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Report for – English Heritage

Aviation Noise Metric - Research on the Potential Noise Impacts on the Historic Environment by Proposals for Airport Expansion in England, Project No. 6865

Final Report

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1.0 Executive Summary

The Airports Commission are currently appraising proposals regarding the future expansion of airport capacity in the South East of England, all of which could lead to changes in aviation noise. This could lead to adverse or beneficial effects on the fabric of heritage assets, the users of the assets and on the setting of heritage assets; all of which could lead to changes in the significance of heritage assets.

Temple Group Ltd (Temple) in partnership with Cotswold Archaeology have therefore been commissioned by English Heritage to develop a methodology to analyse the noise impacts of airport expansion on the surrounding historic environment.

The project includes a literature search and scrutiny of existing methods for the assessment of noise impacts on heritage assets. Additionally the report includes analysis of existing sources of aviation noise information and the specific data published by the Airports Commission to accompany their interim report published in December 2013.

The study identifies that noise impacts on the structure of heritage assets is very unlikely; although resonance induced vibration might intensify the impacts on persons using the asset. The study highlights that existing means of assessing aviation noise can be used to assess the impact on the physical structure of heritage assets and on persons living or working at heritage assets; but there are no established methods for assessing the impact of noise on the setting of heritage assets. The report therefore focuses on this aspect of the study.

The output of the project is a methodology for assessing the impact of aviation noise on the setting of heritage assets that could potentially form part of the Airports Commission's appraisal of their shortlisted proposals for airport expansion. The methodology can be summarised as follows:

1. Use airport noise contours and noise information to identify the spatial scope of the study based on defined absolute levels or changes in noise levels.
2. Use Geographic Information System (GIS) databases to locate heritage assets within the spatial scope of the study.
3. Screen the identified heritage assets into a non-noise sensitive and four noise sensitive categories.
4. Overlay the noise information on the GIS layer with the identified noise sensitive heritage assets.
5. Screen out those heritage assets where a noise impact is unlikely due to the absolute noise levels or change in noise levels not being sufficient to have an adverse effect.
6. Undertake a detailed site specific assessment of the noise impacts on the remaining noise sensitive heritage assets where the absolute noise levels or change in noise levels has been identified as potentially sufficient to have an adverse effect. This detailed appraisal will take into account factors including the following:
    a. The nature, character and level of existing ambient noise levels,
    b. The type of noise sensitive category the asset falls within,
    c. How frequently and for how long the aviation noise is likely to occur,
    d. How high is the absolute level of aviation noise or how big a change in aviation noise is expected,
7. The outcome of the method is an appraisal of whether the impacts of aviation noise or any changes in aviation noise are likely to be beneficial, neutral, or cause substantial harm or less than substantial harm to the setting of heritage assets.

The report includes case studies of the use of the methodology, and describes the assumptions used and the limitations of report. Recommendations are also made for further work that will improve the understanding, assessment and mitigation of aviation noise impacts on heritage assets.

2.0 Introduction

In December 2013 the Airports Commission published a number of shortlisted proposals in regard to the future expansion of airport capacity in the South East of England, which could lead to changes in the intensity and distribution of aviation noise. Potentially this might lead to adverse or beneficial noise impacts on heritage assets, due to effects on the fabric of the buildings; effects on the users of the assets and effects on the setting of the asset; all of which could lead to changes in the significance of heritage assets.

The issue of development pressure on heritage assets is identified in the National Heritage Protection Plan as Activity 2A1 which states:

"Many of England's historic settlements, both urban and rural, are undergoing considerable change. Pace of urban redevelopment and reorganisation of housing provision strategies will have significant impact on heritage. Action will seek to facilitate strategic resource planning and engagement with partners and stakeholders in those places which are (1) undergoing most change, (2) most sensitive to change, and (3) least resourced to manage change. Research on the degree of likely change through planning applications, master planning and other activities, linked to the spatial distribution of heritage assets in those areas, will be used to develop methodologies and tools for guiding sustainable change and minimising negative impacts."

The glossary to the National Planning Policy Framework (NPPF) defines the setting of a heritage asset as:

" The surroundings in which a heritage asset is experienced. Its extent is not fixed and may change as the asset and its surroundings evolve. Elements of a setting may make a positive or negative contribution to the significance of an asset, may affect the ability to appreciate that significance or may be neutral."

The glossary to the NPPF also defines Significance (for heritage policy) as:

" The value of a heritage asset to this and future generations because of its heritage interest. That interest may be archaeological, architectural, artistic or historic. Significance derives not only from a heritage asset's physical presence, but also from its setting."

Clearly, changes to aviation noise affecting a heritage asset have the potential to influence its setting and therefore the significance of the asset; either adversely when noise increases or beneficially when noise decreases. Thereby giving rise to the need for this project. There already exist a number of recognised methods and metrics for assessing the impacts of aviation noise on the health, quality of life and well-being of persons; but nothing similar exists in regard to the setting of heritage assets. Temple Group Ltd (Temple) in partnership with Cotswold Archaeology have therefore been commissioned by English Heritage to develop a methodology to analyse the noise impacts of airport expansion on the surrounding historic environment.

The project includes a literature search and scrutiny of existing methods for the assessment of noise impacts on heritage assets; along with analysis of existing sources of aviation noise information and the specific data published by the Airports Commission to accompany their interim report published in December 2013.

The intended output of the project is a methodology that could potentially form part of the Airports Commission's appraisal of their shortlisted proposals for airport expansion.

3.0 Literature review

The literature review described below covers, firstly how the influence of sound and noise on heritage assets is accounted for in existing national policy and in impact assessment. An overview is given of how airport noise effects are generally assessed and the criteria which are usually applied to determine whether adverse impacts and effects are likely to occur to sensitive receptors. Following on from this an overview is given of the proposed noise assessment as part of the airports commission's appraisal.

There are three potential ways in which a heritage asset may be impacted by noise, these are illustrated below and discussed further in the literature review:

1. Disrupting the fabric of the heritage asset i.e. physical damage;

2. Disturbing persons using the heritage asset;

3. Altering the character and setting of a heritage asset so that its significance is appreciably affected.

Lastly, the concepts of tranquillity and soundscape are discussed as tranquillity can be important to appreciate certain types of heritage asset and research in these areas is helpful to understanding how acoustic and non-acoustic factors may be used to describe and evaluate the noise environment of a location, this can include both qualitative and quantitative factors.

The literature search has used the following resources, including books, journals, articles, databases and internet articles:

- The Institute of Acoustics Library
- Bristol University Library
- http://academic.research.microsoft.com/
- http://scholar.google.co.uk/

3.1 Heritage Policy and Noise

No national planning policies or guidance documents discuss specifically the contribution of sound to the significance of heritage assets or the potential harm that noise could cause; although the potential for noise to harm setting is recognised in English Heritage's guidelines for "The Setting of Heritage Assets" and case law[1] recognises that non-physical or indirect harm can be caused to setting. However, a large corpus of literature exists relating to impact assessment and heritage assets, and ways of defining concepts such as 'sense of place', 'setting' and 'significance'. Heritage guidance has increasingly moved away from simple quantitative assessment (number of specifically designated assets impacted) to a more intelligent, qualitative understanding of what matters, to whom, and why and how that will be affected, and whether it matters.

[1] E.g. Bedford Borough Council v Secretary of State for Communities and Local Government & NUON UK Ltd Second [2013] EWHC 2847 (Admin)

There is no doubt that absence of noise[2] and the presence of sound contribute to the sense of place or setting of many heritage assets, whether through accident or design. For example, churchyards, burial mounds, ruined buildings can all have a very distinct sense of place which is at least partially the result of the absence, or at least recession, of the invasive sounds of day-to-day modern life.

Consequently, it is considered that there is scope for discussion of noise and sound impacts upon heritage within the existing legal framework enshrined in the NPPF and other documents. **Appendix 1** expands on relevant sections of the existing heritage policy guidance and discusses how these are applicable to sound and noise issues.

3.2 Impact assessment considering noise and heritage

A web based search was carried out to identify heritage impact assessments which included an aspect of noise assessment, specifically of aircraft noise, using the resources described above.

This has produced no specific aviation noise heritage impact assessments. Heritage or Cultural Heritage is not an uncommon topic in Environmental Statements (ESs) for a range of developments; and a minority of these ESs include consideration of noise impacts on heritage assets. However, none of the schemes identified used detailed noise level information or more precisely developed specific noise level criteria as part of their assessment. They tend to use the absence of anthropogenic, i.e. man-made, noise in the baseline or it's presence in the with development scenario as a simple pass or fail test to the significance of noise impacts on heritage assets.

Specifically in regard to large scale infrastructure projects, examples of relatively recent assessments that considered noise impacts on heritage assets include those for the HS2 London to West Midlands Appraisal of Sustainability and Environmental Statement, and the Generation 1 proposals for increasing the number of flights at Stansted airport.

The search revealed that there is precedent for noise impacts on heritage assets to have a substantial role in decision making regarding development proposals in a minority of cases. For example in 1997 the secretary of state refused permission for an increase in flight numbers and changes to Liverpool airport, largely on the basis of noise impacts on listed buildings outside the airport perimeter (Speke Hall) and even within the airport perimeter (the disused control tower and 2 listed hangars).

3.3 Aircraft Noise Impact Assessment

Aircraft noise impact assessment in the UK generally focuses on the impact on people. This focuses on the potential for annoyance due to noise at dwellings, inside in habitable rooms and outside in gardens etc. There is also the potential for sleep disturbance due to high levels of aircraft noise in bedrooms. Recent studies have also linked aircraft noise to impacts on children's cognitive development and direct health effects such a [redacted].

In general, aviation noise impact assessment follows the procedure of identifying noise sensitive receptors; predicting the noise level from aircraft at the receptor; and assessing whether the impact

[2] Noise is often defined as "unwanted sound".

leads to a significant effect, such as those described above, either by looking at the potential change in noise level or whether the predicted noise level exceeds a defined threshold.

3.3.1 Airport Noise Prediction

In the UK, two noise models are used to predict airport airborne noise, ANCON (Aircraft Noise Contour model) developed by the Civil Aviation Authority and INM (Integrated Noise Model) from the United States Federal Aviation Authority. Both models use physical characteristics of the airport and information on the numbers and types of aircraft that use the airport to predict noise levels at specific receptors and at points on a grid of varying dimensions. Noise contours can be plotted using the results of the predictions made using these models. Noise contours are lines on a map indicating regions of equal predicted noise level, similarly to height contours which indicate areas of equal height in a landscape.

Noise modelling means calculating noise exposure rather than measuring it. Calculating some aircraft noise characteristics from purely theoretical scientific principles is feasible, but it would be far too complex and computationally intensive for application in the routine production of noise contours. Instead, relatively simple mathematical tools combined with empirical data about the generation and propagation of aircraft noise from a large body of measured data is used.

Airport noise modelling methodology usually comprises three main phases. Firstly, aircraft operations data regarding the number of air traffic movements (ATMs) and types of aircraft that use the airport is obtained e.g. from Air traffic Control (ATC); and used to determine the annual average summer day traffic for the day and night calculation periods. Secondly, flight tracks and associated lateral dispersions are derived from ATC radar information for each departure and arrival route, again for each of the time periods. Thirdly, average flight profiles of height, speed and thrust were generated from the ATC radar data for the noise dominant aircraft types, for departures and arrivals, also for each of the time periods. Flight profiles for the less noise significant types, which would have had little or no effect on the contours are typically aggregated into single or several representative aircraft types.

The International Civil Aviation Organisation (ICAO) and the European Civil Aviation Commision both provide guidance and standards for airport noise modelling with the aim of promoting uniformity so that authorities can be confident in the modelling process and apply the same degree of stringency in accepting the output of compliant systems for assessment procedures. The UK Department of Transport and the Civil Aviation Authority both recognise and contribute to the ICAO and ECAC guidance as the UK is a founder member of both bodies and is a signature to the international treaties covering the environmental impacts of aviation.

Airport Noise Model Methodologies

The fundamental elements of the noise modelling system are illustrated in figure 1 below. The noise model may be thought of as a “black box” which operates on input data describing the scenario - the airport and its air traffic - to produce an output in the form of sound levels of specified noise metrics at discrete points (usually on a calculation grid). These values are the inputs to a post-processor which performs further analysis such as contour generation.

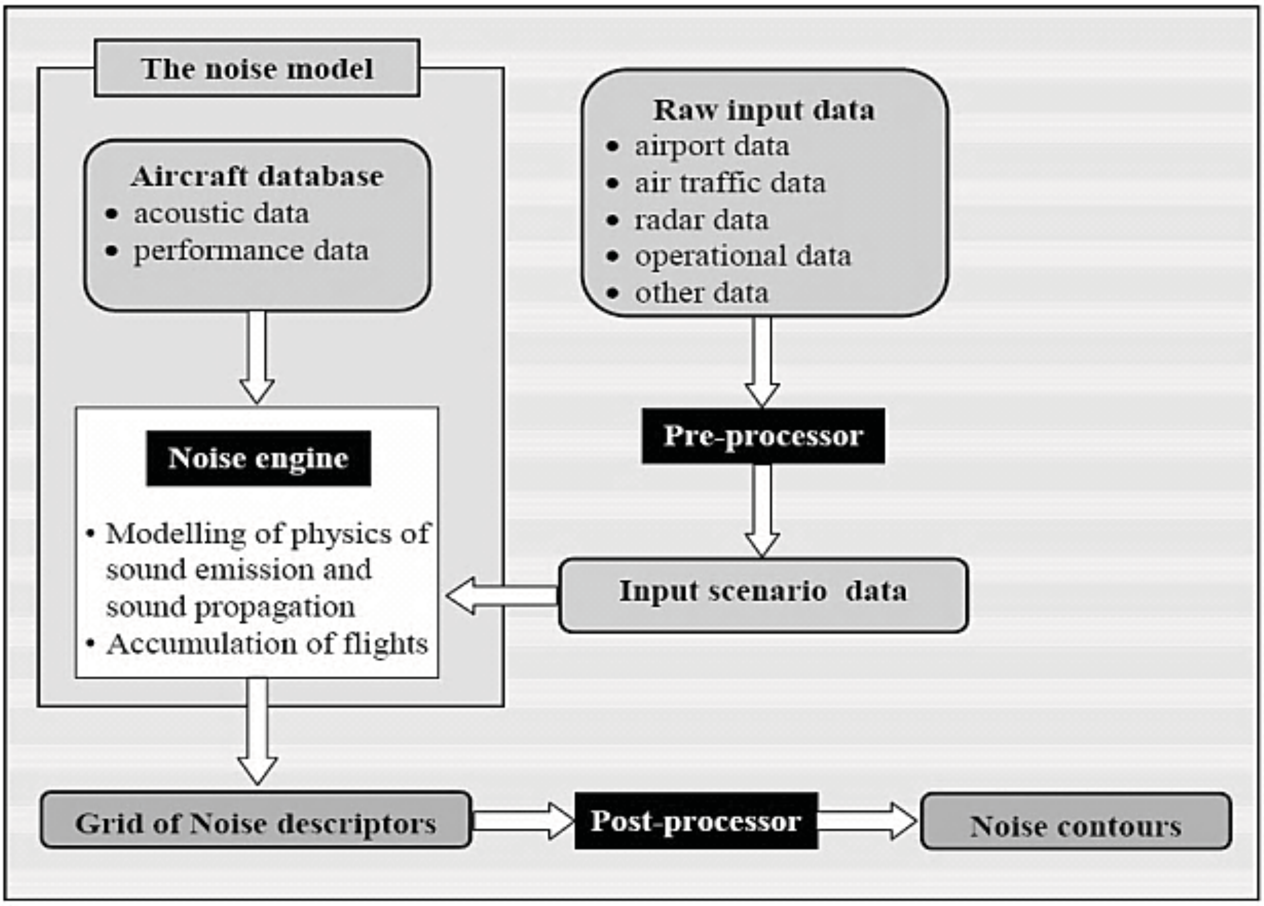


Figure 1- Elements of an Airport Noise Modelling System

Source: ECAC.CEAC Doc 29, 3rd Ed, Vol 1.

Air traffic is broken down into aircraft types or categories with different noise and performance characteristics which are stored in the aircraft database. To minimise computation, individual aircraft types having very similar noise and performance characteristics can be grouped into representative categories. Existing models use between about 10 and 200 categories. However grouping is not necessary if individual flight path information (e.g. from radar track keeping) and adequate noise data are available.

Airport Noise Modelling Approaches

The different ways of approaching along-path integration divide noise modelling algorithms into the three different types:

- Closest Point of Approach (CPA)
- Segmentation
- Simulation

CPA models were developed before the widespread adoption of time-integrated noise metrics to calculate noise descriptors. Their algorithms were relatively simple, being based on the assumption that, for given source characteristics, the peak noise level L_{max} depends only on the shortest distance between aircraft and receiver (i.e. time integration was not required). Although they have been adapted to handle integration based descriptors e.g. L_{eq}, they have been largely superseded by segmentation algorithms.

Segmentation algorithms are developments of CPA-algorithms which calculate the separate contributions to a time integrate noise metric from all noise-significant flight path segments. All segments are straight; i.e. circular segments are described by a series of chords. However, for segmentation models, assumptions on the directional characteristics of aircraft sound radiation have to be introduced.

A simulation model describes the real flight path of an aircraft by a series of discrete points in space which are passed by the aircraft after successive small intervals of time. (This is similar to a segmentation model with small segment lengths) The noise level-time-history at any specific observer location is then constructed by calculating the sound radiated towards it from each flight path point. With this method any noise metric can be derived. Two disadvantages of simulation modelling are heavy demands on computer processing power and time, and the need for very detailed acoustic input data, including information on the 3-D directional characteristics of the source noise, perhaps as a function of frequency of sound (spectral directivity data) and flight configuration. Such data are currently not available in the quantities needed for day-to-day aircraft noise modelling at different airports.

Thus segmentation models currently represent best practice for general aircraft noise calculation. They provide a reasonable compromise between the requirements on input data and the quality and accuracy of the output produced by the computation algorithm. Moreover, comprehensive databases for such models have been assembled over many years for a large number of different aircraft types.

3.3.2 Aviation Noise Assessment Criteria

Following the recommendations of the Wilson Committee report[3] on noise in 1963, the descriptor chosen for predicting and monitoring aircraft noise at Heathrow Airport was the Noise and Number Index, NNI, which is based upon the Perceived Noise Level, in PNL dB, of an aircraft type; and the number of that type operating into and out of the airport.

