements (in the case of Heathrow). Modelling with individual flight tracks also potentially poses issues in terms of a different process being used for historical

contouring compared with forecast contouring. One possible option would be to define separate mean tracks and dispersed tracks for each individual aircraft type. Whilst increasing complexity and run-time by a factor of 50 for the Heathrow contours for example, this would still be far more efficient than modelling individual flight tracks. It would, however, still not address the issue of any track asymmetry for a given aircraft type.

- 5.6 Due to the significant variation in climb performance across different aircraft types, separate mean vertical profiles are already defined for each aircraft type in the ANCON noise model. This greatly reduces the degree of vertical dispersion, but some vertical dispersion remains due to the variation in distances flown and the corresponding variation in take-off weight. As with lateral dispersion, vertical dispersion tends to increase with increasing distance from an airport. The uncertainty due to the vertical dispersion could be assessed by comparing the noise level or contour differences from modelling with either mean height and speed profiles based on all flights for a given aircraft type or individual profiles for each flight in the traffic sample. There are two main difficulties with conducting such an assessment. First, it requires the creation of individual profiles for every flight. This is not a straightforward process since it requires ground speed information to be derived from radar data, which is not generally precise enough for this type of application without significant post-processing on a flight-by-flight basis. Secondly, in order to account for the differing performance of each flight, variation in takeoff weight would need to be accounted for, as well as the variation of each trajectory. Take-off weight on an individual flight basis is often considered commercially sensitive information and thus is not routinely available. Because of these difficulties, an assessment of the uncertainty of vertical dispersion has not been attempted.

6 Conclusions

- 6.1 The data collected at each of the London airports has indicated that it may be difficult to find suitable locations to measure aircraft noise at low levels routinely. The low background levels required are only achievable under conditions with little or no wind and no man-made noise sources nearby. In most cases, only through the use of attended monitoring could uncontaminated aircraft events be measured with any certainty. Attended monitoring, however, would be very much more expensive and time consuming.
- 6.2 The use of floating threshold in the existing noise monitors may allow for a greater proportion of valid lower level aircraft noise events to be recorded, but at the same time result in a greater proportion of non-aircraft events within the NTK system. The high power consumption of more elaborate and costly noise instrumentation, which can automatically identify aircraft noise based on the sound arrival direction, effectively precludes the use of such equipment at rural monitoring sites where battery power is likely to be required. Whilst new and alternative event detection methods are being made available by NTK system providers, some of these remain in the development stage and have thus far not been deployed in standard airport systems and may incur an additional cost to the airport.
- 6.3 Significantly longer timescales and higher associated costs would be required to produce noise contours at lower levels, since each individual flight operation would need to be modelled using its actual ground track rather than using a mean track and distributed sub-tracks. This is primarily due to increased track dispersion and the likelihood of asymmetric track dispersion at greater track distances from the airport.

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Figure 2 Historical monitor locations around Gatwick with thresholds between 52 and 60 dBA

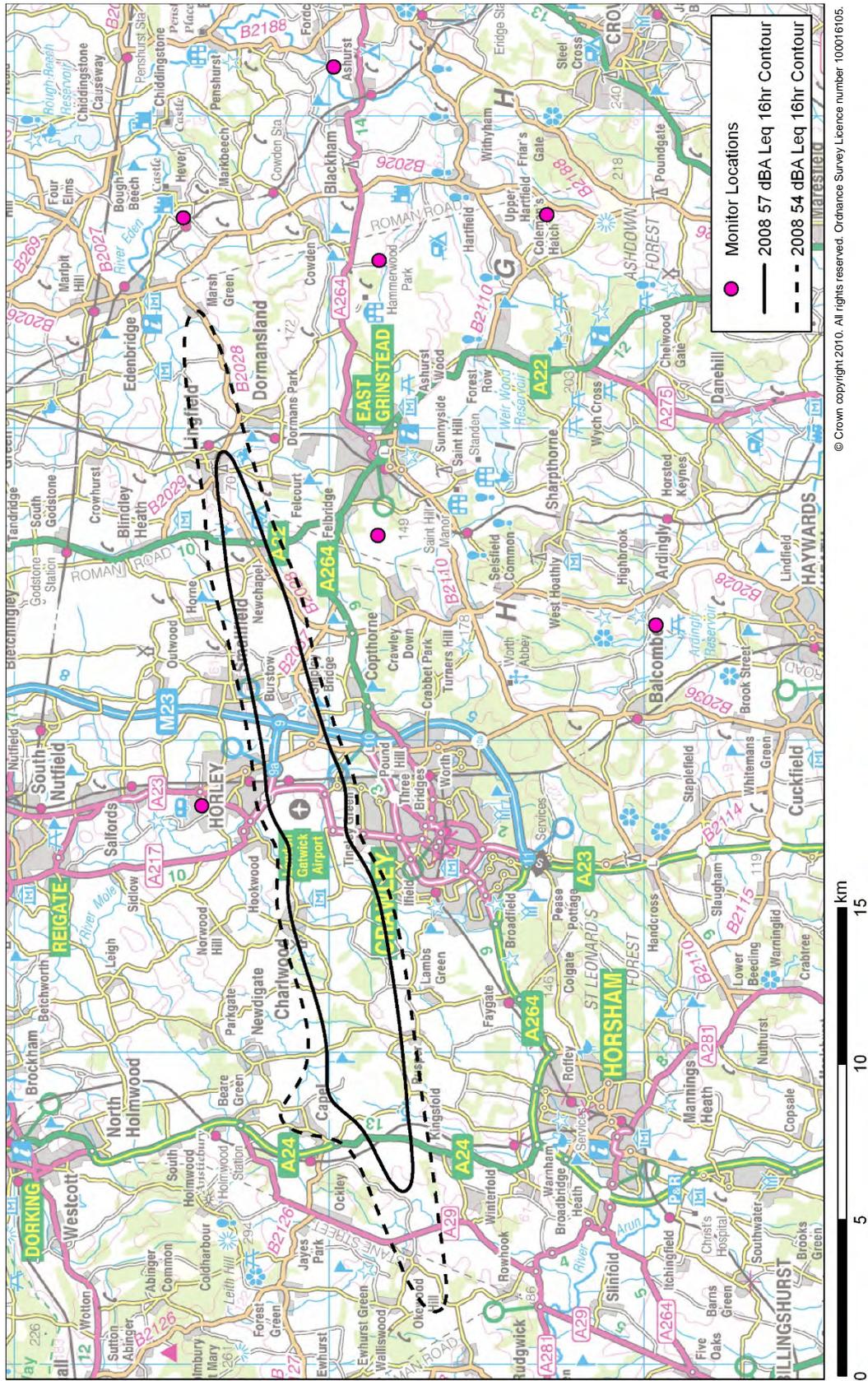
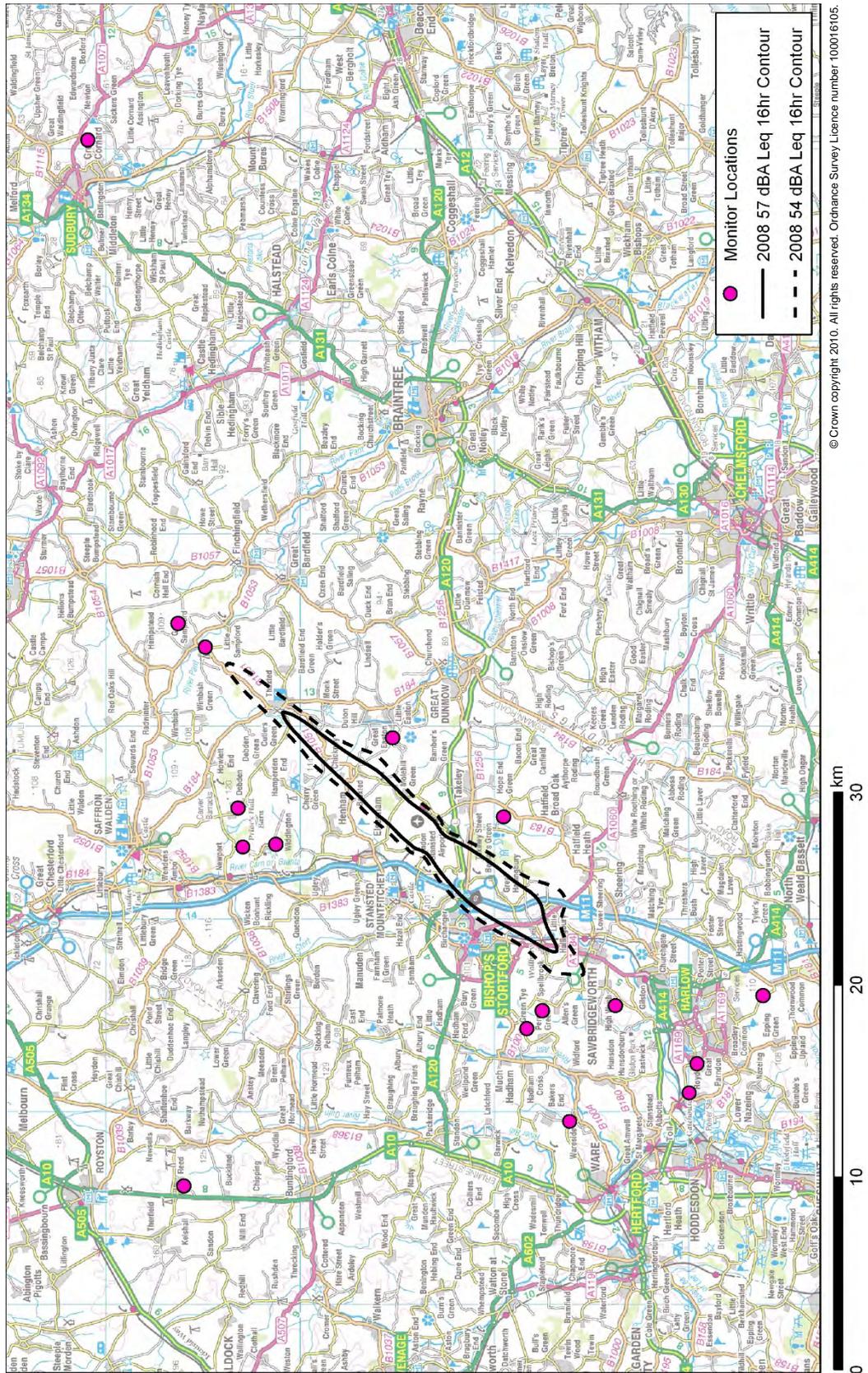