After a survey in 1967[4], the Number was defined as the number of aircraft exceeding 80 PN dB during the 12-hour period from 06:00 to 18:00 GMT (07:00 to 19:00 BST) averaged over the summer period from mid-June to mid-September. Consequently, NNI was a long-term average over the summer period. Meteorological conditions and airport operation may cause the short-term noise exposure at particular points over shorter intervals to be different than in this specified period, but use of this period has become a standard approach in assessment of noise impacts from airports.

Given information about aircraft types and a timetable of arrivals and departures, it is possible to predict NNI levels around an airport. Maps showing contours at 5 NNI intervals from 35 NNI upwards were produced for the major airports.

The Wilson Report found that:

[3] Wilson committee report on the problem of noise (1963)

[4] Survey in 1967

- 35 NNI relates to low levels of community annoyance
- 45 NNI to moderate levels of community annoyance; and
- 55 NNI to high levels of community annoyance.

It is important to understand that the above relates to “community annoyance” i.e. the response of a population, and that within the group exposed to aircraft noise at these levels there will be a wide variability in individual subjective response. For example some individuals would be annoyed at NNI of less than 30, and others might not be annoyed at NNI of 55 or over.

However, continued use of the NNI went against the international trend to use $L_{Aeq,t}$ and there were problems in establishing compliance, as NNI cannot be measured directly and has to be calculated from the relatively complex Perceived Noise Level, in PNL dB, of each aircraft. Additionally, unlike $L_{Aeq,t}$ the NNI was not easily comparable with other national systems and was only valid for Heathrow for which it was formulated. Also it ignored all noise events that are just under 80 PNL dB, and it makes no allowance for the duration of individual noise events or for the degree to which the noise levels exceeds 80 PNL dB.

In order to address issues with the use of NNI the United Kingdom Aircraft Noise Index Study (ANIS)[5], undertaken in 1982, was commissioned by the Department of Transport. The study and its findings were published by the Directorate of Research of the Civil Aviation Authority in 1985 as DR8402 United Kingdom Aircraft Noise Index Study. Areas, each approximately 1km^2 were identified for surveying: 18 in the vicinity of Heathrow; 2 at Gatwick; and one each at Aberdeen, Luton and Manchester airports.

The survey used the Guttman Annoyance Scale (GAS) and found that $L_{Aeq,24h}$ had a slightly better correlation than NNI with perceived annoyance/disturbance averaged over the three summer months, mid-June to mid-September.

In 1986, the Department of Transport undertook a consultative exercise involving all interested parties such as: Local Authorities; airport operators; airline companies; Members of Parliament etc. Responses and comments appeared in the DORA Report 9023 *‘The use of L_{eq} as an Aircraft Noise Index’* (1990)[6].

The UK ANIS report had previously established the relationship between NNI and $L_{Aeq,24h}$ to be:

- 35 NNI is equivalent to 57 dB $L_{Aeq,24h}$ (low levels of community annoyance)
- 45 NNI is equivalent to 63 dB $L_{Aeq,24h}$ (moderate levels of community annoyance)
- 55 NNI is equivalent to 69 dB $L_{Aeq,24h}$ (high levels of community annoyance)

Based on the findings of the UK ANIS and the DORA 9023 reports the above were proposed as impact assessment criteria. However, it was felt that $L_{Aeq,24h}$ would be too radical a change from the 12-hour basis of NNI and therefore the following indices were proposed as these periods aligned with those in PPG 24[7] – the then current Ministerial advice on Planning and noise:

[5] The ANIS report can be viewed at: http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=1441 (viewed at 7th May 2014)

[6] The DORA 9023 report can be viewed at http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=761 (viewed at 7th May 2014)

[7] PPG 24 (1994)

- $L_{Aeq,16h}$ for 07:00 to 23:00 (day)
- $L_{Aeq,8h}$ for 23:00 to 07:00 (night)

In order to correlate with the then current ministerial advice on planning and noise PPG24, it was then proposed that these criteria are referenced over the following time periods:

- 57 dB $L_{Aeq,16h}$ (low levels of community annoyance)
- 63 dB $L_{Aeq,16h}$ (moderate levels of community annoyance)
- 69 dB $L_{Aeq,16h}$ (high levels of community annoyance)

The above values are now incorporated in the current Aviation Policy Framework[8] as follows:

Para 3.17 - "*We will continue to treat the 57dB L_{Aeq} 16 hour contour as the average level of daytime aircraft noise marking the approximate onset of significant community annoyance. However, this does not mean that all people within this contour will experience significant adverse effects from aircraft noise. Nor does it mean that no-one outside of this contour will consider themselves annoyed by aircraft noise.* "

Para 3.36 – "*The Government continues to expect airport operators to offer households exposed to levels of noise of 69 dB L_{Aeq},16h or more, assistance with the costs of moving.* "

3.37 – "*The Government also expects airport operators to offer acoustic insulation to noise-sensitive buildings, such as schools and hospitals, exposed to levels of noise of 63 dB LAeq,16h or more. Where acoustic insulation cannot provide an appropriate or cost-effective solution, alternative mitigation measures should be offered.*"

3.4 Airports Commission Information

The Airport Commission has released a summary and main report on their Appraisal Framework[9] for assessing the options from their interim report. The sections on noise and place of the main report are most relevant.

The shortlisted options from the interim report are as follows:

- Gatwick Airport:
  - Gatwick Airport Ltd's proposal for a new runway to the south of the existing runway
- Heathrow Airport (two options):
  - Heathrow Airport Ltd's proposal for one new 3,500m runway to the northwest of the existing runways
  - Heathrow Hub's proposal to extend the existing northern runway to at least 6,000m, enabling the extended runway to operate as 2 independent runways.

In regard to an option for a new airport in the Thames estuary the Airport Commission stated the following in their interim report:

"*The Commission has not shortlisted any of the Thames Estuary options because there are too many uncertainties and challenges surrounding them at this stage. It will undertake further study of*

[8] Aviation policy framework (2013)

[9] Airports commission appraisal framework

the Isle of Grain option in the first half of 2014 and will reach a view later next year on whether that option offers a credible proposal for consideration alongside the other short-listed options."

The Airport Commission appraisal framework sets out how the appraisal will be done and confirms the information that will be produced.

The system wide base case to be considered for the assessment would be in relation to a 'do-minimum' scenario which will capture the predicted future levels of airport traffic at different airports, and the areas of land and numbers of houses contained within stated noise levels without any of the short listed options in place. The do-minimum will also account for predicted fleet mix and technological improvements to the aircraft fleet. The appraisal will then develop future "do-something" scenarios for each of the short listed options which also account for predicted fleet mix and technological improvements to the aircraft fleet. The assessment of the impacts will then be based on comparison of the do-minimum and do-something scenarios and the overall modelling assessment will progress in the following stages:

- an assessment of aviation noise impacts associated with a scheme (including any other airport sites affected);
- for the local assessment, a high level consideration of changes to surface access noise, modelled where a 25% or greater change in traffic low is expected;
- the estimation of the propagation of emissions from all identified sources, including accounting for local meteorology, within pre-defined study areas;
- an exposure assessment to determine the population and amenities (comprising schools, hospitals, community centres and places of worship) exposed to changes (positive or negative) to the relevant base case;
- an estimate of how the spatial and temporal impacts of airport related ground noise will be minimised through reference to change in air traffic movements and runway location.

The implications of different applications of respite will be fully considered in relation to all of the above.

The information produced form the assessment will include the following noise contours:

- L_{Aeq} - The average summertime noise contours for day (54-72 dB $L_{Aeq,16hr}$) and night (48-72 dB $L_{Aeq,8hr}$),
- L_{DEN} – calculated based on the annual average 24 hour Leq with weightings for evening and night time periods)
- 'Number Above' frequency contours – the N70 and N60 (the number of aircraft in a defined period aircraft exceeding a peak L_{Amax} noise level of 70 dBA at a receptor during the day and 60 dBA at night).

In addition the Airport Commission will also include useful information on the assumptions underlying the noise data in their appraisals e.g. the number and type of aircraft and flight paths etc. that will be helpful in meeting the aims and objectives of this project.

3.5 Noise Affecting Heritage Assets – Physical Damage

If sound energy is assumed to be unlimited, in theory the noise from any source including aircraft could cause physical damage to the structure of a heritage asset provided it is high enough. However, as shown in the table below, the energy content of the loudest sounds likely to occur in even the most extreme circumstances range from very small to small and are insufficient to directly affect the structure of even the most at risk structures.

Table 1: Description of the physical energy associated with specific sound levels from various sources

Situation and sound source	Sound level dB re 10^{-12} W	Sound Power Watts
Threshold of pain	140	100
Machine gun	130	10
Heavy thunder	120	1
Rock concert	110	0.1
Underground Train	100	.01
Large diesel vehicle	90	0.001
Alarm clock	80	0.0001
Noisy office	70	10^{-5}
Quiet office	50	10^{-7}
Quiet home	40	10^{-8}
Broadcast studio	30	10^{-9}
Whisper	20	10^{-10}
Human breath	10	10^{-11}
Threshold of hearing	0	10^{-12}

However, high sound levels in low frequency sound e.g. below 200 Hz, and especially below approximately 80 Hz, can induce perceptible vibration of lightweight building elements. These impacts of low frequency noise can be exacerbated by resonance effects inside a room. Resonances increase the sound level in parts of the room whilst decreasing it in others. For example, a room of dimensions 4m by 5m by 2.5m has low frequency resonances from 34 Hz upwards[10]; therefore the fabric of the structure may be subject to increased noise levels at these frequencies and may exhibit vibration at high sound levels at the resonant frequencies for a particular structure.

Research[11] indicates that high intensity airborne low frequency aircraft noise can induce perceptible vibrations in light weight structures and components of structures e.g. window “rattle”.

A study commissioned by FAA/NASA/Transport Canada[12] showed that windows “known to rattle” would almost always produce audible rattle with peak external aircraft noise levels of 97 dBC L_{max}. An earlier study[13] produced similar results with vibration becoming perceptible in lightweight buildings at peak external aircraft noise levels of 80 to 90 dB. This effect is likely to exacerbate the impact of the aircraft noise on persons inside the building, as it is a “parallel effect” i.e. a simultaneously occurring effect linked to the noise event, likely to draw more attention to the aircraft noise and increase disturbance.

Whilst airborne low frequency noise can induce perceptible vibrations in light weight structures and loose fitting components of structures, the induced levels are typically substantially below levels at which even minor cosmetic damage to buildings and structures may occur[14]. It is also worth considering that whilst high levels of low frequency noise may induce perceptible vibration and parallel effects in light weight structures; the resulting vibration levels are likely to be substantially below those caused by persons walking around the building, using stairs and opening and closing doors etc. However, aircraft noise levels capable of inducing perceptible vibration and parallel effects such as window rattle are only likely to occur at Heritage sites very close to an airport; and are therefore unlikely to change significantly due to the negligible to minor changes in flight paths this close to Heathrow or Gatwick for any of the options at these airports; except for elimination or substantial reduction of the issue if an estuary option goes forward.

It is therefore considered highly unlikely that airborne noise from aircraft will cause even cosmetic damage to heritage assets and as a result is scoped out of this study and will not be considered further.

3.6 Noise Affecting Heritage Assets – Human Response

The second effect of aviation noise considered in the study is disturbing persons using, living or working at the heritage asset. For example, causing speech interference, inducing annoyance and

[10] A Review of Published Research on Low Frequency Noise and its Effects - Report for Defra by Dr Geoff Leventhall Assisted by Dr Peter Pelmear and Dr Stephen Benton (2003) see http://www.defra.gov.uk/environment/noise/research/lowfrequency/pdf/lowfreqnoise.pdf

[11] Building damage due to aircraft noise induced vibration, N Broner, Internoise 1992, Tototonto Canade, Pgs 687-690.

[12] Low Frequency Noise Study prepared byKathleen K. Hodgdon, Anthony A. Atchley, Robert J. Bernhard, April 2007 REPORT N0. PARTNER-COE-2007-001.

[13] Harvey H. Hubbard, Noise Induced House Vibrations and Human Perception, Noise Control Engineering Journal, September-October 1982.

[14] BS 5228:2009 advises that the threshold of perception of vibration lies typically in the Peak Particle Velocity range of 0.14 mm·s−1 to 0.3 mm·s−1. Whereas BS 7386 advise vibration levels, below which damage is unlikely to occur in 95% of buildings. For cosmetic damage, the standard advises the level is 15 mm/s at 4 Hz, increasing to 20 mm/s at 15 Hz, increasing to 50 mm/s at 40 Hz and above. Minor structural damage is possible at vibration levels twice those given, major damage at four times the levels given.

disrupting rest and recreation. Also disrupting use of the asset e.g. teaching and educational uses, use of the asset for performance activities, and use of the asset as a place of worship etc.

The auditory effects of noise such as hearing loss from long term exposure to high levels of persistent noise e.g. noise in heavy industrial work places, or short term exposure to very high levels of impulsive noise e.g. shooting/explosions, has been recognised as a hazard to hearing for a long time. However, this is normally only a risk in occupational situations where long term exposure to high levels of noise may occur; as noise levels in the environment are rarely sufficient to pose a substantial risk of hearing damage. However, there are also non-auditory effects of noise including effects on cardiovascular function ([redacted] and hypertension), and changes in breathing, annoyance, sleeping problems, disruption of communication and activity interference. This wide range of effects has led researchers to believe that noise has the ability to act as a generalised non-specific stressor leading to health effects.

More information on the impacts of aviation noise and its assessment is provided in Appendix 2 of this report

Annoyance due to aviation noise

Annoyance[15] due to aviation noise is commonly used as the overarching effect used to appraise all its impacts except sleep disturbance.

Extensive research into noise annoyance and disturbance over many decades has shown that although average long-term effects e.g. annoyance, can be determined by asking a representative sample of a population to rate their individual annoyance on a numerical or category scale such as 'not annoyed, 'a little annoyed', 'moderately annoyed or 'annoyed very much', these responses tend to be only weakly linked with the degree of sound exposure. This modest correlation reflects very large differences between individuals' reactions to the same noise (due to the modifying non-acoustic factors such as attitude to the noise maker, personality traits, perception of control over the noise and noise sensitivity etc.) rather than a failure of experimental design.

The **Figure 2** below shows an indicative chart of the 'percentage highly annoyed' of a sample of a population plotted against noise exposure level based on data from numerous social survey studies of aircraft noise carried out in different countries[16]. Each point in the diagram represents the response of a sample of respondents exposed to a particular level of noise. The curve is a 'best fit' to the scattered data points, and the general shape has been re-confirmed more recently[17] by further research which shows the similar scattering of data points.

[15] The WHO guidelines for Community Noise (2000) provide a definition of noise annoyance as "*a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Lindvall & Radford 1973; Koelega 1987)"*.

[16] Schultz, T.J: Synthesis of Social Surveys on Noise Annoyance J. Acoust. Soc. America, 64, 377-405, 1978; Fidell, S., Barber, D.S., Schultz, T. J: Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise. J. Acoust. Soc. America, 89, 221 - 233, 1991.

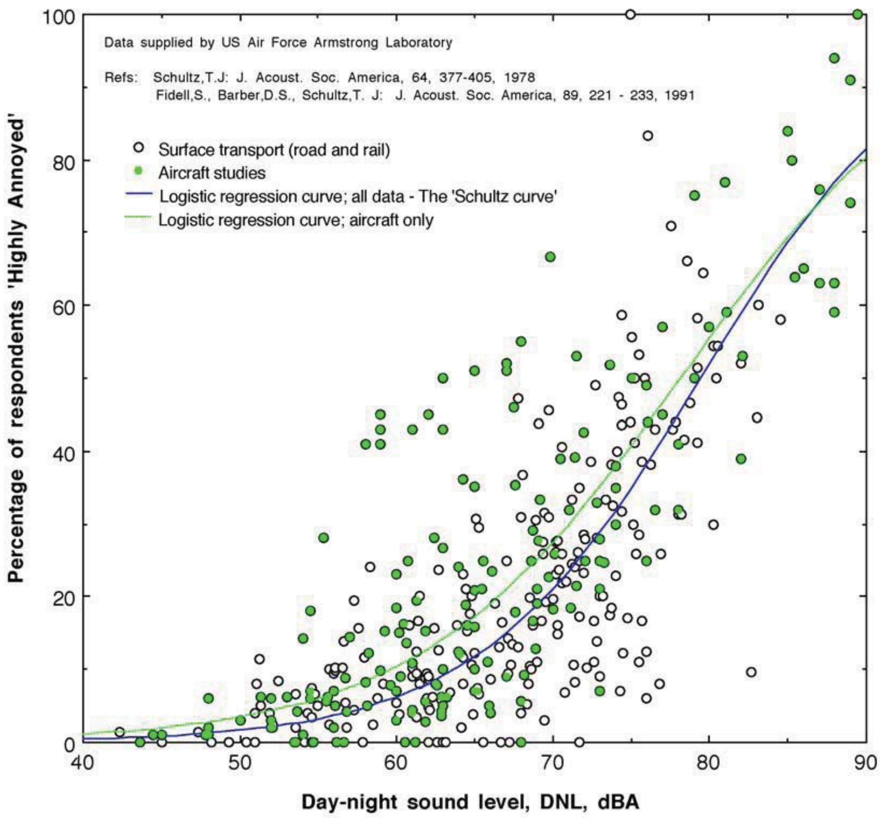
[17] Fidell, S. (2003). The Schultz curve 25 years later: A research perspective. J. Acoustical Society of America 114(6), 3007-3015; Fidell, S. & Silvati, L. (2004). Parsimonious alternative to regression analysis for characterizing prevalence rates of aircraft noise annoyance. Noise Control Engineering Journal, 5(2), March/April, 56-68; and, Miedema, H. M. E., Vos, H. (1998) Exposure response functions for transportation noise. Journal Acoustical Society of America 104, 3432-3445.

The purpose of reproducing this chart here is to illustrate how a statistical estimate of the underlying trend between annoyance and the noise index can be developed for a population as a whole, even though the scatter of data i.e. the variability of individual sensitivity is high; as shown by the deviation of individual points from the trend line.

Environmental noise assessment is not sufficiently precise, primarily due to the substantial variation in sensitivity to noise across a population, to enable the subjective reaction of individuals to be confidently predicted. Consequently, event noise levels and noise exposure contours only provide indications of the likely extent and severity of the general effects of aircraft noise on communities, but due to the significant variability and volatility of individual subjective response to noise, and the significant influence of non-acoustic factors on these traits, they cannot indicate accurately how particular individuals will react.