Figure 3 Historical monitor locations around Stansted with thresholds between 52 and 60 dBA



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Figure 4 Typical background sound levels at historical monitor locations

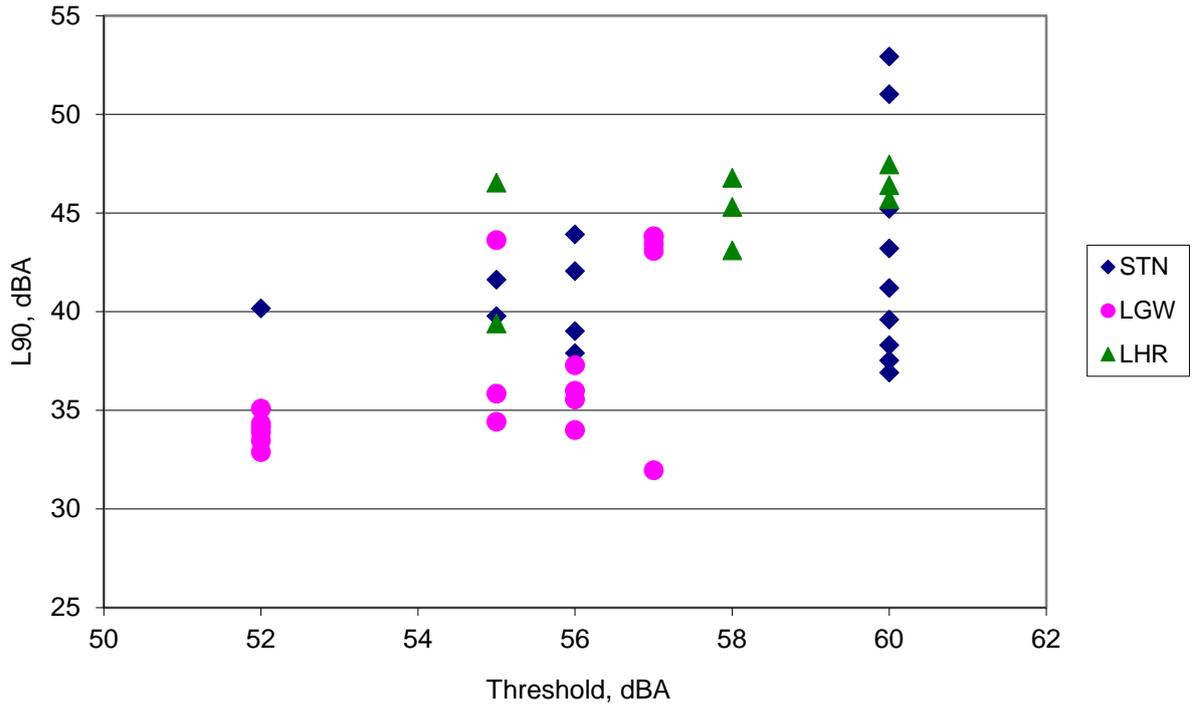


Figure 5 Average L90 against percentage of aircraft events with $L_{Amax} > \text{Threshold} + 10 \text{ dB}$