Despite these limitations, the curve in **Figure 2** illustrates the probable form of the relationship between noise exposure and community annoyance. It aggregates results from many surveys in different countries and may be considered typical, if not average. The main application of current aircraft noise assessment methodology is in comparing the effects of different noise exposures that might result from changes to an airport and its operations (or between different possible future scenarios). It is usual practice to compare, for the *current* and *future* situations, the numbers of people residing between noise exposure contours depicting low (e.g. < 57 dBA), moderate (e.g. >57<63 dBA) and high (e.g. >63 dBA) levels of exposure ($L_{eq,16\ hrs}$); and thus determine the corresponding changes in the extent of annoyance in the community. This, broadly, is the approach adopted in the Airport Commission's appraisal framework.

Figure 2:- Incidence of Community Annoyance due to Aircraft Noise from Social Survey Data



Note: Fig. 2 source – CAP 725 CAA Guidance on the Application of the Airspace Change Process Airspace Change Proposal - Environmental Requirements

Influence of non-acoustic factors

Many studies show that the issue of assessment of the impact of aviation noise is complicated by the influence of non-acoustic factors, some of which have concluded that:

- In regard to noise management at Heathrow airport: "*Non-acoustic factors in environmental noise can be broadly defined as all those factors other than noise level alone which contribute to noise annoyance and similar effects.*[18]
- In regard to changes in flight paths for the East Midlands Airport: "*Those of a higher socio-economic status and average income were shown to have a higher propensity to complain and a further disassociation between noise and complaints was seen in the capacity for media coverage to induce a higher rate of complaint. Finally, serial complainants exhibited very different complaint behaviour and influenced overall trends. Therefore, the evidence shows that many factors in addition to noise can impact the pattern of complaints.*" [19]
- In regard to a study involving Manchester, Lyon and Bucharest Airports: "*There is however a big difference in the tolerance or acceptance of the presence of an airport across the three study areas, and this is almost entirely due to the utility or disutility associated with the airport.*"[20]

The strong influence of non-acoustic factors on the subjective response to noise means that whilst some effects have been measured objectively and quantitatively and correlated well with noise exposure indicators e.g. speech disturbance and noise induced levels of hearing loss. There are some behavioural indicators, including annoyance, which can be quantified, but are strongly influenced by non-acoustic socio-psychological factors such as location, activity, state of well-being, familiarity with the noise, personality, environmental expectations, and attitudes to noise makers. The effects of such modifying factors can dramatically weaken correlations between noise and response indicators by masking or confounding their dependency on noise level. Such relationships are further obscured by variations in the actual noise exposure over time and space, because individuals tend to move around and engage in different activities; and the changes in socio-psychological factors which can be volatile.

The wide variability of individual responses to noise and the strong influence of non-acoustic factors leading to the absence of a clear threshold of acceptability applicable in all circumstances is common for most noise sources and most noise effects. This means that decisions in regard to noise "limits" and criteria are essentially a judgment of the balance between controlling the negative effects of the noise weighed against the positive social and economic benefits of the scheme giving rise to the noise.

[18] Flindell IH, Witter IJ. Non-acoustical factors in noise management at heathrow airport. Noise & Health 1999;1:27-44.

[19] *Pagliari, R. (supervisor); Ashman, Catherine An investigation into the influence of non-auditory factors on community response to aircraft noise* Sept 2007.

[20] Christine Heaver (Faber Maunsell Plc), Attitudes to Aircraft Annoyance Around Airports (5A) FOCUS GROUP REPORT EC/ENV/2002/009, Eurocontrol (2002).

3.7 Noise Affecting Heritage Assets – Heritage Setting

The glossary to the National Planning Policy Framework defines setting of a heritage asset as:

"*The surroundings in which a heritage asset is experienced. Its extent is not fixed and may change as the asset and its surroundings evolve. Elements of a setting may make a positive or negative contribution to the significance of an asset, may affect the ability to appreciate that significance or may be neutral.*"

The same glossary also defines Significance (for heritage policy) as:

"*The value of a heritage asset to this and future generations because of its heritage interest. That interest may be archaeological, architectural, artistic or historic. Significance derives not only from a heritage asset's physical presence, but also from its setting.*"

The English Heritage guidance document The Setting of Heritage Assets comments in several places that noise can be a factor influencing the setting of a heritage asset e.g. in the key principles whilst reinforcing that visual aspects are often important the document also states that "*the way in which we experience an asset in its setting is also influenced by other environmental factors such as noise, dust and vibration;".*

In developing a methodology to assess the effects of aviation noise on heritage assets the principles and conventions from Environmental Impact Assessment (EIA) are being used in this study as they provide an established and robust framework on which to base the project.

Somewhat confusingly, the term Environmental Impact Assessment suggests it means assessing impacts; but the EIA Directive and transposing UK legislation explicitly directs the practitioner to assess the "*significance of effects*". This leads to some practitioners using the terms "impact" and "effect" interchangeably. However, it is becoming common for practitioners to distinguish between impacts and effects, for example by correlating the sensitivity of the receptor with the potential impact, to help identify the environmental effect. The significance of any subsequent effect is then frequently determined by way of professional judgement and/or the use of matrices of quantitative and qualitative criteria. Therefore, despite the terms often being used interchangeably in many Environmental Statements, the definition and prediction of impacts and effects can be viewed as separate elements of the EIA process. The absence of a formal definition of what constitutes an impact or effect in either the EIA directive or the transposing legislation means that a definition of effects or impacts needs to be identified in an ES, for example as follows;

- Noise Impact: the noise level of the source under consideration, and/or any change in noise levels due to the scheme, and/or the relationship between the noise level of the source under consideration and a descriptor of the existing noise climate; at a receptor or group of receptors.

- Noise Effect: the consequence of the noise impact e.g. annoyance, sleep disturbance, speech interference, health consequences, fauna displacement, disruption of setting etc.

Consequently, this study uses the above definitions of "impact" and "effect".

Noise impact and noise effect have a clear relationship with each other; with the noise effect linked to the magnitude of the noise impact and the other factors that influence how the impact will affect the receptor e.g. sensitivity of the receptor etc. The magnitude of impact of aviation noise can be defined as the absolute aviation noise level i.e. how loud it is; and/or any change in aviation noise levels at a heritage asset or group of assets.

The absolute aviation noise level can be used where a heritage asset is currently unaffected by aviation noise; and the change in aviation noise level can be used where a heritage asset is currently affected by aviation noise but will be subject to lower or higher aviation noise levels as a consequence of the Airport Commission's final recommendations.

However, one complication in developing a methodology is that there is no attributable correlation between a heritage asset's sensitivity to noise and any of the following factors that may apply to the asset:

i. statutory protection;
ii. designated status i.e. grade; or ,
iii. perceived local value afforded to the asset.

For example a Grade I Listed building is not necessarily more noise sensitive than a Grade II Listed building. Any attempts to derive a relationship between these factors, without an explicit expression and understanding of what makes the heritage asset significant, is subject to substantial uncertainty and should be avoided.

The 'grading' of statutory protection is often used to determine the relative heritage significance of assets for examples see DMRB Vol. 11, part 2. Although simplistic and recognised as an industry standard, this ranking system, for the reasons defined above, cannot be applied to rank the noise sensitivity of heritage asset to noise i.e. an asset of schedulable quality is not of particular noise sensitivity due to its acknowledged significance / value.

However, if a proposed development (that results in increases in noise) is deemed to cause harm to a heritage asset, the scale of that harm and the relative significance of the heritage asset should influence the judgement of the 'planning balance' used in deciding if the benefits of the proposed scheme outweigh the harm it causes; where the more significant the asset, the greater the weight should be afforded to its conservation or protection.

The literature review carried out as part of this study has found that the Muir Woods National Monument study[21] identified that "*human-caused sounds*" (AKA anthropogenic noise) detracted from the visitor experience. If this evidence can be applied to the way in which we understand how heritage assets are experienced (and there is no reason why it shouldn't be) then all types and forms of heritage asset can potentially be affected.

A fundamental position that might have to be accepted primarily based on accumulated experience rather that the current limited research base, is that noise i.e. "unwanted sound", can affect people and this may undermine the way in which people experience cultural pursuits (the arts, the historic environment and nature). This is not necessarily linked to a specific type of pursuit (or attraction). Therefore, extrapolated from measured visitor data, it does not necessarily matter what type of

[21] Understanding and Managing Experiential Aspects of Soundscapes at Muir Woods National Monument: Ericka J. Pilcher, Peter Newman, Robert E. Manning; Environmental Management (2009) 43:425–435

heritage asset might be experienced, as based on this hypothesis some people will inevitably find that noise will spoil their experience and thus harm the significance of the asset.

3.8 Tranquillity and Soundscape

3.8.1 Soundscapes

Soundscapes can be defined as follows: "*the sound environment in context perceived by an individual, a group or a society*" [Kang, 2009[22]].

[Kang, 2010[23]] provides a summary of soundscape research and notes regarding the effect of soundscape on culture that "*soundscape is a significant factor in the 'sensing of places'*." The study notes that the introduction of more uniform sounds across different society's cities and landscapes leads to more similar sound environments whereas previously there may have been variation which would have helped distinguish and characterise places and show the diversity of cultures. Soundscape studies can help understanding how this aspect of culture may be changing and allow the conservation and restoration of the sound environment.

Five main issues are considered [Kang, 2010] within soundscape research:

- Understanding and exchanging: This encompasses defining what a soundscape is, evaluating it, describing it and potentially modelling it (in order to predict changes).
- Collecting and documenting: Surveys which can include 'soundwalks' where by someone walks through a soundscape and then after a period of time answers a series of questions.
- Harmonising and standardising: it will be important to standardise how soundscape definition, evaluation, surveys etc. are completed in order to promote more widespread use and understanding.
- Creating and designing: production of the tools and guidance on soundscapes.
- Outreaching: promoting the outputs and methods to policy makers and general public.

Key to soundscape research is understanding how the sound environment within its proper context affects its users. The interaction between acoustic and other physical environments is an essential consideration, and of various physical conditions the aural-visual interactions have been intensively studied. Although considerable work has been carried out in the evaluation of soundscapes, it is recognised that there is a need for further work; in particular there is quite a variation in how soundscapes are described and evaluated currently. A soundscape may be described in terms of 'designable' factors, these can essentially be broken down into four factor 'types' [Zhang and Kang, 2007[24]]:

- **Individual sound sources** (such as traffic, birdsong etc.) – these can each be described in terms of sound level, frequency spectrum (or tonality), temporal conditions (time of day, duration, impulsiveness), location and movement (i.e. is the source moving) and psychological / social characteristics (such as it's positive or negative meaning, natural or anthropogenic sound, relationship to activities etc.)

[22] Report on the COST Edinburgh workshop on Hot topics in Soundscapes. ISO?TC43/SC1/WG54 Meeting, Seoul, Korea; Kang J. and Management Committee.

[23] Soundscapes where are we?, Kang .J : Proc of Institute of Acoustics & Belgian Acoustical Society – Noise in the Built Environment, Ghent, 2010

[24] A systematic approach towards intentionally planning and designing soundscape in urban open public spaces. Kang. J. Proc of the international Congress on Noise Control Engineering, Istanbul, Turkey, 2007

- **Effect of the space** – the characteristics of the space (such as reverberation times an d acoustic reflection patterns) in which the soundscape is experienced can affect the perception of the sound sources.
- **Social aspect** – An individual 'user' of the soundscape can perceive it differently due to their social (cultural) or demographic characteristics or their typical acoustic conditions in everyday life (at home, at work) and other previous experience.
- **Other aspects** – this can include temperature, humidity, lighting, visual and landscape characteristics, for example.

Regarding the social aspect, it has been suggested [Bruce et al. 2009[25]] that soundscapes can lead to issues of distraction when it does not conform to a user's perceived sense of normality (expectations) or interferes with listening. Expectation is shown to be an important factor in the users rating (positive or negative) of a soundscape.

3.8.2 Tranquillity

Whilst there is no formal definition of tranquillity there are several in common use e.g. "*Tranquillity is the quality or state of being tranquil; meaning calmness, serenity and worry free*." [Wikipedia, 2014] and it "*is a highly valued yet seemingly elusive experience. It is stimulated by sight, sound and other senses either directly or as a trigger to memories*." [Jackson et al, 2007[26]]

Tranquillity research generally uses similar factors for description of the sound environment as soundscapes, as one aspect to help evaluate or describe the level of tranquillity at a location. Whilst it was mentioned above that it is important for soundscapes to consider non-acoustic aspects such as the landscape or visual aspects, it is particularly essential when describing how tranquil a location is.

Tranquillity Rating Prediction Tool

The University of Bradford (Watts et al[27].) have looked at developing a Tranquillity Rating Prediction Tool (TRAPT). The tranquillity rating is a score between 0 and 10 where 0 is '*not at all tranquil*' and 10 is '*most tranquil*'.

The TRAPT initially used a measure of the noise level ($L_{Aeq,T}$) and the percentage of natural features (excluding sky) within the scene (NF). An equation was derived through experiments surveying subject's subjective responses in controlled scenarios. It was found, however that there was not sufficient correlation between the predicted tranquillity score and the actual tranquillity score (from subjective experiment). The primary reason identified was that certain man-made cultural and contextual features can contribute to the perception of tranquillity. These features include heritage assets such as listed buildings, religious and historic buildings, landmarks,

[25] Expectation as a factor in the perception of soundscapes; Bruce, NS, Davies, WJ, and Adams, MD; Euronoise 2009, 26-28 October 2009, Edinburgh, U.K..

[26] Tranquillity Mapping: Developing a robust methodology for planning support; S Jackson, D Fuller, H Dunsford, R Mowbray; Northumberland University, Technical Report on Research in England, January 2008 (revised).

[27] Watts G R, Pheasant R J, Horoshenkov K V, 2010, "Validation of tranquillity rating method", Proceedings of the Institute of Acoustics and Belgium Acoustical Society: Noise in the Built Environment, Ghent, Belgium.

monuments, and man-made elements of the landscape that that are geographically and aesthetically in keeping with the surrounding environment.

The TRAPT was revised, therefore to use the percentage of NCF (natural and contextual features) in a scene rather than purely natural features. The tool was further revised as additional moderating factors (MF) are taken into account such as masking of anthropogenic noises e.g. from road traffic with natural sounds e.g. running water, which may increase the tranquillity, or the addition of litter to the scene; reducing the tranquillity. The TRAPT equation is given below.

Equation 1: $TR = 9.68 + 0.041\ NCF - 0.146\ L_{Aeq} + MF$

The equation shows that for fixed levels of natural and contextual features an increase in the noise level will lead to a decrease in the tranquillity rating. With higher noise levels, of approximately 65 dB $L_{Aeq,T}$ or higher, the tranquillity rating is around 4 or lower, so there is effectively a limit to how tranquil a scene may be when subjected to high noise levels, except with the addition of moderating factors.

CPRE Tranquillity Mapping

In 2006 CPRE commissioned a project to map tranquillity on a national scale. The maps were derived by giving a tranquillity score to each 500m by 500m grid square that the land was broken into. The tranquillity scores are derived from the individual relative tranquillity scores of 44 different factors which influence the overall tranquillity scoring (21 positive factors, 23 negative factors). The scores from each factor are weighted and added together for each square to give an overall relative tranquillity score for the grid square. The different factors are split into seeing and hearing, some positive and some negative. Positive factors include seeing lakes or trees in the landscape and hearing running water or no human sounds. Negative factors include seeing roads or wind turbines and hearing low flying aircraft or non-natural sounds. The weighting for each factor was derived through questionnaires whereby people would rate each factor as either positive or negative to the tranquillity at the location.

Interestingly, seeing villages and scattered houses is a negative attribute for the purposes of CPRE tranquillity mapping, however should they be in the right context; the above TRAPT study would treat them as positive to the tranquillity rating.

The research is useful as it highlights which factors are more important to others in maintaining a tranquil location. For example, '*seeing a natural landscape*' (positive) is weighted as 6.59% of the tranquillity score and '*Hearing, Constant noise from cars, lorries and/or motorbikes'* (negative) is 10.96% of the score, whilst '*Seeing, Villages and Scattered Houses*' is negative but only weighted 0.06% of the score.

As described above, the soundscape can be important to understanding the cultural characteristics of a place, and therefore can be important to understanding the significance heritage In heritage terms. Soundscape and tranquillity research provide a useful list of factors which help describe the sound environment and attempts to weight those factors to describe which are more important to people than others. The tranquillity research is also helpful as it illustrates that man-made features within a landscape, particularly heritage features, can add to the tranquillity rating of a location and that the introduction of certain types of noise can be detrimental to the positive soundscape required for tranquil conditions.

4.0 Aircraft Noise Impact Assessment using Tranquillity Maps

At first sight noise effects on heritage assets appear to be accounted for in the airports commission's appraisal framework's statement that it will review the effect of aviation on tranquillity using the CPRE's tranquillity maps as they *"also identify designated heritage assets located within tranquil areas, highlighting those that may be particularly susceptible to noise intrusion."* Also by the comment that the appraisal framework's "*methodology for assessing impacts on tranquillity from aircraft noise will involve overlaying maps showing flight paths below an altitude of 7,000 feet with the Campaign to Protect Rural England's (CPRE) national tranquillity maps, to illustrate areas where low-flying aircraft impact on landscapes and sites of tranquillity."*

The CPRE's tranquillity maps accounts for aviation noise as two negative attributes of the location assessed – *"Hearing, Low Flying Aircraft"* and *"Hearing, High Altitude aircraft"*

"Hearing, Low Flying Aircraft" is quantified by *"Modelling Noise – Time weighted"*. (PA weighting = 2.78%)

- Noise source level at distance from location (attenuated in 500m intervals)
- Source location is airport control zones (see figure 1) (and Military low flying areas) – relatively wide areas surrounding the airports.
- A time weighted coefficient is applied – this is an estimate of the amount of time an aircraft is audible at the location within a 12 hour period.