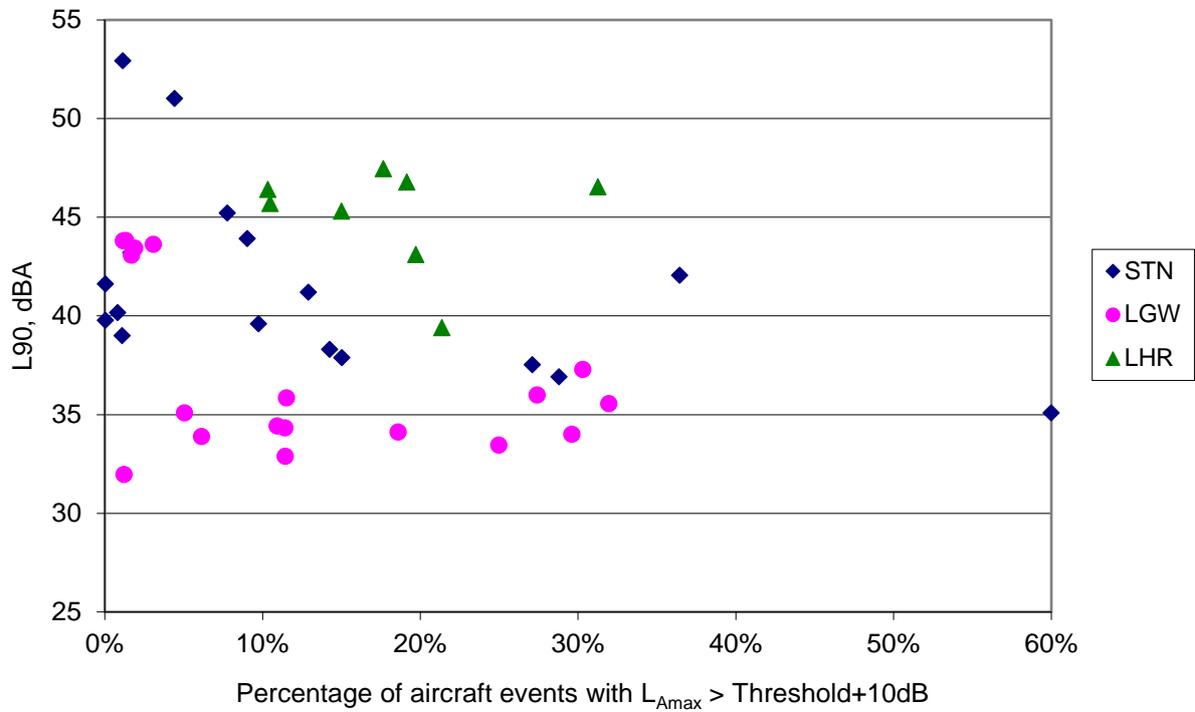


Figure 6 Noise time histories for a Stansted monitor with a threshold of 52 dBA

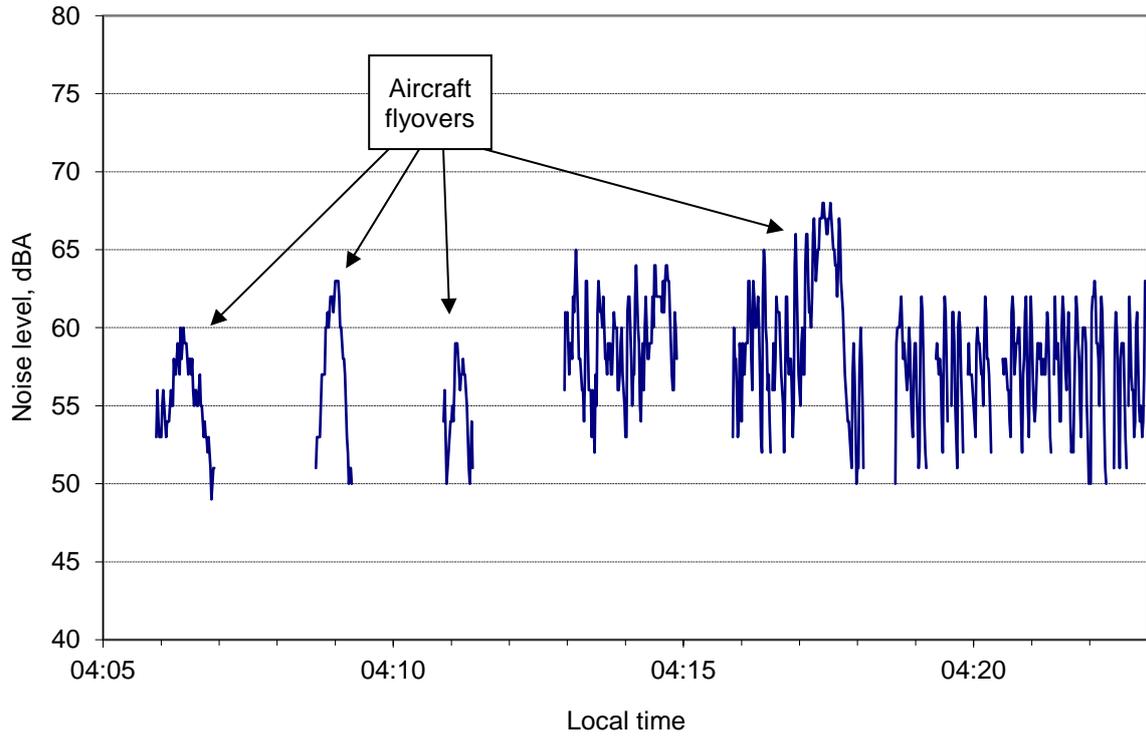


Figure 7 Distribution of L_{Amax} noise levels for a Heathrow monitor with a threshold of 55 dBA

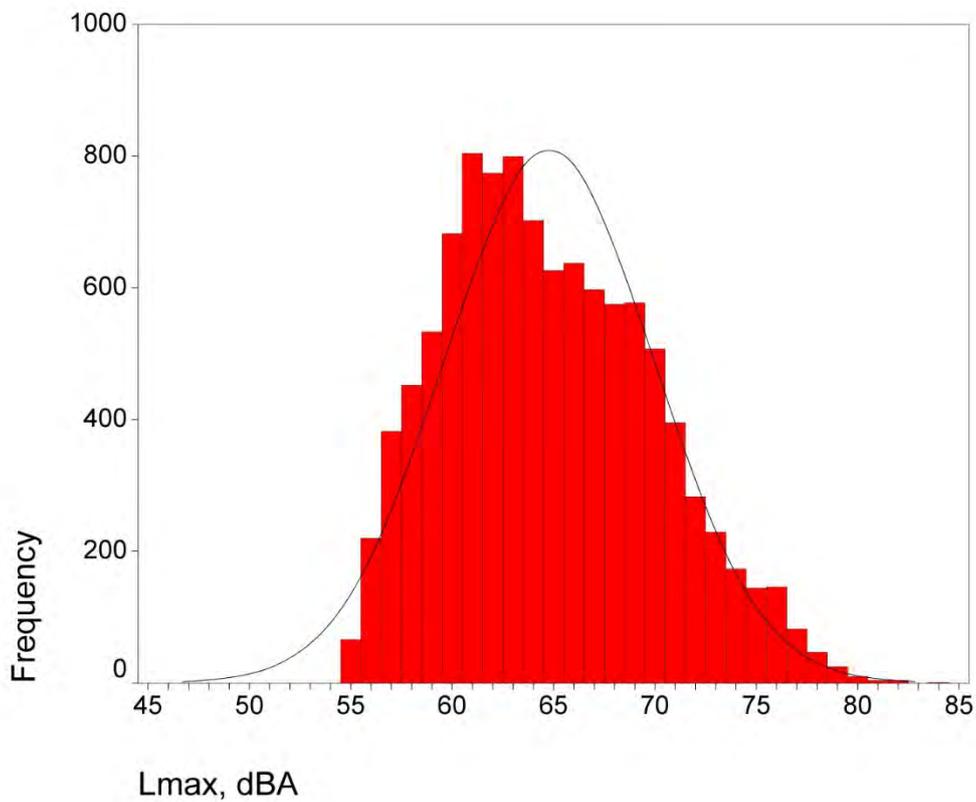
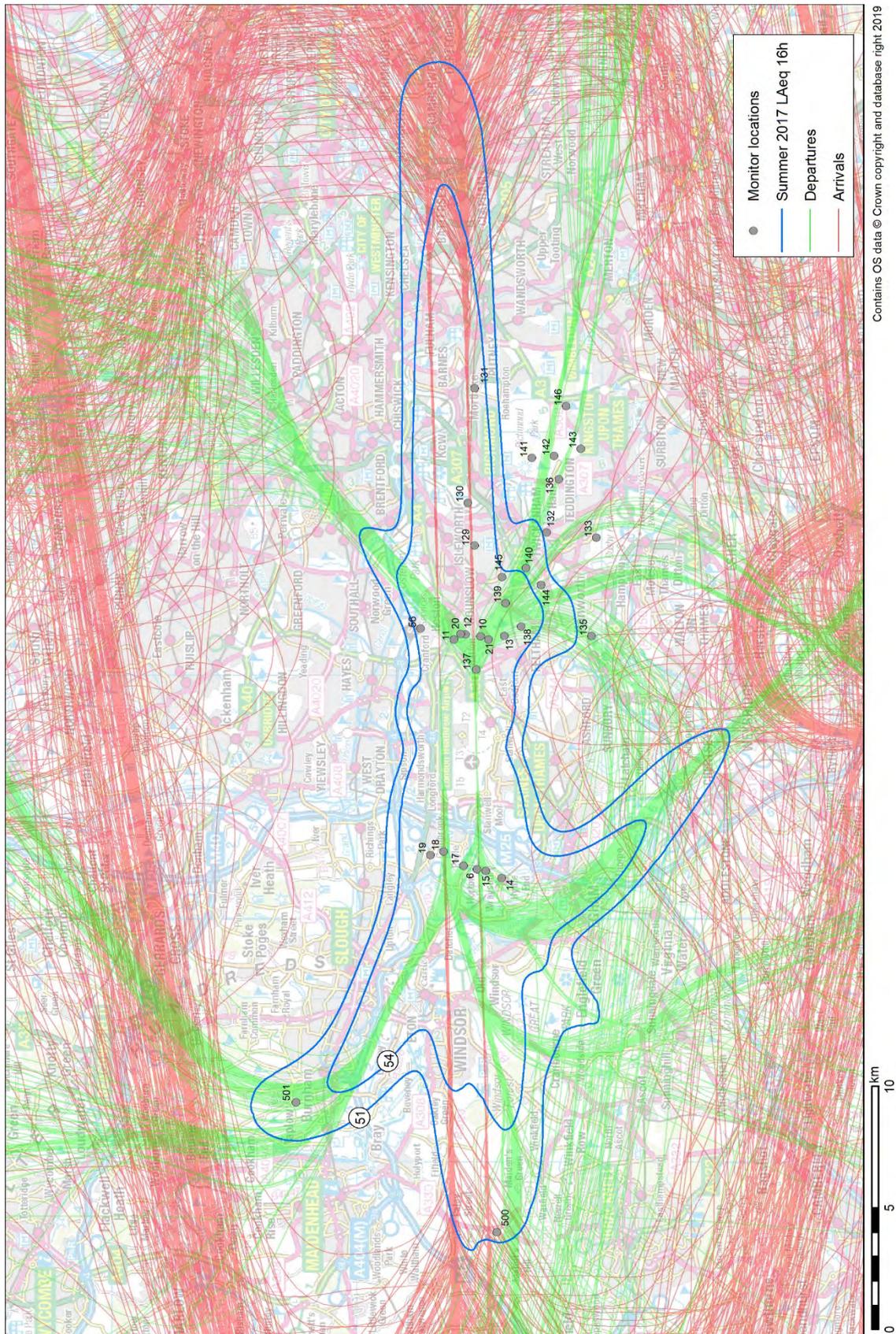


Figure 8 Noise monitoring sites at Heathrow, summer 2017



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Figure 9 Site survey locations near the Bovingdon hold