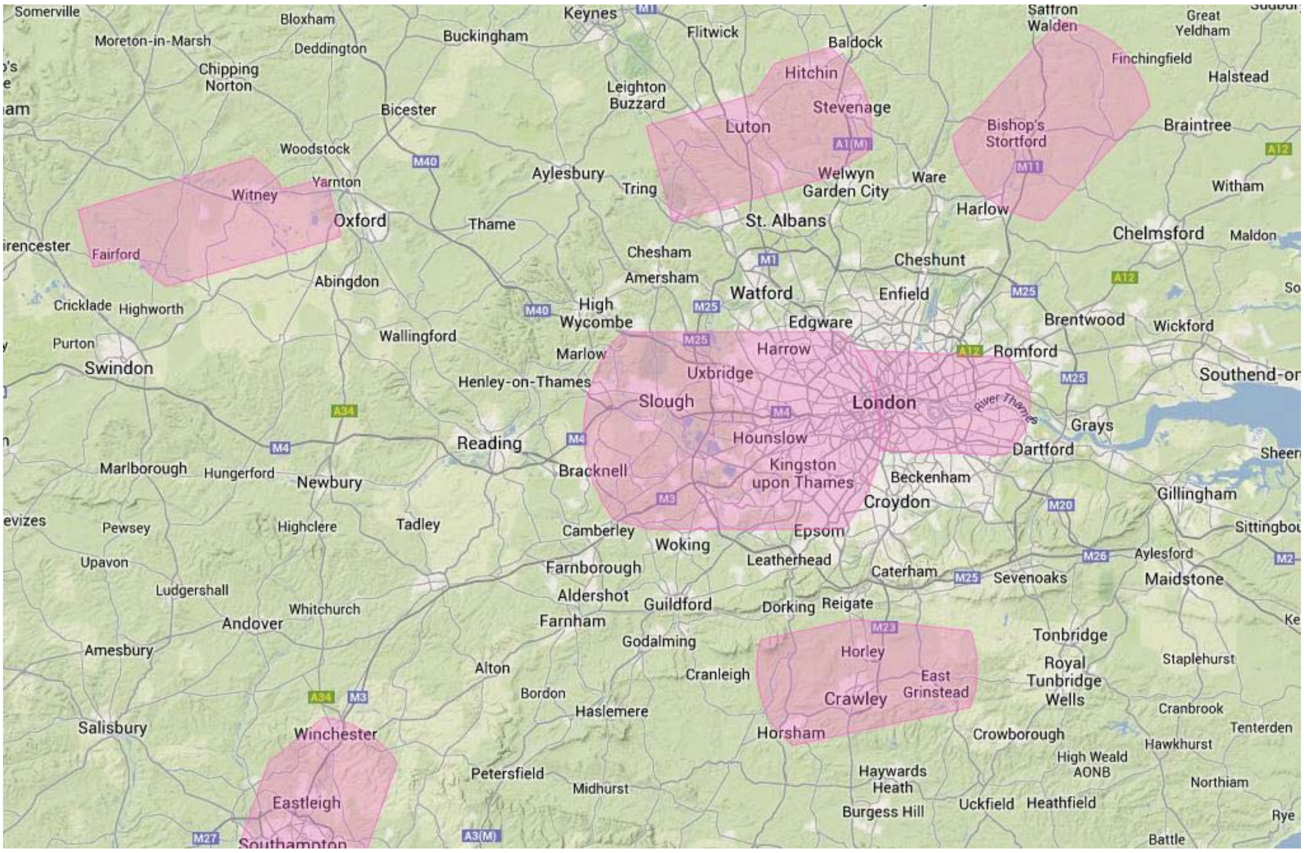
"Hearing, High Altitude Aircraft" is quantified by *"Modelling Noise - Context Specific Presence/absence"*. (PA weighting = 0.14%)

- Areas that lie underneath the main flight paths of England and that lie within each individual 500m x 500m grid cell are used as a proxy for noise for this option choice.

Overall, as described in the preceding section, the CPRE tranquillity score is made up of 44 different attributes (21 positive and 23 negative). The CPRE study found a range of absolute tranquillity scores in England from 148.51 (high) to -140.51 (low). This gives a range of 289. The maximum change at a location due to the presence of the maximum level of aircraft noise compared to no aircraft noise is a 'swing' of 29.2 or around 10% in the tranquillity score. In a scenario where the aircraft noise is increasing or decreasing by relatively small amounts then a 1 to 2% swing is more likely to be expected. Applying the CPRE method exactly, but with a 'new' airspace scenario may alter tranquillity scores, but it is unlikely to be by a significant amount, largely due to the 'coarseness' of the resolution of the mapping.

It is also worth noting that a location could have a relatively high score from the aircraft noise attribute but still lead to a relatively low tranquillity score compared with the surrounding area, particularly as aircraft flight paths may be directed over less populated areas. In this case the apparent change in tranquillity which may be assumed when overlaying aircraft flight paths on areas of relatively low tranquillity may be overstated.

Figure 3: - Illustrating Aircraft Control Zones (pink areas) in the South East of England. (Source: notaminfo.com)



In order to identify the heritage assets which may be exposed to a change in aircraft noise exposure, a scoping exercise should be undertaken. The airports commission have indicated that this would be achieved by overlaying updated flight track of noise information over up to date database information of all nationally designated historic places including:

- listed buildings;
- scheduled monuments;
- protected wreck sites;
- registered parks and gardens;
- registered battlefields;
- World Heritage Sites;
- applications for Certificates of Immunity; and
- current Building Preservation Notices

As indicated above, CPRE's tranquillity maps may be used to indicate heritage assets particularly susceptible to noise intrusion.

We have illustrated in a number of maps **(Figures 1 to 4 Appendix 4)** what the spatial scope might look like if this method is used:

1. Gatwick noise insulation boundary and heritage assets – this map indicates where noise insulation is currently offered due to noise from Gatwick. This is relevant as the heritage

buildings which are within this area have the potential for their building fabric (windows, roof) to be materially changed to protect noise levels inside.

2. CPRE tranquillity overlaid by heritage assets – this map indicates how the airports commission framework suggests highlighting heritage assets that may be particularly susceptible to noise intrusion.
3. CPRE tranquillity overlaid by heritage assets and Gatwick noise contours – this map indicates map 2 but overlaid by the aircraft noise contours from summer 2012.
4. CPRE tranquillity overlaid by heritage assets and Heathrow westerly departures – this map indicates the contents of map 2 but overlaid by an estimate of the footprint of westerly departures' radar track data below 4000ft.

5.0 Method to Assess Noise Impact on Heritage Assets

5.1 General Description of Methodology

The methodology developed to assess the impact of noise on heritage assets progresses using the following steps which are illustrated in the flow chart in **Figure 1**:

1. Scoping – the heritage assets with the potential for a noise impact are identified through a process of scoping using the National Heritage List and predicted noise change contours.
2. Sensitivity of Asset – the heritage assets which are identified in the scoping exercise are categorised according to how the sound environment contributes to the significance of the heritage asset. The assets which qualify within these categories could potentially be adversely effected (or benefit) from changes to the sound environment.
3. Detailed assessment – Heritage statements of significance, informed by an analysis of the existing sound environment would be assessed when an understanding of the nature of the noise change is known. .

The methodology is described in further detail below.

5.2 Scoping

The aim of the scoping exercise is to define which heritage assets are to be assessed and which of those are likely to experience a change in the ambient noise environment due to proposals from the Airports Commission on the future expansion of airport capacity in the South East of England.

The scoping exercise uses a geographical information systems (GIS) approach. Datasets identifying heritage assets including location information are obtained and mapped. A footprint (the noise change footprint) which covers all locations where there may be a change in aviation noise is derived from information provided by the Airports Commission appraisal. All designated heritage assets within the footprint are then identified as having the potential for a noise impact on their significance..

Designation data from The National Heritage List for England datasets and other readily available on-line data sets are to be used in the assessment. These will allow information to be captured on the following asset designations:

- Listed Buildings
- Scheduled Monuments
- Registered Park and Gardens
- Registered Battlefields
- World Heritage Sites
- Conservation Areas

Although it is acknowledged that airport noise can affect non-designated heritage assets, the large geographical scale of the study areas for this specific assessment (and thus potential quantity of heritage assets affected) necessitated a refinement in the scope to include only designated assets. However, if specific intelligence is available on non-designated heritage assets that warrant consideration they can be included within the scope of the assessment without the need to modify or amend the methodology in any way.

The noise change footprint is derived from the average summertime noise contours for daytime and the N60 contour (the number of flights where the maximum noise level exceeds 60 decibels at a particular location i.e. is likely to cause speech interference outdoors) for both the existing scenario and the future scenario.

The base case for this exercise will be informed by the base case put forward by the airports commission appraisal national assessment ‘do minimum’ scenario i.e.:

“The national (or ‘system-wide’) assessment will be measured in relation to the Commission’s ‘do-minimum’ scenario which captures, as far as possible, the predicted future levels of airport traffic at different airports, and the areas of land and numbers of houses contained within stated noise levels. The do-minimum will also account for predicted fleet mix and technological improvements to the aircraft fleet.”

The future scenario is the noise conditions due to aviation noise impacts associated with a scheme (including any other airport sites affected).

Firstly, the footprint indicating where changes in average summertime noise is derived. This involves overlaying the two scenarios contours in GIS to derive areas where there will be a 1 dB change in the average summertime noise level (positive or negative).

Secondly the footprint indicating where changes in number of significant over flights are likely will be derived. This will involve overlaying the N60 contours of both the scenarios in GIS to derive areas where there will be a 25% change in the number of flights exceeding the outdoor noise levels of 60dB L_{Amax} (positive or negative).

The two footprints showing locations of a potential positive change noise conditions will be combined to form the final ‘positive change in aircraft noise conditions scoping footprint’.

The two footprints showing locations of a potential negative change noise conditions will be combined to form the final ‘negative change in aircraft noise conditions scoping footprint’.

The two footprints will be overlaid in GIS over the identified heritage assets to give two lists of heritage assets which may have a positive or negative change in aircraft noise conditions. Each of the heritage assets in the lists will then be assessed as to whether the noise environment is important to the significance of the asset; this is described in the following section.

5.3 Potential Sensitivity of Heritage Assets

The assessment of sensitivity to noise is informed by a qualitative, thematic approach to understanding how the noise environment can specifically contribute to the experience of the heritage significance of the asset. A heritage asset which may be sensitive to the sound environment will qualify within one of the categories below; if they do not qualify, then the assets heritage significance is not deemed to be sensitive to changes in noise. Please note that the examples of heritage asset type are provided for illustrative purposes only, this is not a definitive list.

A. When solitude, embedded with quietness, is intrinsic to understanding the form, the function, the design intentions and the rationale for the siting of a heritage asset, e.g::

- Hermitages and retreats;
- Monastic sites e.g. those associated with Cistercian Order;

- Most places of worship;
- Components of designed landscapes; and
- Memorials and graveyards;

B. When a non-quiet and specific existing soundscape forms part of the functional understanding of the heritage asset, e.g:

- Working windmills (the grinding machinery and 'whoosh' of the sails / blades)
- Industrial sites e.g. working furnaces and workshops;
- Open air theatres;
- Specific areas within places of worship e.g. bell towers and chanting halls; and
- Cascades and fountains

C. When the abandonment of a heritage asset; a monument, building or landscape, in antiquity (or more recently), has created a perceived 'otherworldly romanticism' enabled by the absence of anthropogenic sounds (quietness) e.g:

- Battlefields; and
- Ruinous remains of former:
  - Estate houses;
  - Amphitheatres;
  - Factories and workshops;
  - Collieries and mining landscapes;
  - DMVs;

D. When the absence of 'foreign (modern) sounds' allow an asset to be experienced at 'a very specific point in time' that is intrinsic to understanding the heritage assets significance. This could be associated with e.g:

- The period of the monument or buildings construction;
- A key moment intrinsic to the heritage asset's 'story', i.e. its association with an important historic individual or event;
- An important phase of its redevelopment; and
- It's abandonment or destruction;

The provisional identification of an asset that could qualify within one of these categories will allow the assessment process to be taken forward in greater detail. It is envisaged that at this stage, the assessment will be derived from desk-based information. Therefore, it should be noted that the ease by which an asset can be classified within one of the categories, or the confidence that can be ascribed to the decision, could vary from asset to asset, due to the quality of the available information on the asset(s).

The approach advocated above does not allow for a heritage asset's sensitivity to noise to be 'ranked' or any relative scoring of sensitivity to be applied; this approach functions within the rationale that soundscape *either contributes to heritage significance or does not.* However, the different categories of asset do differ in their capacity to accept change i.e. in their tolerance to the introduction of noise or increased levels of noise. This tolerance can be determined following more detailed assessment of the heritage assets significance and the existing soundscape at each asset.

5.3.1

5.4 Detailed Assessment

Once a heritage asset has been identified as being sensitive to a change in environmental noise (in this case aviation noise), further assessment can be made. The assessment will be based on onsite observations, which will help inform what aspects of the noise environment are important to the setting of the heritage asset, and therefore what impact the change might have.

5.4.1 Aspects of Noise Environment Important to Setting

Before the site visit can be carried out initial identification of the aspects of the sound environment which are important to the significance of the heritage asset will need to be carried out to inform the noise survey.

The scope of the noise survey will be informed by:

- Locations at which setting may be experienced. These locations will inform the locations noise monitoring will be carried out. Whilst it may not always be possible to survey precisely at the sensitive location, alternative locations may be used to establish typical conditions.
- Time at which acoustic aspects of the setting may be important. This will inform the time of day or week when measurements are carried out. The noise survey, ideally, would take place during the sensitive times of day.
- Noise environment expectations. The expectation of the existing noise environment which lead to the assumption at this stage that the noise environment is important to the setting should be ascertained prior to the survey. This may include specific sounds which may be important for category B or D, for example.

5.4.2 Noise Survey

The noise survey will collect information on the following:

- Noise levels at sensitive locations derived above. The actual requirements of the noise survey may vary depending on the existing noise sources and the expectations of the noise environment. However L_{Aeq}, and L_{AMax} noise levels over the sensitive time period (e.g. day and night) and of specific aircraft fly overs (if currently present) may be measured to allow comparison to predictions of future air traffic noise changes. Should the site be in category B, for example, then additional measurements may be made of the specific noise important to the setting. Additional relevant factors should be recorded depending on the noise source, such as number and frequency of over flights for aircraft noise.
- Existing noise sources audible at the sensitive locations should be noted. The noise sources should be listed and information included on both their contribution to the setting of the heritage asset (e.g. positive/ negative/ neutral to the setting) and contribution to the measured ambient noise levels (e.g. dominant, significant, minor).
- The noise survey should be carried out at identified sensitive times of day or week. It is likely this would involve an attended survey at the most sensitive times, with additional unattended monitoring period to cover the typical 24 hour period during the weekdays and weekends if relevant.

- The noise survey would also confirm any existing contributions of ambient noise climate, or aspects of it, to the heritage setting, based upon the noise environment expectations.

5.4.3 Existing Noise and Future Aircraft Noise Impact on Setting

The assessment should progress by comparing the existing noise and assessing whether the introduced aircraft noise will change the impact (e.g. if the noise survey shows that road traffic noise already influences the setting of the heritage asset then the introduction of aircraft noise might not change the existing noise impact). Heritage assets fitting into categories A, B, C and D will respond differently to existing noise sources, and also to changes in the existing noise environment, as discussed above, the tolerance to noise changes will vary depending on the category.

The noise survey results, combined with any predicted changes likely to occur at the time of the 'do minimum scenario, should be used to inform the assessment of the existing setting of the heritage asset.

Future changes to the noise environment should be assessed using noise level predictions. The airports commission will provide $L_{Aeq,T}$ contours and N60 contours for each scenario.

Category A & C Assessment

It is important to assets falling into Category A and C to have relatively quiet sound environments. It is also important to note that how often any distractions occur within the setting. The impact on the setting of the heritage assets in Category A and C that may be caused by the noise can be described as follows:

- **Highly adverse impact** to the setting will result when noise is often highly disturbing during sensitive times.
- **No impact** to the setting will be caused when noise is either not noticeable, or just noticeable occasionally during sensitive times (i.e. there is respite from the just noticeable noise).
- **Adverse impacts** may be caused between these two categories depending on how disturbing the noise is (disturbing / highly disturbing) and how often this occurs.

Category B & D Assessment

It is important for the setting of assets falling into Category B and D to be able to hear specific sounds within the noise environment. It is therefore important how much the specific sound is interfered with by other sounds in the soundscape, from other sounds being just audible, to the specific sound that informs the setting being masked. It is also important to note that how often any interference occurs is important to the setting. The harm on the setting of the heritage assets in Category B and D that may be caused by the noise may be described as follows:

- **Highly adverse impact** to the setting will result when noise is often masking the specific sounds which are important to the setting during sensitive times.
- **No impact** to the setting will be caused when noise is either not audible, or just audible alongside the specific sounds, whilst not interfering with them occasionally during sensitive times (i.e. there is respite from the noise).
- **Adverse impacts** may be caused between these two categories depending on how much the noise interferes or masks the specific sounds and how often this occurs.

5.4.4 Quantitative Assessment

In the descriptions above there are a number of qualitative measures used to describe the impact of the environmental noise (such as when noise becomes 'disturbing'). These may be assessed quantitatively using thresholds (e.g. a threshold noise level when noise becomes disturbing); however the quantitative thresholds may vary depending on the specific asset, the existing noise environment, and the person experiencing the setting (given that the thresholds are likely to be subjective).

Below gives some guidance on how some of the qualitative measures given above might be quantified:

How disturbing the noise is: This may be described by an absolute noise level threshold informed by existing aircraft noise studies:

- Above 66 dB $L_{Aeq,T}$ (T is the sensitive time period identified) – aircraft noise is likely to be highly disturbing to most people.
- Below 54 dB $L_{Aeq,T}$) – aircraft noise is not likely to be disturbing to most people.
- Between the two extremes, noise may be disturbing to a greater or lesser proportion of the population depending on the noise level.

How much the noise is interfering with the specific noise: This may be described by a threshold change in noise level combined with a minimum noise levels, also informed by existing aircraft noise studies:

- Increase above 10 dB $L_{Aeq,T}$ with a minimum of 57 dB $L_{Aeq,T}$ – aircraft noise is likely to mask or interfere with the existing noise.
- Increase of less than or equal to 1 dB $L_{Aeq,T}$ with a minimum of 54 dB $L_{Aeq,T}$ – aircraft noise is not likely to interfere with existing noises in the noise environment.
- Between the two categories, noise may interfere with the specific noise sources in the setting, and may mask quieter specific noises during fly over.

How often the noise disturbance or interference occurs: This may be described by both how often the location may be overflown in any one mode of airport operation (e.g. number of flights per hour with westerly aircraft departures) and how often the airport might be overflown given the anticipated changes to modal operations throughout the year (e.g. only overflown on easterly departures and this accounts for 25% of the year).

- Modal operations leading to overflights for 75% of the year or more and number of flights over L_{Amax} of 60dB (N60) of greater than 100 a day could be described as 'often'.
- Modal operations leading to overflights for 25% of the year or less and/or number of flights over L_{Amax} of 60dB (N60)[28] of less than 20 a day could be described as 'occasional'.