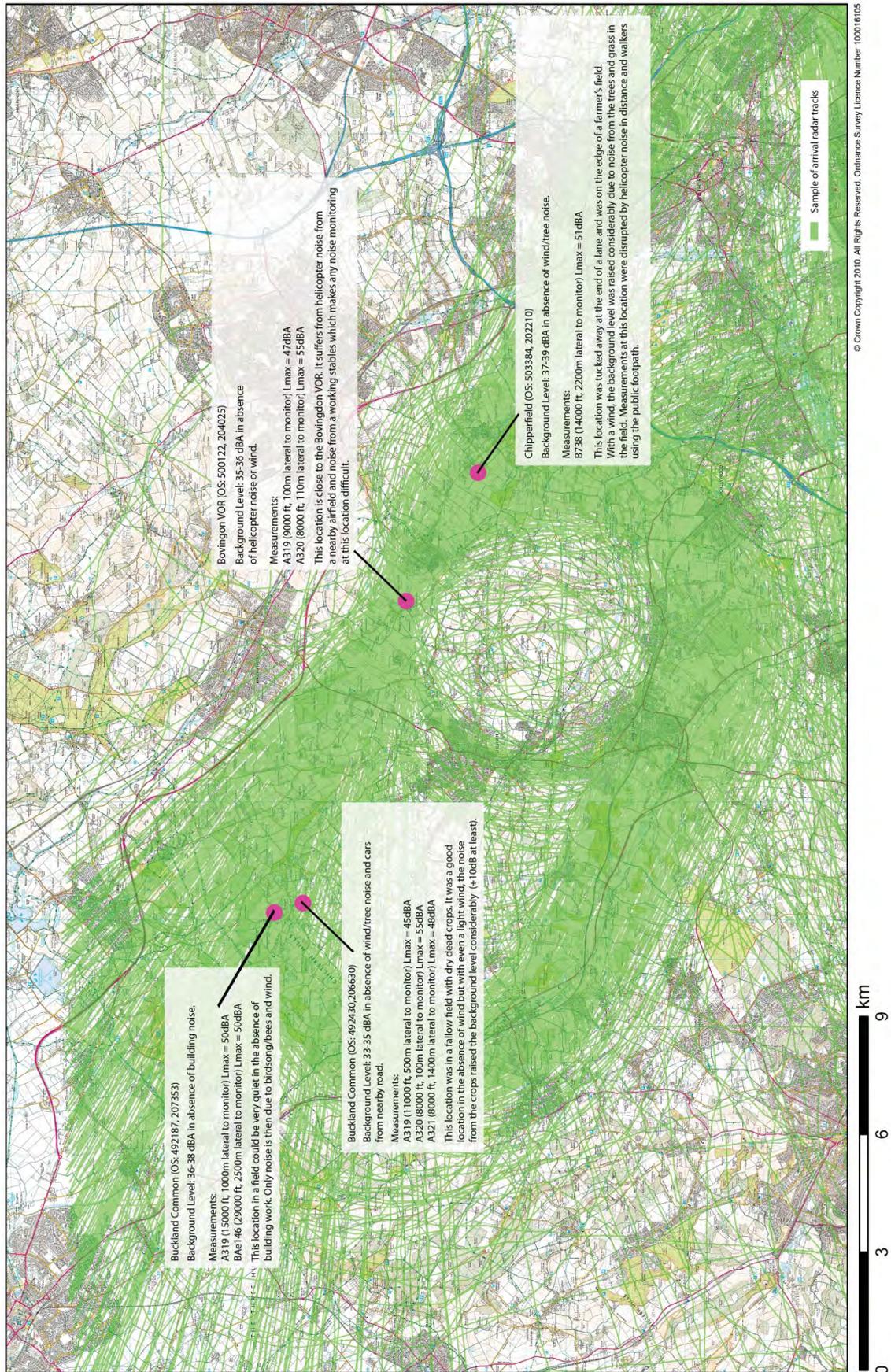
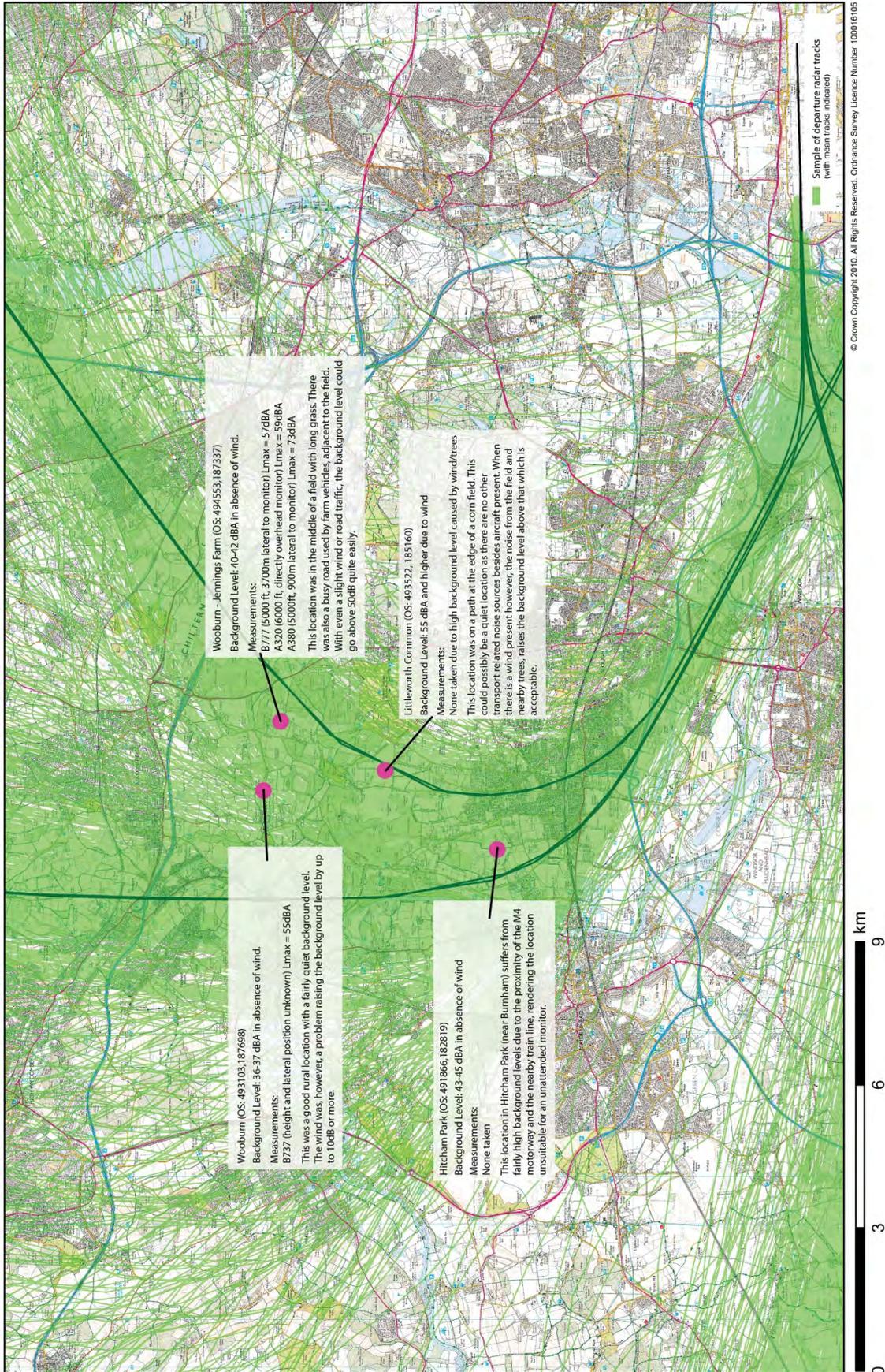


Figure 10 Site survey locations near Heathrow Airport westerly Brookmans Park and Wobun departures



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Figure 11 Site survey locations near the Lambourne hold

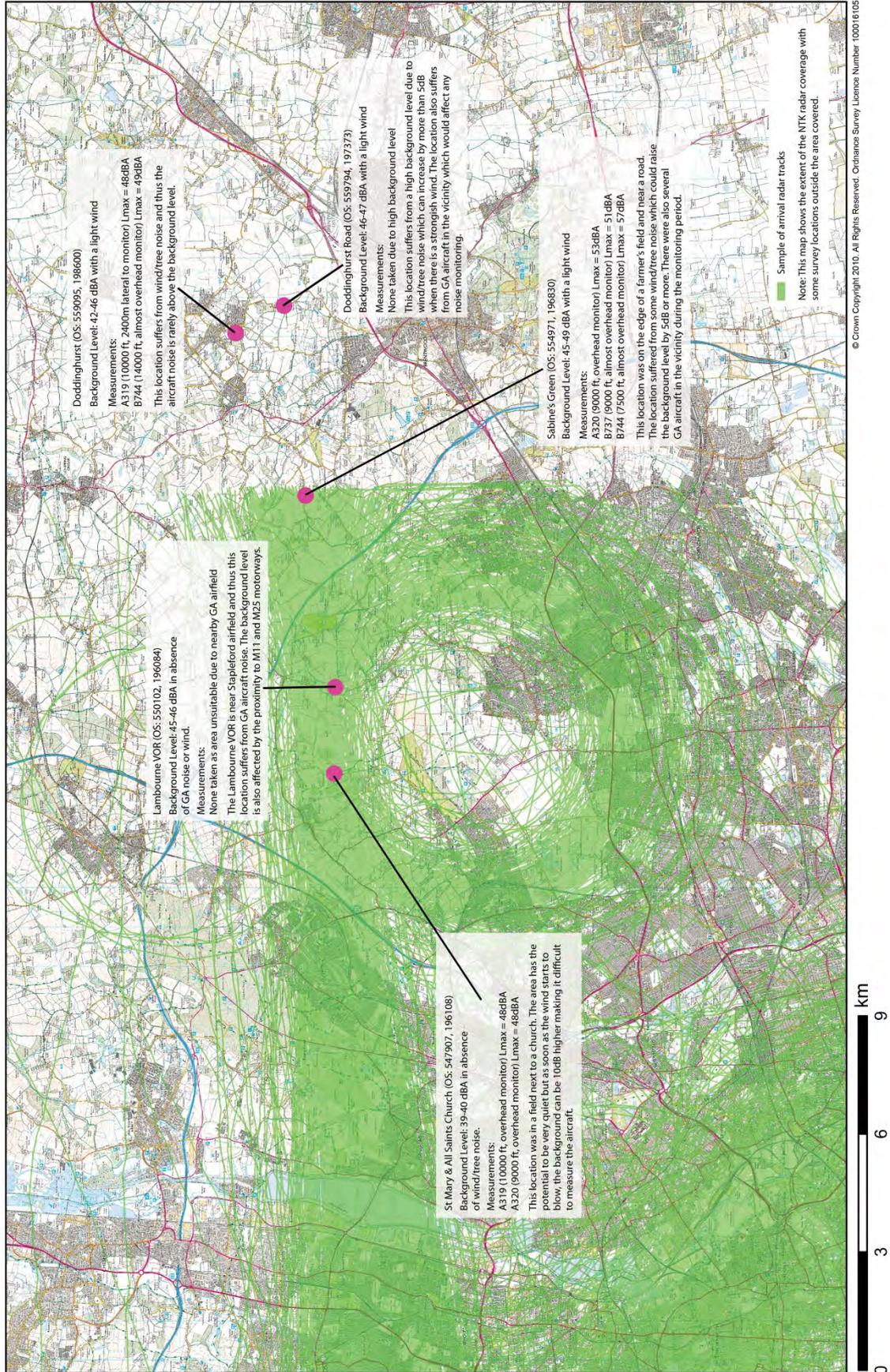


Figure 12 Site survey locations near Gatwick Airport westerly arrivals

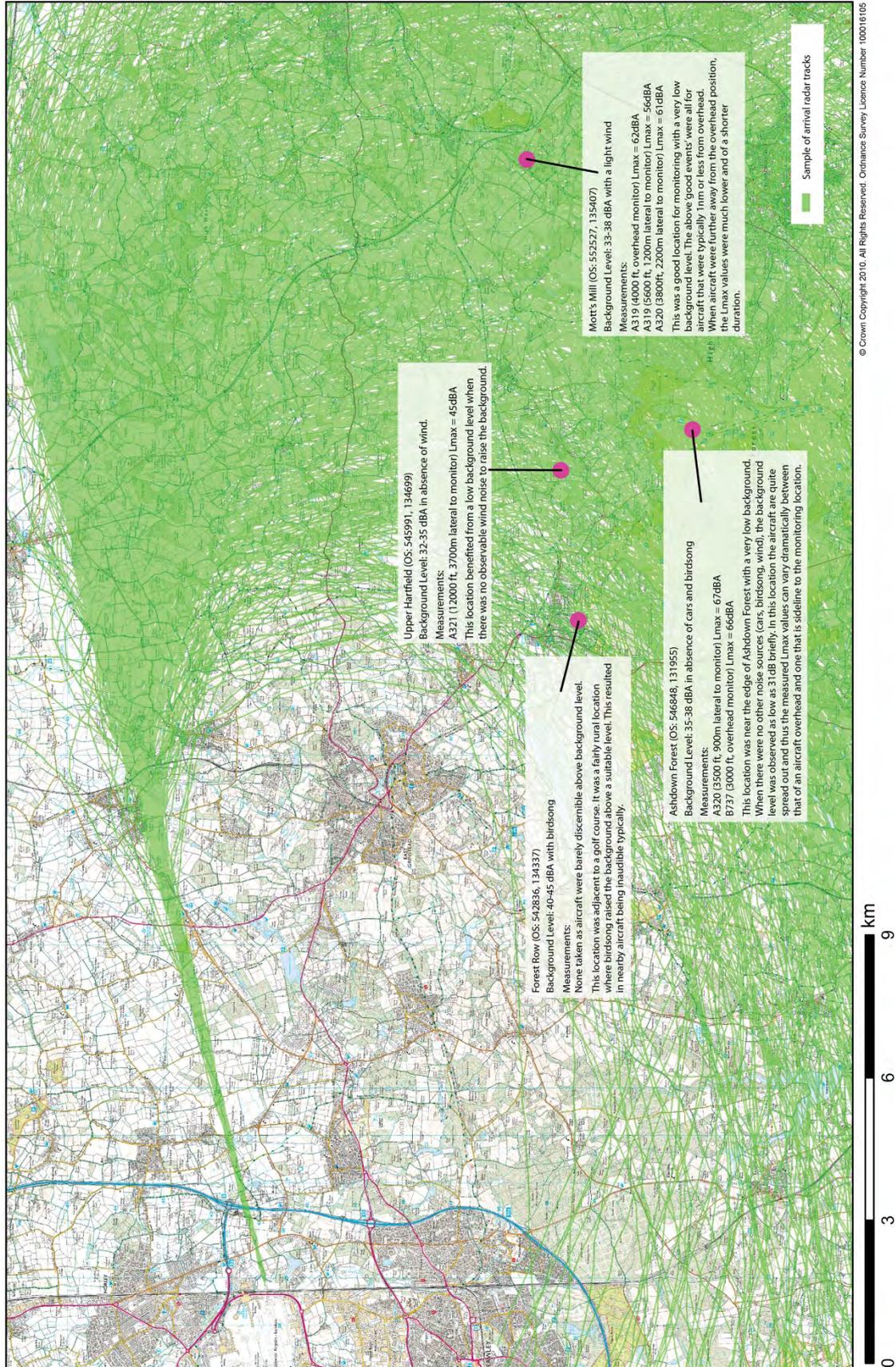


Figure 13 Site survey locations near Stansted Airport south-westerly arrivals