5.4.5 Harm to Heritage Significance

The preceding sections have developed an understanding of the significance of a heritage asset's tolerance to change to its soundscape. The final consideration in the assessment process is

[28] Research has found that the maximum sound pressure level (L_{Amax}) and the percentage of natural features present at a location were key factors influencing perceptions of tranquillity - The acoustic and visual factors influencing the construction of tranquil space in urban and rural environments tranquil spaces-quiet places: R Pheasant, K Horoshenkov, G Watts and B Barrett; J. Acoust. Soc. Am. 123, 1446 (2008).

whether this change would constitute harm[29] to heritage significance and ultimately, an expression of the weight that this harm should be afforded in determining the sustainability of a proposed scheme.

The NPPF, paragraph 132, states that "*When considering the impact of a proposed development on the significance of a designated heritage asset, great weight should be given to the asset's conservation. The more important the asset, the greater the weight should be. Significance can be harmed or lost through alteration or destruction of the heritage asset or development within its setting*."

The same paragraph goes on to state that "*Substantial harm to or loss of a grade II listed building, park or garden should be exceptional. Substantial harm to or loss of designated heritage assets of the highest significance, notably scheduled monuments, protected wreck sites, battlefields, grade I and II* listed buildings, grade I and II* registered parks and gardens, and World Heritage Sites, should be wholly exceptional*."

Paragraph 134 states that "*Where a development proposal will lead to less than substantial harm to the significance of a designated heritage asset, this harm should be weighed against the public benefits of the proposal*…."

Therefore, although it is recognised that *substantial harm* is a key defining threshold to understanding the weight that should be attributed to determining the suitability of development proposals, it is also necessary to recognise that an impact of *less than substantial harm* can also influence the decision making process

Neither the NPPF nor PPG provide a definition of *substantial harm*, although several recent High Court and Planning Appeal decisions have sought to explore the concept. The consensus that is emerging from these decisions is that in the context of physical harm, *substantial harm* would apply in the case of demolition or destruction of a heritage asset, i.e. total loss. It would also apply to a case of serious damage to the structure of a monument, building or historic landscape. In the context of change within the setting of a heritage asset (such as aircraft noise) the test is effectively the same, i.e. where the change would have such a serious impact that the significance of the heritage asset was either vitiated altogether or very much reduced.

When the experience of a heritage asset is clearly affected, but not to the scale defined above, this would constitute less than *substantial harm*.

[29] Not all changes will necessitate harm; proposals can bring about changes to the soundscape that would enhance the heritage significance of assets i.e. reduction in noise levels or frequency of noise events

6.0 Case Studies

In order to illustrate the above methodology, a number of case studies have been prepared. An area in Windsor has been used. All heritage assets within this are have been ranked as described above. A map illustrating the area used is attached in figure 1.

An illustration of the list which would be produced in order to initially assess the potential sensitivity of the heritage assets is shown in the table below; a more complete list is included in Appendix 3.

Table 2: Example List of Heritage Assets and Methodology Grouping

Name	Grade	List Entry	Brief Description	Methodology Grouping
MAUSOLEUM OF THE DUCHESS OF KENT	I	1117780	Neo-classical mausoleum c.1850. Set within Frogmore Gardens.	A
THE ROYAL MAUSOLEUM	I	1117781	Romanesque mausoleum c.1862-71. Set within Frogmore Gardens. Burial place of Queen Victoria and Prince Albert.	A
FROGMORE HOUSE	I	1319304	The three-storey, stucco-faced central block (c.1680), flanked by early 19th century bow-fronted pavilions, with a Tuscan colonnade running along the ground floor of the central block overlooking the main lawn. Located in the north-east of Frogmore Gardens.	A
PRINCE ALBERTS DAIRY AND COTTAGE	II*	1272281	The Dairy Cottage dates back to circa 1830-40 but was refaced circa 1850-60 with the erection and decoration of dairy itself. Elaborately decorated in picturesque style. Within Frogmore Gardens.	N/A
ADELAIDE COTTAGE	II*	1319270	Formerly known as Adelaide Lodge. Incorporating part of John Nash's original Royal Lodge, built for the Prince Regent. Re-erected in this part of the Home Park, east of the Castle in 1831. On the edge of Home Park golf course and within Home Park RPG.	N/A
GOTHIC RUIN OF TEMPLE BY LAKE IN FROGMORE GARDENS	II*	1319305	c. 1793 by James Wyatt, as garden house with extensions in ruinous manner. Within Frogmore Gardens	A
1-3, TRINITY PLACE	II	1117678	Circa 1850 2 storey stock brick block of 3 houses. On minor road on the edge of Windsor centre. Residential area.	N/A

Further description is included below for selected assets to illustrate the decisions made above regarding the asset's sensitivity.

6.1 Duchess of Kent's Mausoleum, Frogmore Gardens, Windsor: Grade I Listed Building

The mausoleum is the burial place of Queen Victoria's mother, Victoria of Saxe-Coburg-Saalfeld, the Duchess of Kent, designed by the architect A J Humbert to a concept design by Prince Albert's favourite artist, Professor Ludwig Gruner. The mausoleum is located within an outcrop of land stretching into the serpentine Frogmore Lake in the centre of the designed landscape of Frogmore Gardens. Mature planting is located around the mausoleum, which can be access by a number of designed pathways through the gardens as well as via an ornamental bridge. The location of the asset provides an isolated, tranquil setting.

The primary element of the mausoleum is a galleried, ribbed copper domed rotunda surrounded by a pink granite colonnade with bronze iconic capitals in French Neo-Classical Design. The main approach to the rotunda, facing an ornamental bridge over a serpentine lake, comprises of a double flight of balustrade steps, which return to meet on a terrace in front of a rusticated opening at the base of the rotunda. Encased by the flight of steps is a heavily rusticated retaining wall with a central wall and bust. Within the mausoleum are heraldic paintings by Professor Gruner of Dresden, and a statue of the Duchess by William Theed the Younger.

The significance of the Duchess of Kent's Mausoleum is embodied within the surviving historic fabric and its architectural and historic interest reflected in the aesthetic value of the architectural design, and the associative value of its connection to notable members of the Royal Family, architects and artists. The associative value of the setting of the mausoleum within Frogmore Gardens (a former home of the Duchess) contributes to the significance of the asset, as does its tranquil setting and appreciation.

Based upon the above desk-based assessment it is considered that the existing soundscape has the potential to contribute to the significance of the Duchess of Kent's Mausoleum, and as such it qualifies as a Category A asset.

6.2 Prince Albert's Dairy and Cottage, Windsor: Grade II* Listed

Prince Albert's Dairy and Cottage is located to the north of the Prince Consort's Model Farm, a model farmstead commissioned by Prince Albert 1855 within Windsor Home Park.

The Dairy Cottage dates back to c. 1830-40, but was refaced circa 1850-60 with the erection and decoration of dairy itself. Italianate in its design, the structure has two storeys and is constructed of stock brick with ashlar dressings. The dairy is on north side of the two structures and features a four bay arcaded screen or veranda, with a stone balustrade to the exterior. Decorated entirely of Minton tiles and fayence, probably designed and partly executed by Prince Albert's sculptor John Thomas, the interior is the principal feature of the dairy. The supporting piers are elaborately decorated, and the ceiling compartmented to allow for ventilation, which alongside the double-walled construction served to keep the area cool at all times. Between the piers and along the walls on all sides are broad slabs of marble holding individual marble basins. A tiled frieze encompassing the main dairy room is embellished with portrait medallions of Queen Victoria, Prince Albert and the Royal children.

Although heavily ornate in its design, the dairy was functional in its use and formed part of the bustling domain of Home Farm.

The significance of Prince Albert's Dairy and Cottage is embodied within the surviving historic fabric and its architectural and historic interest. This is most accurately reflected in the aesthetic value of the interior design of the dairy, and the associative value by way of its connection to Prince Albert and the model farm of his design. The setting of the asset within Windsor Home Park and its historical and visual relationship with the other structures of the model farm contributes to the significance of the asset.

Based upon the above desk-based assessment it is not considered that the existing soundscape contributes to the significance of Prince Albert's Dairy and Cottage, and hence does not require specific consideration.

6.3 Frogmore Gardens, Windsor: Grade I Registered Park and Garden

Frogmore Gardens is a Picturesque landscape garden, laid out in the 1790s for Queen Charlotte on the site of an earlier 18th century formal garden, largely with advice from Major William Price, brother of Uvedale Price a pioneer of the Picturesque movement. Queen Victoria further developed the gardens in the 19th century.

The c.15ha grounds are laid out on largely level ground, with relief provided by various large, artificial mounds created and placed so that the whole area is not visible at once. The grounds are dominated by the serpentine Frogmore Lake, which enters as a small stream from the north-east, and broadens out to encircle an island lying c.150m west of the house, before continuing in sinuous form southwards, leaving the grounds 200m south-west of the house.

The setting is largely rural, with the Home Park surrounding the estate, the 19th century Prince Consort's Home Farm adjacent to the east, the vast Royal Gardens (walled kitchen gardens) to the south-east and further farm buildings to the south-west.

The principle building of the grounds is the Grade I Listed Frogmore House, located in the north-east of the grounds. The three-storey, stucco-faced central block (c.1680) is flanked by early 19th century bow-fronted pavilions, with a Tuscan colonnade running along the ground floor of the central block overlooking the main lawn. A number of Listed structures are incorporated into the design of the garden including an ornamental ruin (Gothic Ruin, James Wyatt c.1790), a marble Indian Kiosk (c.1850s) and Queen Victoria's Tea House (c.1869). At the south-eastern end of the garden are the Grade I Listed Duchess of Kent's Mausoleum and The Royal Mausoleum, situated on either side of the meandering serpentine lake with designed access via ornamental bridges. South of The Royal Mausoleum, in an area set back from the main garden complex, is the Royal Burial Ground. Since 1928, most members of the Royal Family, except for sovereigns and their consorts, have been interred here.

The significance of Frogmore Gardens is embodied within the surviving designed nature of the gardens and its aesthetic and historic interest reflected in the aesthetic value of its Picturesque design and the associative value of its connection to notable members of the Royal Family and designers associated with the Picturesque movement. The group value of the built assets within the gardens, and their relationship to its design, contribute to its setting and significance, as does its tranquil setting, particularly in the areas surrounding the lake, mausoleums and the Royal burial ground.

Based upon the above desk-based assessment it is considered that the existing soundscape has the potential to contribute to the significance and appreciation of Frogmore Gardens, and as such it qualifies as a Category A asset.

6.4 Adelaide Terrace, King's Road, Windsor: Grade II Listed

Adelaide Terrace is a symmetrical terrace of eight houses dated to 1831, set back slightly from a minor road on the fringes of the centre of Windsor. The houses are three storeys high, faced in Roman cement (rear elevations of stock brick) with a moulded cornice and blocking course. Numbers 64 and 66 form a central feature within the terrace, and project slightly from the flanking houses and feature an iron balcony at first floor level. The upper floors have flanking Ionic pilasters which divide the dwellings and support an entablature and pediment, with the name of the terrace and date of construction included within the tympanum.

The significance of Adelaide Terrace is embodied within the surviving historic fabric and its architectural and historic interest. This is most accurately reflected in the aesthetic value of the terrace as an example of Regency Neo-classical architectural design of early 19th century suburbia. The setting of the terrace facing onto The Long Walk and Windsor Home Park is considered to contribute to the significance of the asset. It is not considered that the existing soundscape contributes to the significance and appreciation of Adelaide Terrace as a heritage asset, with primary focused being upon its architectural interest and designed views.

Based upon the above desk-based assessment it is not considered that the existing soundscape contributes to the significance of Adelaide Terrace, and hence does not require specific consideration.

6.5 Moated site at Moat Park, New Windsor: Scheduled Monument

The monument comprises a small sub-rectangular moated site situated in a low- lying area at the northern end of Windsor Great Park, appearing on a Norden's map of 1607 as a moated lodge. The maximum external dimensions of the site are c.60m by 45m, with the 'island' surviving as a platform standing c.0.5m above the level of surrounding ground, c.50m by 35m in size. The 'island' is encircled by a dry moat surviving to a depth of up to 0.5m and a maximum width of 5m. The site is bisected by the Bourne Ditch, which is excluded from the scheduling.

Although a large number of moated sites are known in England, relatively few survive in Berkshire. This example is particularly important as it survives well as a small moated site and provides an interesting contrast to the larger and more complex moated sites which survive in the Great Park. The site also has a good level of historical documentation.

The significance of the moated site is principally derived from the historic illustrative value of the physical remains and the evidential value inherent in the potential for recovery of archaeological and historical evidence relating both to the monument and to the landscape in which it was constructed. The setting of the asset is not considered to be contemporary having experienced landscaping during the 19th century, however, the tranquil setting in which the ruinous state of the asset is now appreciated is considered to be contribute to its significance.

Based upon the above assessment it is considered that the existing soundscape has the potential to contribute to the significance of the Moated Site at Moat Park, and as such it qualifies as a Category C asset.

6.6 Church of Holy Trinity, Windsor: Grade II Listed

The Church of Holy Trinity is a uniform, buff brick church, constructed c.1842-44 to designs by Edward Blore. The Church is located on an 'island' site created as part of the mid-19th century suburban development in Windsor, and forms the closing vista to Trinity Place and Claremont Roads. In its present and designed state, the island within which the Church is located acts as a roundabout for the confluence of a number of busy, residential roads.

The significance of the Church of Holy Trinity is embodied within the surviving historic fabric and its architectural and historic interest. This is most accurately reflected in the associative and aesthetic value by way of its connection to Edward Blore, a 19th century British architecture who, among other sites, worked on Buckingham Palace and the restoration of the Salisbury Tower at Windsor Castle. The setting of the Church amongst 19th century designed suburbia, within which it forms the closing asset of a number of views and has 'group value', further contributes to the significance of the asset. The Church, although located on a designed 'island' does not sit within a grounds from which to experience it.

Based upon the above desk-based assessment it is not considered that the existing soundscape contributes to the significance of the Church of Holy Trinity, and hence does not require specific consideration.

6.7 Windsor Town Centre Conservation Area

Windsor Town Centre Conservation Area, amended to its current extent in 1991, is focused upon the historic core of the town and the built environment surrounding Windsor Castle, including: the High Street; Peascode Street; Windsor and Eton Central Station and Windsor Bridge. The built heritage and settlement planning of this section of the town is reflective of the key relationship between the development of the settlement and the dominance of Windsor Castle and the River Thames. Today this historic core remains the main focus of the experience of the settlement including a number of key 'gateways' such as the train station and Windsor Bridge; the main tourist attractions; busy shopping streets and; the main route between Windsor and Eton. The busy streets, both in terms of traffic and pedestrians, created a bustling setting.

Elements of the Conservation Area which contribute to its significance include the historic built fabric and the historic street planning; both of which demonstrate the historic development of the settlement and its relationship with both the Castle and the River Thames.

Based upon the above desk-based assessment it is not considered that the existing soundscape contributes to the significance of Winsor Town Conservation Area, and hence does not require specific consideration.

7.0 Assumptions, Limitations and Further Work

7.1 Assumptions and Limitations

The assumptions and limitations of this study include the following:

7.1.1 The Lack of Verified Research and Data on the Impact of Noise on the Setting of Heritage Assets

The study does not benefit from a pool of research providing verifiable data on the impact of noise on the setting of heritage assets. Ideally, in order to develop a wholly quantified method of assessing the impact of aviation noise on heritage assets the study would be able to draw on a range of cross-sectional research that provides information of how specific noise levels of various sources are linked to the setting of different types of heritage asset; and longitudinal studies that show how changes in noise levels influence the setting of different types of heritage asset.

However, in common with many areas of acoustics and the consideration of the effects of noise on humans, e.g. industrial noise; no such pool of research exists. Instead, the study takes a pragmatic approach that recognises that for certain categories of heritage asset noise can influence the setting and therefore the significance of the asset, and proposes a framework for assessing those impacts on a case by case basis using quantified noise data and a qualitative approach to assessing the impact.

7.1.2 Using Noise Contours to Define the Spatial Scope and Intensity of Potential Noise Impacts

The Airport Commission (AC) assessment framework uses “average mode” contours to assess the impact of noise from the airports. These contours are based on average daily aircraft movements over three months during the period June to September, during the 16 hours from 0700 to 2300 hours. Consequently, they take into account the variability of the operation of the airport over this period e.g. Heathrow and Gatwick broadly operate with take-offs to the west and landings from the east approximately 75% of the year and vice versa for the remaining approximately 25% as a reflection of the prevalent wind direction.

As an addendum to their approach the AC produced single mode noise contours in order to provide information in regard to the variability of airside noise propagation from the designated airports. The single mode contours generally show that the noise contours grow slightly further in the direction of take-off and shrink by marginally more in the direction from which aircraft are landing (because normally aircraft are noisier on take-off than landing). Use of single mode contours provides a worst case assessment. However, it has been argued that it would not reflect the reality of variable noise propagation from the airport simply to examine noise contours for a single mode or day, as community response to noise will reflect experience over longer time periods, including periods with varying mode, and could therefore include habituation to the noise. Community aviation noise exposure will change throughout the year as Air Traffic Movements at Heathrow and Gatwick airports fluctuate between easterly and westerly operations and; furthermore, as residents and workers near an airport are not static, but move around, they will experience further variability in aviation noise.

Consequently, in regard to the assessment of noise impacts on persons living and working at locations affected by aviation noise, it is therefore normally considered appropriate to use average mode contours reflecting typical long term exposure, rather than those that only apply for shorter periods and cover only a single mode of airport operations, as these reflect the overall noise exposure of the surrounding community over time. The approach of using ‘average mode’ contours for assessing noise from airports has been current for many years. It is also the approach adopted throughout Europe by virtue of the EU Noise Mapping project; Directive 2002/49/EC. Additionally, the noise measurements used in the ANIS study, which directly informs UK aviation noise policy, were carried out over at least 22 days, a period which would have included a degree of variation of the modes of operation of each of the airports studied. Even though the study found the best correlation with subjective response was with the subject’s previous seven days noise exposure, the study still established a reasonable degree of correlation between aviation noise and community response based on this variable exposure due to mixed modes rather than focussing on any single mode of use of the airports. However, most persons visiting a heritage asset do so for part or the whole of a day; although they may visit the asset repeatedly. Therefore for these “day visitors” any impact of aviation noise on the setting of the asset will be in the context of the effects on any particular day; which will be dependent on the mode of operation of the airport on that day; in which case the single mode contours should be used.