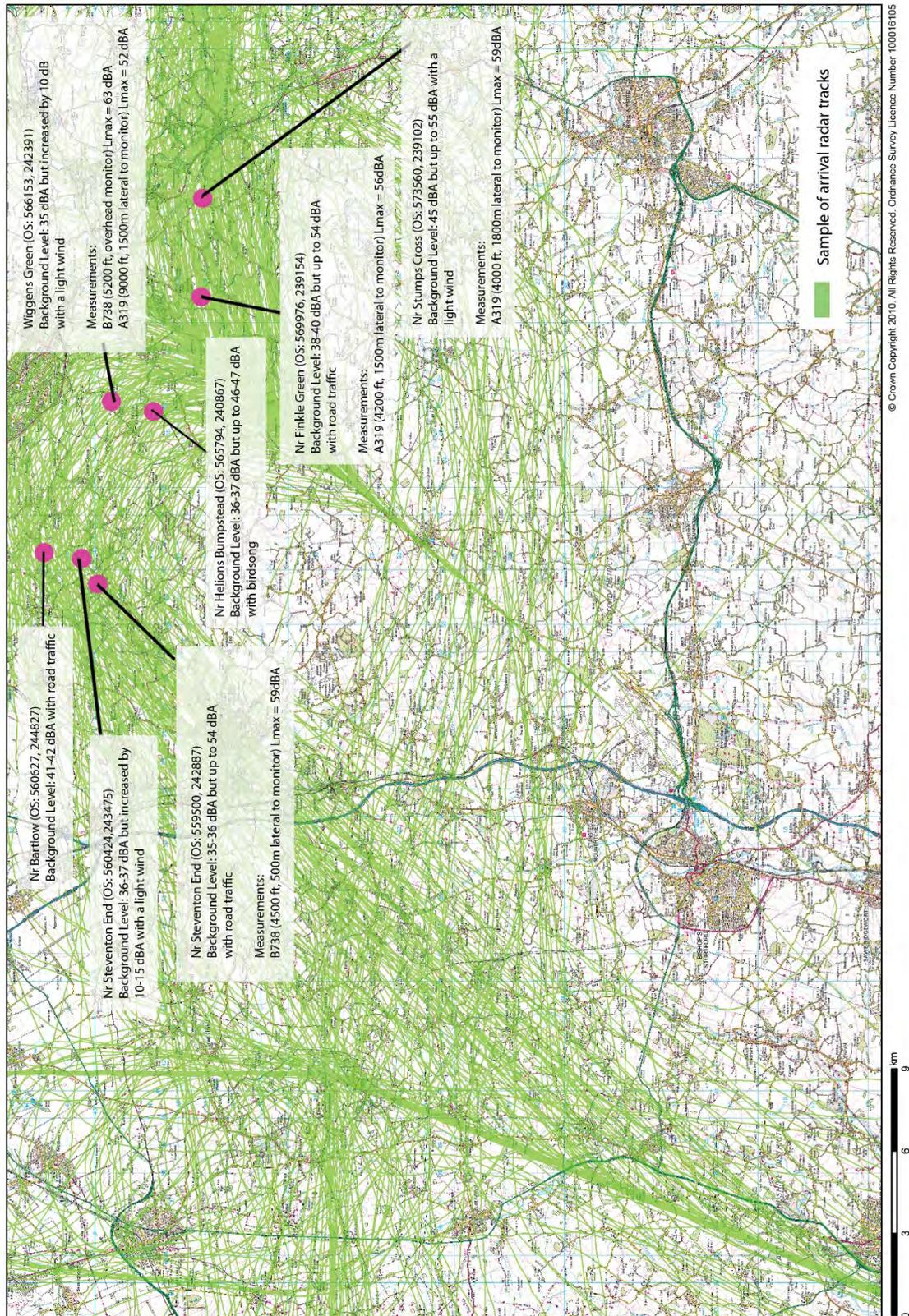


Figure 14 Site survey locations near Stansted Airport north-easterly departures

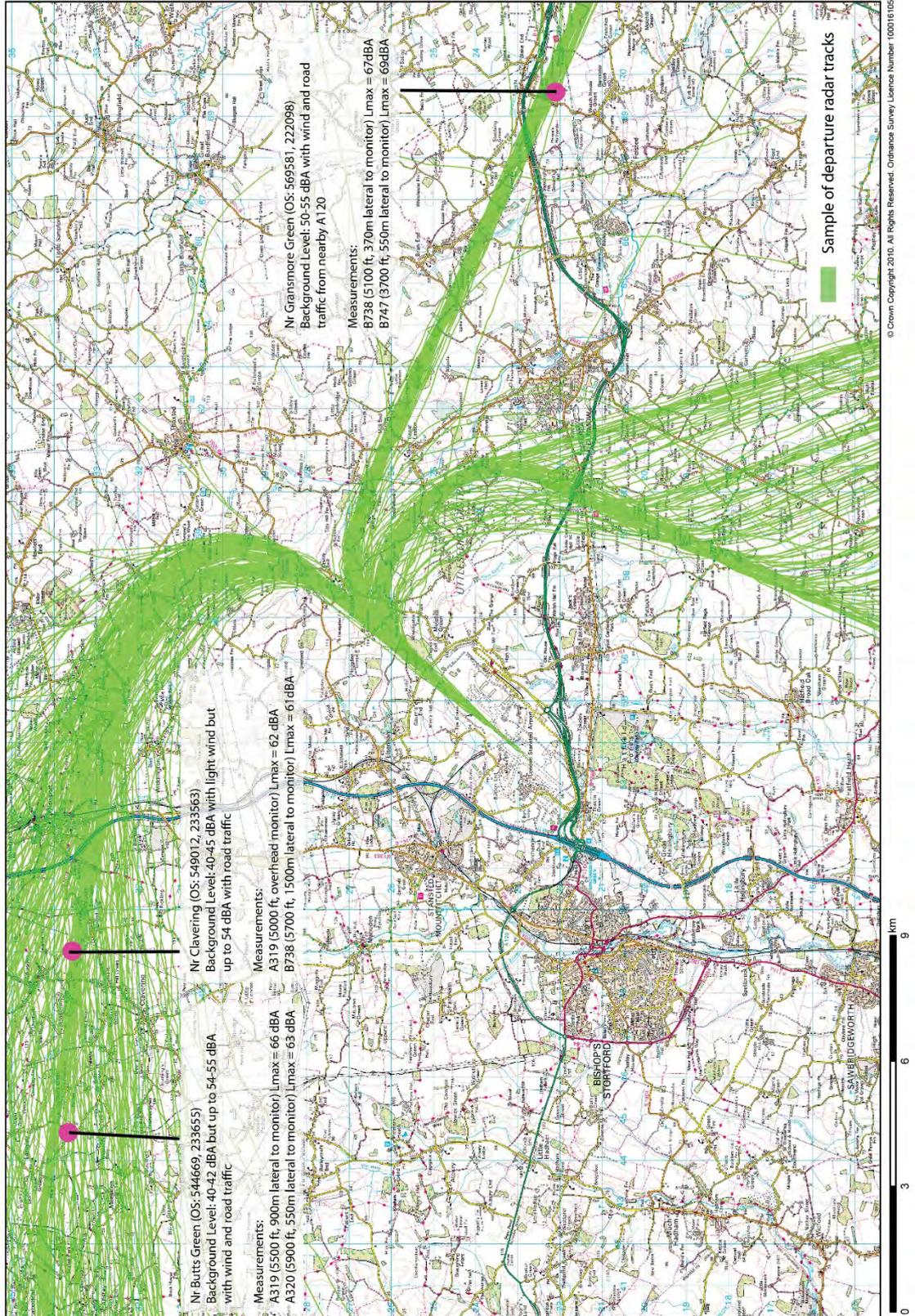


Figure 15 Summary of noise events recorded at the Gatwick Capel monitor between February and November 2009