7.2 Further work

7.2.1 Research into the Impact of Noise on the Setting of Heritage Assets

As described above there is very little research into the effects of noise on the setting of heritage assets; although policy and expert opinion recognises that noise can affect the setting and therefore the significance of an asset. It would help further develop means of assessing the impact of noise on the setting of heritage assets if research was carried out to investigate what the effect on the setting of heritage assets might be of a range of different noise levels from a variety of specific noise sources and mixtures of various noise sources. It would be helpful if these studies could establish how different noise levels effect the setting of the same type of heritage assets (the steady state condition); and how change in noise levels effect the setting of particular heritage assets (the change condition). The studies should include extensive acoustic surveying of a wide range of noise metrics coupled with social surveys of the users and visitors to the assets so that the correlation between quantified acoustic measurement and perception of the effect on the setting and the expectation of users and visitors to the assets can be explored. The inclusion of soundscaping techniques in the studies would also help reduce some of the established shortcomings in the use of objective measurement of the physical characteristics of sound in the appraisal of the subjective impacts of noise.

7.2.2 Mitigation and Compensation

Where impacts of noise on the setting of heritage assets are identified, there may be a need to identify how those impacts can be mitigated; or compensated for where mitigation is impracticable. It would be helpful if further work were undertaken to review the range of established noise mitigation methods to assess their suitability for use in regard to heritage assets e.g. noise screening and potential visual impacts, and noise insulation and conflicts with listed building status; and to consider how more recent and emerging methods and technologies e.g. introducing positive soundscape sounds to mask or distract from negatively impacting noise, and using localised active noise control noise to eliminate or reduce the intruding noise, might be used to mitigate noise impacts on the setting of heritage assets. Where mitigation would be impracticable, only partially successfully or have secondary negative impacts, then compensation for the negative effects of noise on the setting of heritage assets might be appropriate. Decisions regarding the value of compensation would be better informed if further work were carried out to value the noise impacts on the setting of heritage assets and on the significance of the heritage asset.

8.0 Conclusions

Intrusive noise i.e. unwanted sounds, including from aviation sources, has the potential to adversely affect the setting and therefore the significance of heritage assets. Conversely, the absence or restriction of noise and the presence of positive sounds can improve and enhance the setting and therefore the significance of heritage assets.

Heritage assets that are sensitive to noise can be classified into four categories that relate to how the noise environment contributes to the significance of the heritage asset. The assets which qualify within these four categories could potentially be adversely effected (or benefit) from changes to the noise environment in their setting.

Unfortunately, whilst there is a need for a consistent means of doing so; there are no established methods and metrics for assessing the impacts of noise on the setting of heritage assets. However, the principles of Environmental Impact Assessment (EIA) can be used to develop a method of assessing the impacts of aviation noise on heritage assets. Such a methodology can be summarised as follows:

- Use airport noise contours and noise information to identify the spatial scope of the study based on defined absolute noise levels or changes in noise levels.
- Use Geographic Information System (GIS) databases to locate heritage assets within the spatial scope of the study.
- Screen the identified heritage assets into a non-noise sensitive and four noise sensitive categories.
- Overlay the noise information on the GIS layer with the identified noise sensitive heritage assets.
- Screen out those heritage assets where a noise impact is unlikely due to the absolute noise levels or change in noise levels not being sufficient to have an adverse effect.
- Undertake a detailed site specific assessment of the noise impacts on the remaining noise sensitive heritage assets where the absolute noise levels or change in noise levels has been identified as being potentially sufficient to have an adverse or beneficial effect. This detailed appraisal will take into account factors including the following:

  a. The nature, character and level of existing ambient noise levels,

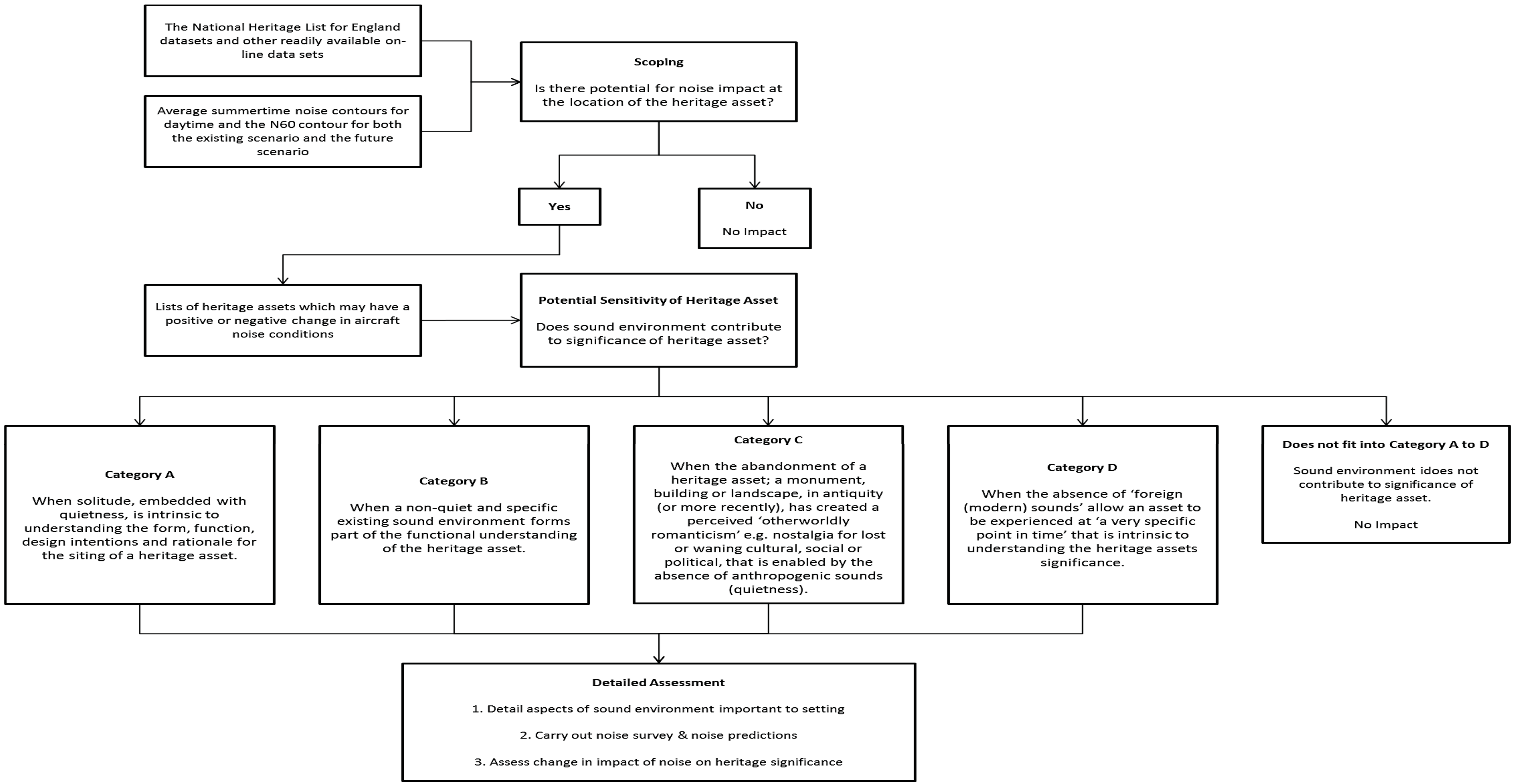
  b. The type of noise sensitive category the asset falls within,

  c. How frequently and for how long the aviation noise is likely to occur,

  d. How high is the absolute level of aviation noise or how big a change in aviation noise is expected.

The outcome of the method is an appraisal of whether the impacts of aviation noise or any change in aviation noise are likely to be beneficial, neutral, or cause harm to the significance of heritage assets.

Figure 1: Method Flow Chart



Appendix I Heritage Planning Policy Context

Legislative framework, national planning policy and relevant sector guidance

Advice and guidance to developers and decision-makers regarding the suitability of new development proposals and the potential affect (adverse or beneficial) on heritage assets is contained within a variety of legislative, planning policy and guidance documents. These documents are also supported by local planning policy, and some cases site specific policy and guidance, all designed to manage the historic environment.

No national planning policies or guidance documents deal in any meaningful detail with the potential harm that new noise, or appreciable increases in noise levels, can have on heritage assets. However, the following documents do include elements within their policies and guidance that allow 'heritage and noise impacts' to be contextualised within the decision-making process:

> ***Heritage asset:*** *A building, monument, site, place, area or landscape identified as having a degree of significance meriting consideration in planning decisions, because of its heritage interest. Heritage asset includes designated heritage assets and assets identified by the local planning authority (including local listing) (NPPF; DCLG, 2012).*

- Planning (Listed Buildings and Conservation Areas) Act (1990);
- Ancient Monuments and Archaeological Areas Act (1977);
- National Planning Policy Framework (2012);
- National Planning Policy Guidance (2014);
- English Heritage Conservation Principles: policies and guidance for the sustainable management of the historic environment (2008);
- English Heritage the setting of heritage assets: a guidance document (2011)

Planning (Listed Building and Conservation Area) Act

The Planning (Listed buildings and Conservation Areas) Act 1990 provides the statutory underpinning for the protection of built heritage in England. Under the act the Secretary of State (or persons on his/her behalf i.e. English Heritage) has a statutory duty to compile or approve a List of buildings of special architectural or historic interest. The act also considers the curtilage of the buildings, but does not refer to its setting, except in regard to the desirability of protecting the setting as a consideration in determining planning applications for Listed building consent.

Under the 1990 Act local authorities have a statutory duty to identify and designate 'areas of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance'. Section 72 of the Act requires that Local Planning Authorities pay special attention in the exercise of planning functions to the desirability of preserving or enhancing the character or appearance of a conservation area. They should take account of this in the adoption of planning and council policies, development control decisions, enforcement, controls relating to trees, advertisements, properties in need of maintenance and in exercising their highway powers.

Where new developments are proposed the Local Planning Authority must have special regard to the desirability of preserving or enhancing the conservation area, and those features which make it special.

National Planning Policy Framework (NPPF)

The National Planning Policy Framework sets out planning policies relating to 'conserving and enhancing the historic environment'. It defines the historic environment as 'all aspects of the environment resulting from the interaction between people and places through time, including all surviving physical remains of past human activity, whether visible, buried or submerged, and landscaped and planted or managed flora.' It further classifies a 'heritage asset' as 'a building, monument, site, place, area or landscape identified as having a degree of significance meriting consideration in planning decisions, because of its heritage interest'.

Heritage assets include designated heritage assets and assets identified by the local planning authority (including local listing). Policies relate to both the treatment of the assets themselves and their settings, both of which are a material consideration in development management decision making.

The NPPF states that "The purpose of the planning system is to contribute to the achievement of sustainable development" and that there are "three dimensions to sustainable development: economic, social and environmental". The role the environment will play is described as "contributing to protecting and enhancing our natural, built and historic environment; and as part of this, helping to improve biodiversity, use of natural resources prudently, minimise waste and pollution, and mitigate and adapt to climate change including moving to a low carbon economy".

Within the over-arching roles that the planning system will play, a set of 12 "core land-use planning principles" have been developed to underpin place-shaping and decision making. The 10th principle is:

- "conserve heritage assets in a manner appropriate to their significance, so that they can be enjoyed for their contribution to the quality of life of this and future generations"

When determining planning applications local planning authorities should take account of:

- "the desirability of sustaining and enhancing the significance of heritage assets and putting them to viable uses consistent with their conservation;
- the positive contribution that conservation of heritage assets can make to sustainable communities including their economic vitality; and
- the desirability of new development making a positive contribution to local character and distinctiveness."

Further to this, local planning authorities can request that the applicant should describe "the significance of any heritage assets affected, including any contribution made by their setting". The level of detail required in the assessment should be "proportionate to the assets' importance and no more than is sufficient to understand the potential impact of the proposal on their significance". "Where a site on which development is proposed includes or has the potential to include heritage assets with archaeological interest, local planning authorities should require developers to submit an appropriate desk-based assessment and, where necessary, a field evaluation."

Local planning authorities should take this assessment into account when considering the impact of a proposed development, "to avoid or minimise conflict between the heritage asset's conservation and any aspect of the proposal".

A key policy within the NPPF is that “when considering the impact of a proposed development on the significance of a designated heritage asset, great weight should be given to the asset’s conservation. The more important the asset, the greater the weight should be.”

“Significance can be harmed or lost through alteration or destruction of the heritage asset or development within its setting. As heritage assets are irreplaceable, any harm or loss should require clear and convincing justification. Substantial harm to or loss of a Grade II listed building, park or garden should be exceptional. Substantial harm to or loss of designated heritage assets of the highest significance, notably scheduled monuments, protected wreck sites, battlefields, Grade I and II* listed buildings, Grade I and II* registered parks and gardens, and World Heritage Sites, should be wholly exceptional.”

However, where a proposed development will lead to “less than substantial harm to the significance of a designated heritage asset”, this harm should be weighed against the public benefits of the proposal.

With regard to non-designated heritage assets specific policy is provided in that a balanced judgement will be required having due regard to the scale of any harm or loss and the significance of the heritage asset affected.

National Planning Policy Guidance (NPPG)

The National Planning Policy Guidance provides supporting and expanded guidance relating to the NPPF, including more detailed definition of key terms and concepts. This includes further guidance on ‘significance’, why it is important in decision making, and more detail on using the concept of ‘substantial harm’ as a test.

There is only one explicit reference to noise or sound in the document, where the NPPG defines the setting of a heritage asset as including non-visual elements: “Although views of or from an asset will play an important part, the way in which we experience an asset in its setting is also influenced by other environmental factors such as noise…”

Conservation Principals

“Conservation Principles: Policies and Principles for the Sustainable Management of the Historic Environment” sets out a series of broad ideas designed to inform the management of the historic environment. Although there are no specific references to noise or sound within this document, there are more general concepts of ‘place’, of which sound forms a part.

Specifically, ‘place’ in this document is defined as any part of the historic environment with a perceptibly distinct identity. This idea of a distinct identity is key, particularly the crossover between the distinct identity of an aspect of the historic environment and the ‘sense of place’ unique to significant locations. A specific location or asset, for example, can form part of several overlapping ‘places’ defined by different characteristics.

This idea of ‘place’ goes beyond physical form, and one of these characteristics can certainly be considered to be noise or sound. For example, multiple heritage assets can be located within a country churchyard, a coherent landscape area at least partially defined by stillness and tranquillity.

Similarly, each place can have a setting, a combination of the surroundings in which it is experienced and its local context. This setting is defined by the extent to which change within it could affect the significance of the place. Although not directly referenced in the document, change in noise levels or soundscape could clearly affect significance, and therefore must be considered to form part of the concept of 'setting'.

Conservation Principles also provides a framework for assessing why places or assets are valued. One of these values, *Aesthetic*, is derived from the ways in which people draw sensory and intellectual stimulation from a place. The soundscape certainly forms part of this sensory environment, and can contribute to the aesthetic value of a heritage asset.

A further point relevant to noise relates to the origin of this aesthetic value. Conservation Principles suggests that aesthetic value can be the result of conscious design, but also from a fortuitous, organic way in which a place has evolved over time. This includes the concept of the enhancement of a sense of place by the passage of time, known as the 'patina of age'. This patina of age can add to the range and depth of aesthetic value. This concept is particularly relevant to the noise/sound aspect of heritage assets, particularly with relation to the 'otherworldly romanticism' of certain assets, such as ruinous remains or prehistoric funerary monuments. The 'patina of age' is thrown into relief by the absence or recession of man-made sounds in these locations.

The setting of heritage assets: a guidance document

Setting is the surroundings in which a heritage asset is experienced. All heritage assets have a setting, irrespective of the form in which they survive and whether they are designated or not. Elements of a setting may make a positive or negative contribution to the significance of an asset, may affect the ability to appreciate that significance, or may be neutral.

> ***Setting is not a heritage asset****, nor a heritage designation. Its importance lies in what it contributes to the significance of the heritage asset. This depends on a wide range of physical elements within, as well as perceptual and associational attributes, pertaining to the heritage asset's surroundings. Each of these elements may make a positive or negative contribution to the significance of the asset, or be neutral. (SoHA; English Heritage, 2011).*

The extent and importance of setting is often expressed by reference to visual considerations. Although views of or from an asset will play an important part, the way in which we experience an asset in its setting is also influenced by other environmental factors such as noise, dust and vibration; by spatial associations; and by our understanding of the historic relationship between places. For example, buildings that are in proximity but not visible from each other may have a historic or aesthetic connection that amplifies the experience of the significance of each. They would be considered to be within one another's setting.

Setting will, therefore, generally be more extensive than curtilage, and its perceived extent may change as an asset and its surroundings evolve or as understanding of the asset improves.

The setting of a heritage asset can enhance its significance whether or not it was designed to do so. The formal parkland around a country house and the fortuitously developed multi-period townscape around a medieval church may both contribute to the significance.

The contribution that setting makes to the significance does not depend on there being public rights or an ability to access or experience that setting. This will vary over time and according to circumstance.

Appendix 2: Further information on Aircraft Noise Assessment

This Appendix provides a summary of how aircraft noise is currently assessed in the UK.

The assessment of the effects of aircraft noise has conventionally focussed on effects on humans. The auditory effects of noise such as hearing loss from long term exposure to high levels of persistent noise e.g. noise in heavy industrial work places, or short term exposure to very high levels of impulsive noise e.g. shooting/explosions, has been recognised as a hazard to hearing for a long time. However, auditory effects of aircraft noise are very rare beyond the perimeter of an airport as the levels are typically below recognised thresholds of harm. Nevertheless, there are also non-auditory effects of noise including effects on cardiovascular function [redacted] and hypertension), and changes in breathing, annoyance, sleeping problems, disruption of communication and activity interference. This wide range of effects has led researchers to believe that noise has the ability to act as a general, non-specific stressor. Unfortunately, many other environmental factors have similar effects making it often very difficult to pin point what the effects of noise are compared to the effects of a wide range of other general stressors.

Non-auditory effects can be divided into two categories - physiological effects and performance effects.

Physiological Effects

Examples of physiological effects are:

- the startle response to sudden loud noise, where muscles burst into activities, generally, with the intention to protect;
- the muscle tension response, where muscles tend to contract in the presence of loud noise;
- the respiratory reflexes, where the respiratory rhythm tends to change when noise is present;
- increases in stress hormones;
- increased blood pressure;
- [redacted];
- changes in the heart beat pattern; and
- changes in the diameter of the blood vessels, particularly in the skin.

All these effects are similar to the response of the body to other stressors.

Performance Effects

Noise can interfere with verbal communications and can be distracting and annoying. Below are some examples of how these factors can affect work performance.

Speech Intelligibility

Speech intelligibility is the ability to understand spoken words. The presence of noise interferes with the understanding of what other people say. This includes face-to-face talks, telephone conversations, and speech over a public address system.

In order to be totally intelligible the sound level of speech must be greater than the background noise at the ear of the listener.

In social situations people often talk at distances of 2 to 4 metres. In such cases noise levels typically fall in the range 55 to 60 dB(A) for good intelligibility, when the background noise is not higher.

Table 3: Speech Communication Capability versus Level of Background Noise in dB(A)

Communication	Below 50 dB(A)	50-70 dB(A)	70-90 dB(A)	90-100 dB(A)	110-130 dB(A)
Face-to-face (unamplified speech)	Normal voice at distances up to 6 m	Raised voice level at distances up to 2 m	Very loud or shouted voice level at distances up to 50 cm	Maximum voice level at distances up to 25 cm	Very difficult to impossible, even at a distance of 1 cm
Telephone	Good	Satisfactory to slightly difficult	Difficult to unsatisfactory	Use press-to-talk switch and an acoustically treated booth	Use special equipment
Intercom system	Good	Satisfactory	Unsatisfactory using loudspeaker	Impossible using loudspeaker	Impossible using loudspeaker
Type of earphone to supplement loudspeaker	None	Any	Use any earphone	Use any in muff or helmet except bone conduction type	Use insert type or over-ear earphones in helmet or in muffs; good to 120 dB(A) on short-term basis
Public Address System	Good	Satisfactory	Satisfactory to difficult	Difficult	Very difficult
Type of microphone required	Any	Any	Any	Any noise-canceling microphone	Good noise-canceling microphone

Source: C.M. Harris. Handbook of Noise Control, 2nd Ed. New York: McGraw-Hill, 1979.

Children's cognitive development

The 2005 RANCH study in Britain, Holland and Spain published in The Lancet, found that young children living near airports lagged behind their classmates in reading by up to approximately two months for a five decibel increase in aviation noise in their surroundings. The study also associated aircraft noise with lowered reading comprehension, even after socio-economic differences were considered.

Annoyance

Noise is annoying. In noisy environments, people generally prefer to reduce the noise loudness, avoid it, or leave the noisy area if possible. However the study of noise annoyance is complicated by significant individual variability in annoyance response to the same level of the same sound, and to different noises i.e. the same noise could be annoying to some people but acceptable to others. There is no definite relationship between the degree of annoyance or unpleasantness of noise and the risk of adverse health effects. For example, loud music may be pleasant to one group of people and annoying to another group.

Besides loudness of sound, several other factors contribute to annoyance. The following table lists examples of such factors:

Table 4: Factors that affect annoyance due to noise

Factors that Affect Annoyance due to Noise	
Primary acoustic factors	Sound level Frequency Duration
Secondary acoustic factors	Spectral complexity Fluctuations in sound level Fluctuations in frequency Rise-time of the noise Localisation of noise source
Non-acoustic factors	Adaptation and past experience Fear Physiology How the listener's activity affects annoyance Predictability of when a noise will occur Is the noise necessary? Individual differences and personality traits Perception of need for or control over the noise Attitudes towards the noise maker

Activity interference

Depending on the type of activity, noise can affect efficiency of task performance. For example:

- Noise may distract a person and affect their concentration, hence reducing the ability to focus on a task or activity.
- A noisy environment could create an additional hazard, since audible alarms might not be heard.
- A noisy environment interferes with oral communication and thus, interferes with the activity.

Noise Perception and Indices

Between the quietest audible sound and the loudest tolerable sound, there is a million to one ratio in sound pressure (from 10-6 Pascals, Pa, to 1 Pa). Due to this very wide range of values, a noise level scale based on logarithms is used, called the decibel (dB) scale. Consequently, the typically audible scale of sound covers a relatively small decibel range of approximately 0 to 140 dB.

The human ear system does not respond uniformly to sound across all frequencies and as a result instrumentation used to measure noise can apply weighting networks that approximately represent the performance of the hearing system. The commonest used network is known as 'A weighting' and annotated as dB(A). The table below lists the sound pressure level in dB(A) for common situations.

Table 5: Indicative Noise Levels for Common Situations

Typical Range of Noise Levels, dB(A)	Example
0	Threshold of hearing
30-40	Rural area at night, still air
40-50	Public library, refrigerator humming at 2 m
50-60	Quiet office, no machinery, boiling kettle at 0.5 m
60-70	Normal conversation at 1 m
70-80	Telephone ringing at 2 m, Vacuum cleaner at 3 m
80-90	General factory noise level
90-100	HGV at pavement, powered lawnmower at operator’s ear
100-110	Pneumatic drill
110-120	Rock Concert/Discotheque 1 m from speakers
140	Threshold of pain

The noise level at any specific point is rarely steady from one moment to the next, even in quiet situations, and varies over a range dependent upon local noise sources. For example, close to a busy motorway, the noise level may vary over a range of only 5 dB(A) as the near continual flow of traffic provides a persistent stream of overlapping noise events whose individual levels only vary over a narrow range; whereas in a suburban area this variability may increase to 20-30 dB(A) due to intermittent noise sources of varying level spread out over a wider area (cars, dogs, children playing etc.); in rural locations an even greater range of noise levels tends to occur e.g. up to 40 dBA, as noise sources tend to be more wide spread and less frequent in operation. Furthermore, in most locations the range of night-time noise levels will often be smaller and the levels significantly reduced compared to daytime levels, as activity rates tend to be lower at night. When considering environmental noise, it is necessary to consider how to quantify the existing variable noise (the ambient noise) to account for these moment to moment, and longer term variations. Consequently, the science of acoustics has developed a range of different noise indices that produce more easily interpreted single figure values to describe rapidly changing and variable noise levels and how they relate to the subjective impact of noise.

The term ambient noise is often used to describe the overall noise conditions in a location and the A-weighted equivalent continuous sound pressure level index, LAeq, represents the total sound energy measured over that period. The LAeq is the A-weighted sound level of a notionally steady sound having the same energy as a fluctuating sound over a specific period. It is commonly used to express the energy level from individual sources that vary in level over their operational cycle. ISO 1996: 'Description, assessment and measurement of environmental noise' and BS 7445: 'Description and measurement of environmental noise. Guide to quantities and procedures', support the use of the LAeq to describe environmental noise; and this index, and variants, is the most commonly used for that purpose. Because the LAeq reflects the total noise energy in a defined time period and the decibel is logarithmic, then subtle changes in decibels can reflect large changes in noise energy i.e. a 3 dB change in noise level is equivalent to a doubling of noise energy, a 10 dB change is equivalent to a tenfold increase in noise energy, and a 20 dB change a 100 times increase in noise energy etc. As a result the LAeq will tend to be biased towards the highest noise levels that occur during a defined period.

A derivative of the LAeq is the sound exposure level (SEL), which, for example, for an aircraft event is defined as the sound level in A-weighted decibels of a one-second burst of steady sound which contains the same total A-weighted sound energy as the whole longer noise event i.e. it is the LAeq of the noise event over a period T seconds, normalised to a time period of only 1 second. For typical aircraft over flight most of the sound energy is concentrated in the time period during the middle part of the flyover when the instantaneous sound level is within 10 dB of LAmax, and the standard measurement procedures reflect this. For typical aircraft flyover events the SEL is often around 10 dB higher than the equivalent LAmax, reflecting a duration during the middle part of the flyover event of around 10 to 20 seconds. It is most commonly used to calculate longer term LAeqs and assess the potential for night-time sleep disturbance

The LAmax noise index is the maximum instantaneous sound pressure level attained during the measurement period. It is most commonly used to assess the potential for night-time sleep disturbance and speech interference.

An index that is widely used to describe the underlying noise in a location is the background noise level, LA90. This is the noise level exceeded for 90% of the measurement period and generally reflects the noise level in the lulls between individual noise events. Over a 1-hour period, the LA90 will be the noise level exceeded for 54 minutes.

An index that has been widely used in the UK to describe road traffic noise is the LA10 noise level. This is the noise level exceeded for 10% of the measurement period and generally reflects the higher noise levels as individual vehicles pass the microphone. Over a 1-hour period, the LA10 will be the noise level exceeded for 6 minutes.

The human ear can react very quickly to rapid changes in noise level, consequently noise measurement systems must consistently and quickly sample noise levels over a regular period in order to record meaningful data. Time weighting determines how quickly the sound level meter responds to changes in noise level. The 'fast' time weighting averages the measured level every eighth of a second, whereas the 'slow' weighting averages every 1 second. The 'fast' time weighting most closely follows the response of the human ear to sound level changes and is most commonly specified for environmental noise measurement purposes (including the LA90 and LA10 statistical parameters). In the past the slow time weighting has been used to determine the peak LAmax noise events for aircraft movements (ATMs) but is used les commonly nowadays.

Measuring sound in decibels means that a 3 dB change is a doubling of the sound energy and a 10 dB change is a tenfold increase. Conventionally, for sounds which are very similar in all but magnitude, a change or difference of 1 dB is just perceptible under laboratory conditions, 3dB is perceptible under most normal conditions and a 10 dB increase appears to be twice as loud . These findings really only apply to changes in the same noise source, not changes due to introduction of a new noise into an existing soundscape, and do not necessarily apply to transient, non-steady or intermittent noise sources. It is important to recognise that these “rules” may not necessarily apply to changes in magnitude of the value of a noise index (which is the single figure representation of complex varying noise levels) as opposed to noise level. Additional factors that may influence the subjective impact of a change in magnitude of a noise index include the following :

- averaging time period;
- nature of the noise source (intermittency, variability of level etc);
- frequency of occurrence of the noise;
- spectral characteristics;
- absolute level; and,
- influence of the noise index used.

Aviation Noise

Noise disturbance around an airport is typically caused by noise from:

- aircraft in the air;
- reverse thrust used by aircraft to slow down after landing;
- aircraft on the ground, including taxiing, engine testing and running of on-board electrical generators;
- departing aircraft that stray from the Preferred Noise Routes (PNRs) ;
- road traffic to and from the airport; and,
- construction activity.

Regulation of Aircraft Noise

The control of aircraft noise reflects the international nature of the aviation industry and the wide range of ownership and operation of aircraft. The way in which aircraft are flown is not only determined by the pilot, who is completely responsible for the safety of the aircraft, but also by the safety rules set by the aircraft maker, the airlines, the Civil Aviation Authority and finally the airport. Often aircraft using an airport are required to stay on agreed Preferred Noise Routes (PNRs). These routes are designed to take aircraft away from built up areas where possible. Accurate ‘track keeping’ of where aircraft fly is also important as it assists planning authorities in identifying where sensitive developments such as housing should be built.

Agreements, laws, regulations and guidelines on the control of aircraft noise are laid down by a number of different organisations including:

- Department of Environment Food and Rural Affairs;
- Department of Transport;

- Civil Aviation Authority (CAA);
- National Air Traffic Services (NATS, part of the CAA);
- •Airports Council International;
- International Air Transport Association; and
- International Civil Aviation Organisation.

Noise Certification of New and Upgraded Aircraft

The noise certification requirements for aircraft are governed by International Treaty given in the Convention on International Civil Aviation (ICAO) Annex 16, which govern noise levels from individual aircraft. The UK discharges its responsibilities regarding ICAO requirements through the Aeroplane Noise Regulations 1999, the Aeroplane Noise (Amendment) Regulations 1999 and the Air Navigation (Environmental Standards) Order 2002.

The index used to assess aircraft noise in the ICAO certification scheme is the effective perceived noise level (EPNL) measured in EPN dB. This depends on factors including:

- The tonal content of the noise spectrum;
- The time during which the aircraft noise remains within 10 dB of the peak noise at the measurement position.

$$L_{EPN} = 10\lg\left(\frac{1}{10}\int_{t_1}^{t_2} 10^{\frac{PNL}{10}}\,dt\right)$$

Where:

PNL is the tone corrected perceived noise level of the over flight; and,

t1 and t2 are the times between which the PNL is within 10dB of the peak value.

The derivation of PNL is complex and uses the 1/3-octave frequency spectrum of the sound. It is very approximately equal to the dB(A) level + 13dB.

In the certification process the EPNL is measured at specified fixed positions beneath the approach and take off flight paths and on either side of the take - off flight path. This means the derived EPNL is a good descriptor of the relative noisiness of different aircraft; but has limited use in assessing the noise impacts of aircraft movements at any particular airport as the way in which planes fly in and out of the airport may not match the way they do in the standardised noise certification method.

Aircraft Noise Classification

Aircraft are classified according to the noise levels they produce by the International Civil Aviation Organisation (ICAO). Certification is based upon an international scale of ‘chapters’ (called Stages in North America). These include:

- Unclassified – the first generation of jet aircraft, which are now banned by international agreement (with rare exceptions), e.g. the Trident, Comet and Boeing 707;
- Chapter 2 – the older, noisier aircraft which have been phased out or upgraded by 2002. For example the BAC1-11, Boeing 727 and Boeing 737-200;
- Chapter 3 – the more modern, quieter aircraft. For example the Boeing 757, Boeing 767 and Boeing 737-300;

- Chapter 4 – in force for new aircraft designs from 2006 and 10 dB EPNL quieter than chapter 3. For example the Airbus 318, Boeing 737-600 and Bombardier CL-600-2B19;
- Chapter 5 –modern propeller aircraft including the BAE Advanced Turbo Prop and 'Shorts'.

Each ICAO Chapter covers a relatively wide range of noise levels, because the noise emission of an aircraft is dependent on weight, an aircraft can be certified at several noise levels and in more than one chapter depending on the certified loading of variants, and aircraft can be re-classified to a more stringent chapter by retro-fitting of "hush kits". In addition, noise for the same aircraft varies depending on altitude, loading, weather and how it is flown by the pilot. Over the past 30 years, improvements in aircraft technology have resulted in substantial reductions in the noise of individual aircraft and a significant minority of the current fleet already achieves a noise target better than the Chapter 3 standards. However, further improvements beyond the Chapter 4 standards (which, from 2006, required a 10 dB(A) reduction on Chapter 3 standards) will be increasingly difficult to achieve.

Some commentators have expressed concern about how the proposed 'Chapter 4' will effectively control future noise from aircraft. The 10 dB reduction represents the sum of the noise reduction at three measurement points and could be met by a combined margin including a reduction of only 2 dB at two of the three measurement points. It has been suggested that almost all aircraft currently in production can already meet the new standard and therefore the increase in stringency is not enough to promote technological advances. Furthermore, regardless of how quiet a new aeroplane may be, the existing noise may not be improved until the operations of the noisier aircraft are limited.

Aircraft noise arises from engines and from the movement of turbulent air over the physical structure (airframe) of an aircraft. To date, noise reduction has focused mainly on reducing engine noise. This is now sufficiently low that tackling noise from the airframe is becoming as important (although it may be more challenging to reduce) in terms of reducing the overall noise from aircraft. Technologies under development point to the perceived noise level from individual aircraft being halved, but translating laboratory-tested concepts into a fully functioning aircraft is difficult. In particular, the noise performance of new aircraft is difficult to characterise fully before they are built and flown.

More Recent Developments

More recently than the ANIS study described in section 2.3.7 above a report entitled Attitudes to Noise from Aviation Sources in England (ANASE) study has been published. The ANASE study can be viewed at:

http://www.dft.gov.uk/pgr/aviation/environmentalissues/Anase/

The purpose of the ANASE study was to produce an up-to-date analysis of the impacts of aircraft noise, building on previous research.

The ANASE study found that average annoyance was greater than in the previous ANIS survey. It then found that, using a new index in which a doubling of movements gave a 4.5 dB increase, as opposed to an equivalent 3 dB change for LAeq 16h, the regression lines for the ANIS and ANASE study converged. However, the correlation of this new number based index with annoyance was worse, at 0.665 compared with 0.739 for LAeq 16h. Based on the ANASE study two extreme hypotheses" can be inferred i.e. that:

(1) LAeq,t is the appropriate measure, and people really are more annoyed by a given sound level now than in the early 1980s;

and,

(2) LAeq,t is not the appropriate measure, and annoyance in both studies would correlate better with another measure of aircraft sound levels.

The Government had commissioned the study as it intended to review national policy in regard to noise from aircraft and wished to base any changes it might make on a sound and robust evidential basis. Consequently, the study incorporated a significant element of peer review, one purpose of which was to provide a means of assessing just how much weight could be given to the outcomes of the study. The peer review of the ANASE study can be viewed at:

http://www.dft.gov.uk/pgr/aviation/environmentalissues/Anase/nonsppeerreview.pdf

Unfortunately, the peer review of the ANASE included the statements that:

" 'the results of ANASE study are inconclusive and therefore should be treated with caution. Although the issue of the noise exposure characterisation of the [Common Noise Areas] could, in theory, be resolved by using the published values, the issues raised regarding the social survey cannot be addressed without repeating the survey using a modified approach that minimises the risk of bias.'

and

"…in the first version of this review it was stated that there were sufficient technical and methodological uncertainties still remaining with the study to mean that reliance on the detailed outcome of ANASE would be misplaced. In view of developments since the review of the July 2007 version of the ANASE main report, the reviewers are even more convinced that their concerns are fully justified…"

Other commentators have reviewed the ANASE study and strongly question its findings, e.g. Peter Brooker, "ANASE: Lessons from 'Unreliable Findings' - Proceedings of the Institute of Acoustics, Vol. 30. Pt.2. 2008. The Brooker paper and presentation slides can be viewed at:

https://dspace.lib.cranfield.ac.uk/handle/1826/2242

Since publication of the ANASE study and its peer review, the Government has decided that at this time there is insufficient evidence to warrant a change in policy on noise from aircraft, and the previous advice of the ANIS study remains current. Consequently, Government policy therefore remains that 57 dB LAeq (16 hour) marks the approximate onset of significant community annoyance from aircraft noise and that this should be used as the starting point for assessing trends in aircraft noise emissions and in forecasting impacts.

Other ways of describing aircraft noise

In 1994, Sydney Kingsford-Smith Airport opened its third runway. Following the opening, residents in areas predicted not to be affected during the planning stage, found themselves being disturbed by aircraft noise. Due to the great magnitude of publicity that surrounded the case a Senate Select Committee was formed to examine the issue of aircraft noise in Sydney. As a result of the Committee's findings, the Australian Department of Transport and Regional Services undertook an investigation of different methods of aircraft noise assessment. In March 2000, the Department published a discussion paper entitled "Expanding Ways to Describe and Assess Aircraft Noise".