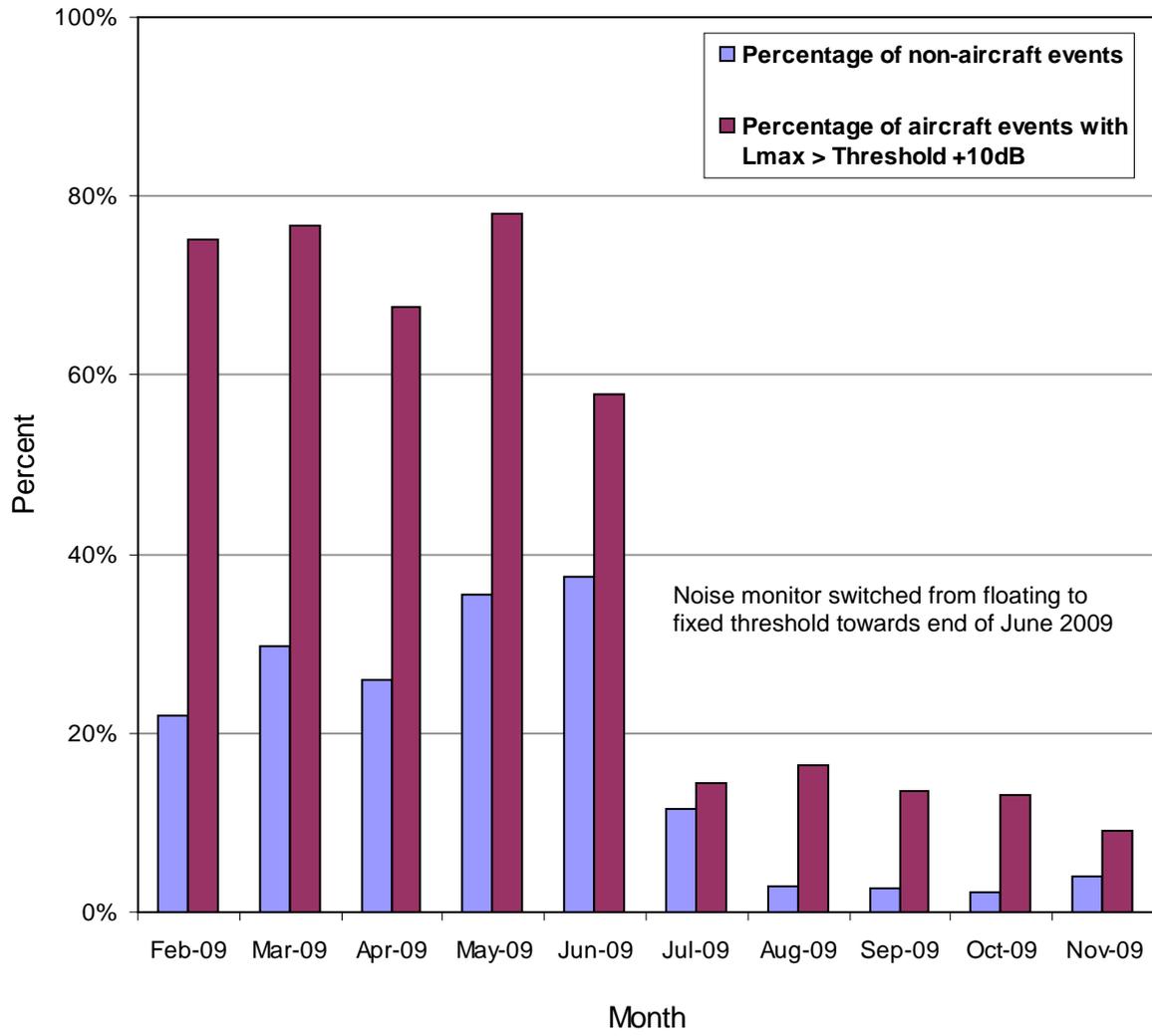


Figure 16 Comparison of mean and dispersed tracks versus individual radar tracks

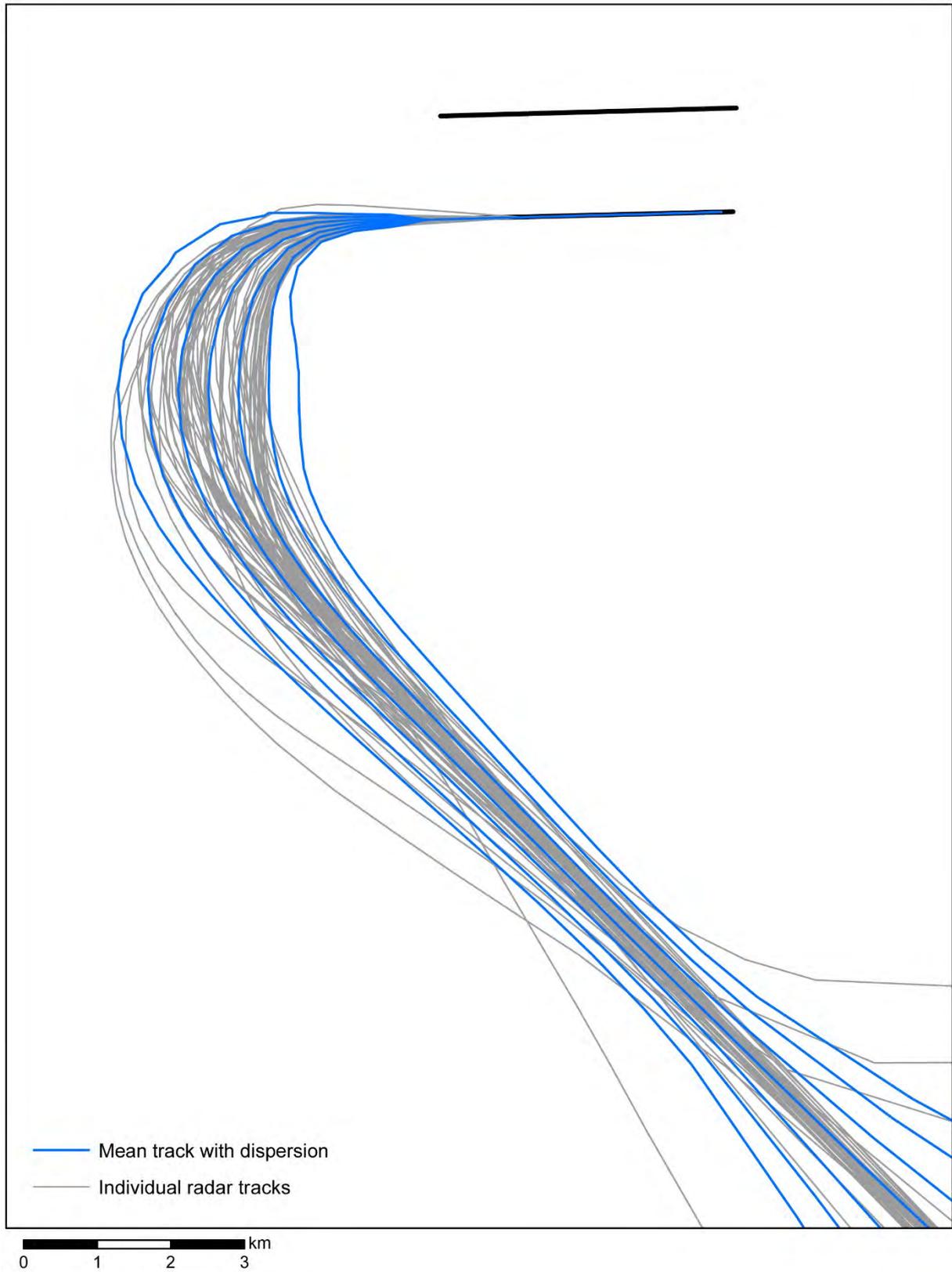


Figure 17 Comparison of contours generated (48 to 54 dBA $L_{Aeq\ 16hr}$)