The document was produced to "promote debate on the development and use of more transparent approaches to describing and assessing aircraft noise around Australian airports". The paper makes the suggestion that in order to allow aircraft noise to be better understood by the layperson, it should be described in terminology that relates to the most common questions asked by the layperson in connection with aircraft noise. It suggested that members of the public were often interested in answers to the following questions:

- "Where will the flight paths be?"
- "How many aircraft will use the flight paths?"
- "At what time will I get the noise – during the day, early morning, evenings or weekends?"
- "What will it be like on the 'bad' days?
- "Will I get more noise in the summer?"
- "Will the largest and noisiest aircraft fly over my area?"
- "Will I get take-offs or landings over my houses?"
- "When will I get a break from the noise?"

Whilst the questions may be simple, the conventional use of providing cumulative noise contours on their own does not give explicit answers to any of them. The paper was careful not to reject or dismiss the use of cumulative noise contours, but instead proposed that supplementing its use with other metrics should improve understanding of the impacts surrounding the introduction of or proposed changes to aircraft operations. Four main methods of presenting the level of aircraft noise are described.

These are as follows:

- Flight Paths and Movement Numbers
- Respite
- The N70
- The Person-Events Index and The Average Individual Exposure

Flight Paths and Movement Numbers

When looking at buying homes near airports people may examine flight path data in order to assist them with their task. It is assumed that if a property is under a flight path it will be noisy, and if not it will be quiet. Whilst this is an oversimplification of the situation the basic principle is correct. The level of air traffic utilising the different flight paths is also a major factor that will affect the level of noise received on the ground. To answer questions such as "where do the aircraft fly" and "how many overflights are there", the use of flight path movement charts has been developed.

Unlike traditional flight path plans which show individual thin lines for each path, those shown on the new charts get wider as they get further away from the airport. This displays the natural dispersion of aircraft in flight and dispelling the myth of aircraft flying along "railway tracks in the sky". In addition, the charts include:

- Data for each path on the average number of daily movements;
- The number of jet aircraft utilising the route as a percentage of the total number of jet aircraft movements;
- The daily range (i.e. min and max) of aircraft movements along the route; and,
- The percentage of days with no movements.

The discussion paper states that these types of charts have been used at Sydney Airport since 1998 and have been well received. However, limitations of this method have been identified. These include that there is no distinction between small and large aircraft (all are taken to be similar) and that the wider paths, showing more dispersion, are often wrongly interpreted as noisier in comparison with narrower paths where flights are concentrated over a smaller area.

Respite

A significant issue with the use of the LAeq index or similar systems is that they assume that annoyance levels will remain the same if the number of aircraft operations are doubled so long as the individual aircraft noise levels are reduced by 3 dB. Whilst a reduction of 3 dB for an individual aircraft event may only just be noticeable, a doubling of movements is likely to have a greater effect.

With this in mind, and as the number of aircraft movements increases, as they have in recent years and are predicted to in the future, the layperson is interested to know when they will have a break from the noise, hence the idea of specifying respite. In Australia, “extensive debate” took place over the most effective way to define respite. Examination was made of the threshold noise level and the time period over which no aircraft events occur. Due to difficulties with definitions and computation the use of a specific threshold noise level was not feasible. Instead, flight path usage was utilised for the purposes of respite description. This still left the issue of what time period should be used. The approach adopted by Sydney Kingsford-Smith Airport for their monthly monitoring report was to calculate the number of whole clock hours when no movements occurred on a given flight path. This figure is then presented as a percentage of the total number of clock hours in the period under examination. The example offered is that “if there were no movements on a particular flight path during 50 clock hours in a 100 hour clock period then it would be reported as ‘Respite Hours 50%’”. A clock hour is, for example, between 07:00 and 08:00 or 10:00 and 11:00, etc. The respite hours are calculated for the following four periods:

a) Morning Respite: 06:00-07:00 hrs (Weekdays)

b) Evening Respite: 20:00-23:00 hrs (Weekdays)

c) Weekend Respite: 06:00-23:00 hrs (Saturday or Sunday)

d) Daytime Respite: 07:00-20:00 hrs (Weekdays)

Periods a), b) and c) have been identified as sensitive times. The night-time period is not a prominent issue at Sydney Airport due to it’s strictly enforced curfew hence the lack of information relating to 23:00-06:00 hrs. Consideration has been given to producing a single figure for respite at a particular location by weighting and then combining the results for the various time periods. To date, this has been avoided since, it is felt, it would reduce the clarity of the information.

Respite charts have not been as well received as the flight path and movement charts described earlier. One criticism of the technique and its use in Sydney has been that certain areas may be close to more than one flight path. This would mean that whilst no aircraft might be operating on the nearest route to a particular location, it might still be affected by noise from activity on other routes. This problem is likely to be particularly prevalent at locations close to an airport. No obvious solution has been found for this problem though it is noted that “for most parts of Sydney the charts give a very good indication of the extent to which respite is being achieved”.

Another problem with the system in its current form is that the use of clock hours can lead to an underestimation of respite. The example given is that “if there were one movement at 12:05pm and one movement at 1:55pm no respite would be recorded for that two hour period. This would be despite the fact that for virtually the whole of the period (110 minutes) there were no movements".

The N70

Due to some of the apparent shortcomings of the ANEF system, discussions took place in Sydney between the airport and the various local communities to find the best way to provide an easily comprehensible method to describe actual aircraft noise levels. After trialling the use of SEL footprints for individual aircraft it was found that to provide such information for all aircraft types, on all routes, and including information on the number of movements was unworkable. Instead, 'Number Above' contours were proposed. The N70 indicates the number of aircraft movements that exceed 70 dB(A) SEL at a given location. Locations with similar numbers of aircraft movements that exceed 70 dB(A) SEL, i.e. locations with similar N70 results, are joined together to provide the various N70 contours. The N70 is by no means a new concept but has been around for over 20 years and was examined in a study carried out by the National Acoustic Laboratory in Australia in 1982.

The Australian Standard AS202123 specifies the single event level of 60 dB(A) as "the indoor design sound level for normal domestic areas in dwellings" since this is the level at which "a noise event is likely to interfere with conversation or with listening to the radio or the television". Given that a house with partially open windows provides around 10 dB(A) attenuation of external noise sources leads us to the rationale behind the choice of 70 dB(A) SEL as the noise threshold, and hence the N70. The equivalent external value e.g. for outdoor amenity spaces, gardens, balconies etc. is 60 db i.e. N60.

The Person-Events Index and The Average Individual Exposure

A useful way to assess the impact of aircraft noise is to determine the number of people that will be affected by it. At many airports noise preferential routing is used to divert aircraft away from greatly populated areas. Whilst assessing the total number of people affected is important, decisions sometimes have to be made as to whether it is worse for a small number of people to be exposed to high noise levels or if it is worse for a large number of people to be exposed to lower noise levels. This question creates a problem for decision makers, many of whom will not be experts with regards to noise, since they may not understand the differences between the two scenarios sufficiently to make considered judgements. To assist non-experts with interpretation of this type of information, the Department of Transport and Regional Services in Australia has devised the Person-Events Index (PEI). The discussion paper states that "the index is not intended to replace existing noise indicators but to supplement them".

The PEI is calculated using the equation below:

PEI(x) P N N = Σ

Where:

x = The single event threshold noise level expressed in dB(A)

PN = The number on persons exposed to N events > x dB(A)

The PEI is summed over the range between Nmin (a defined cut-off level) and Nmax (the highest number of noise events louder than x dB(A) persons are exposed to during the period of interest)". An example given in the discussion paper is that if a single departure by one aircraft exposes 20,000 people to a single event level of 70 dB(A) or greater, the PEI (70) would be 20,000 for that event. If an additional departure took place, similar to the first event, then the total PEI (70) for both events combined would be 40,000. A more detailed example of the use of PEI is presented in the discussion paper examining different operating scenarios at Sydney Airport. The information provided by the PEI is not comprehensive and requires further computation to make it so. It is very well knowing that the PEI(70) is, for example, 1,000,000, but this could mean that one person is exposed to a million events of 70 dB(A) or more, or it could mean that a million people are exposed to one event of 70 dB(A) or more, or any other situation between these two extremes. This requirement for further clarification has led to the creation of average individual exposure (AIE) which is calculated using the equation below:

Total Exposed Population

AIE = PEI

As with the PEI, the AIE is based on a defined minimum cut-off level of x number of events per day. Like the N70 described earlier, the PEI and AIE are both arithmetic and therefore show “differences between scenarios much more starkly than logarithmic indices which dampen any difference”. The discussion paper notes that the PEI is useful “for computing partial noise loads” and can produce meaningful results even one or a small number of movements. It can also be used to compare results at different airports. It is advised that the AIE should not generally be used for this purpose but that it is useful “when comparing different operating scenarios at a particular airport”.

Consequently this study proposes that the use of the LAeq,T noise index to assess the impacts of aviation noise on heritage assets should be supplemented by information regarding flight numbers and flight paths and the peak noise levels from aircraft over flight in terms of the N60 (for outdoors impacts) and N70 (for indoors impacts) indices.

Use of the LAmax Index to Assess Aviation Noise Impacts

Assessment of day time aircraft noise from airports conventionally uses contours presenting the LAeq (16 hrs) noise levels, these provide an estimate of the total noise from aircraft using the airport, as recommended by the UK government. This method takes into account the number of aircraft, how noisy each aircraft is and for how long the noise of each aircraft movement occurs.

However, the sole use of the LAeq (16 hrs) index for assessment of aviation noise has been criticised and use of supplementary indices has been discussed .

For example, the LAmax is a measure of the peak (or maximum) dB (A) value of the noise of a single aircraft passing by. On approaching an observer’s position, aircraft noise increases to a maximum level, before fading gradually as the aircraft moves away from the observer’s position to a point where it is no longer audible. Consequently, the LAmax can be used as part of the assessment of aviation noise impacts as it represents the highest levels of the aircraft noise experienced and, therefore arguably the worst case in terms of noise impact; and is a noise descriptor more easily understood by the non-acoustician than the energy average based LAeq (16 hrs).

Dis-advantages of using the LAmax noise index to asses aviation noise include that most of the total noise associated with an aircraft noise event will fall below the maximum level as it increases to its maximum level (as an aircraft approaches the listener) and declines (moves away from the listener); that the LAmax represents only the loudest single noise event during the assessment period and does not take account the number of aircraft noise events or the duration of each aircraft noise event, and there is little research in to the correlation of LAmax with the subjective impact of aviation noise.

Normally airport LAmax noise contours show subtle changes in the peak aviation noise levels, with a slight reduction predicted in the LAmax values and areas covered for the future scenarios. At first sight this might appear counter intuitive as the future fleet mix at the airport may include larger aircraft than at present. Historically larger, heavier aircraft have tended to be the noisier than smaller, lighter types. However, these future larger aircraft will have to be in the quieter Chapter 4 category compared to the current majority of aircraft using the airport that fall in the noisier Chapter 3 category

Interestingly airport LAeq (16 hrs) noise contour maps can show the opposite trend, with the predicted future scenarios showing moderate growth in the areas covered, reflecting the ability of the LAeq (16 hrs) index to weight any future reduction in peak noise level from individual aircraft movements against any overall increased number of flights.

The LAmax contours on their own are of limited value as there are few established standards or guidance against which to weigh the data, except for night time sleep disturbance and speech interference in environments where good intelligibility is required.

As most Heritage assets are not normally visited during standard night time hours e.g. 0700 to 2300 hrs, the assessment of sleep disturbance is somewhat redundant; although consideration of speech interference is appropriate.

Many of the Heritage sites relevant to this study are currently affected by aircraft noise to a greater or lesser extent, and at a substantial minority the existing LAmax noise levels from aircraft movements are high enough to cause speech interference outdoors i.e. > 60-65 dBA; and will intrude to a varying degree inside buildings on these sites (depending on the sound insulation provided by the building envelope). Consequently, the impact of the expansion of airport capacity is likely to remain unchanged in terms of the magnitude of the airside LAmax noise levels (except for in the case of the Estuary proposal). Because even if the increased number of flights leads to modest decreases or increases in the LAmax of individual air movements, this will not result in any individual air movement causing less or more speech interference, as any reduction will not be to below the speech interference threshold and any increase will not lead to more speech interference as the threshold for this effect is already exceeded. As a result, the number of air movements becomes relevant, as increasing the frequency of occurrence of aircraft movements and the overall number and frequency of occurrence of potential speech interferences each day therefore increases the probability that such impacts are likely to occur. This also goes some way to explaining why existing residents affected by aviation noise at airports sometimes acknowledge that although individual aircraft have got quieter over time; they perceive that conditions have become noisier as the number of aircraft movements has increased over the same period i.e. the noise from individual aircraft has reduced, but still causes speech interference, and the number of occurrences of interference with speech has increased.

Use of the LAeq,t Index for Assessment of Aircraft Noise

The Aviation Policy Framework[30] , and other sources advise that aircraft noise is assessed in terms of LAeq, furthermore the LAeq forms the basis of methods of assessing noise recommended by the Government and the World Health Organisation (WHO) and the European Union (with

[30] Aviation Policy Framework – see https://www.gov.uk/government/publications/aviation-policy-framework

supplementary indices when deemed appropriate). Additionally there is a substantial body of international research which uses and corroborates the use of the Leq to assess aviation noise. Fields[31], in a study which examined more than 70 aircraft and railway noise surveys, found that although estimates of the impact of the number of events differ considerably, none is significantly greater than the impact implicit in the LAeq,t index. Miedema, Vos and de Jong[32] found that the trade-off between the levels of events assumed by a metric based on LAeq,t is approximately correct for the prediction of annoyance caused by aircraft noise in a large study conducted around Schiphol airport in Holland. Whilst Vogt[33] found that in a laboratory assessment the effect of number of events was less than for the LAeq index.

Notwithstanding the reservations in regard to other conclusions of the ANASE study it did conclude that "Overall, we consider that while LAeq continues to be a good proxy for measuring community annoyance….."

On the other hand, the sole reliance on LAeq,t to asses aviation noise has been criticised on the grounds that the time averaging element of the index disguises or underestimates the true impact of aircraft noise. For example, at the Public Inquiries relating to Heathrow T5, the increase in capacity at Stansted Airport, and proposed developments at several regional airports; typically it was pointed out that a significant increase in the number of Air Traffic Movements (ATMs) would have only a small effect on the value of the LAeq level, and it was suggested that the peak noise levels (Lmax) of individual events and the number of events also have a bearing on the perceived noise impact.

One of the arguments advanced by those sceptical of the use of the LAeq for aviation noise is that such noise is normally experienced as a series of discrete noise events with quiet periods between, rather than as part of a continuous but fluctuating noise, and so Lmax or SEL, and the number of aircraft movements are also significant parameters.

A particular point of contention in the use of the Leq,t to asses aviation noise, is its use for the assessment of the significance of the impact of changes in aviation noise where the time averaging period, t, is relatively long e.g. 16 hours. Conventionally, from various sources , the guidance on the significance of the impact of changes in a noise level can be summarised as:

- A change in noise level of 1 dB is only perceptible under controlled conditions, and;
- A change in noise level of 3 dB(A) is the minimum perceptible under normal conditions.

It has been pointed out that crucial to the interpretation of the above "rules" is an understanding of the differences between the terms noise level and noise index. If the moment to moment noise level of steady sound or the peak noise level of a specific noise event only changes by 3 dBA, then such a change is likely to be only just perceptible. Whereas, if the value of a noise index, which is a single figure means of representing a complex fluctuating pattern of noise over a defined time

[31] Fields, James M., The effect of numbers of noise events on people's reactions to noise: An analysis of existing survey data, J. Acoust. Soc. Am.75(2), February 1984

[32] Miedema, Henk, M.E., Vos, Henk, de Jong, Ronald G. Community reaction to aircraft noise: Time-of-day penalty and tradeoff between levels of overflights, J. Acoust. Soc. Am. 107(6), June 2000

[33] Vogt, Joachim, Kalveram, Karl Th., *Trading Level for Number of Aircraft Immissions: A full-factorial Laboratory Design*, University of Dortmund

period, changes by 3 dB or less, then these "rules" may not be applicable. For example, where the LAeq,t, changes by 3 dBA due to a doubling or halving of the number of noise events in the period t, then such a change in noise events is not likely to go un-noticed; although the significance of any noticeable change will be influenced by factors including the number of noise events to begin with and the noise level of each noise event.

As described above, in the UK before the change to use of the LAeq,t ,there was an index that treated the number of events in a way that increased its value by more than 3 dB per doubling e.g. the Noise and Number Index (NNI). This index used a 15 x Log N term which gave a 4.5 dB increase per doubling of noise events. However, the term in the NNI formula that accounted for noise level was insensitive to the duration of each noise event and noise events that were just under the cut-off limit, or the degree to which the peak noise level exceeded the cut-off limit. Whereas all these factors are included in the LAeq,t index.

At public inquiries for various airport developments the application of the "rules" described above to changes in noise indices such as the LAeq,t has been challenged, and evidence presented that the subjective response to changes in LAeq,t noise levels containing a series of discrete noise events with a large difference between the peak and minimum noise levels is more sensitive than suggested by the "rules", particularly when the time averaging period is longer than the duration of each noise event. Typically, it has been argued that a supposedly barely perceptible 3 dB reduction in noise level of each individual aircraft would permit a doubling of the number of aircraft movements within the relevant time averaging period, and there would be no change in the overall LAeq,t, or noise impact. Many find this counter-intuitive as a doubling of aircraft movements would tend to be clearly noticeable in a wide range of circumstances. At the Heathrow Terminal 5 inquiry an expert witness for the DfT conceded that changes in LAeq,16 hr of less than 3 dBA could be significant. For example, if a less than 3 dB change in LAeq,16 hr was due to a large increase in aircraft movements during a much shorter and sensitive part of that longer period e.g. early in the morning or late evening, being averaged over the longer 16 hour period. In which case even though the apparent variation in the LAeq,16 hr could be less than 3 dB, the increased noise impact during the shorter sensitive period could be likely to be clearly noticed by some of the persons affected.

The T5 Inspector appeared to be concerned that LAeq, 16hr does not directly indicate the maximum noise of individual events so that it cannot indicate how many times conversation is interrupted in a particular location. This is largely true, but this is really a criticism of the presentation of the information using LAeq, 16hr, as these factors are incorporated into the index, rather than explicitly articulated by it.

Since levels of aircraft noise vary according to type, size, height and location of aircraft, the maximum noise levels at a particular location vary. As a result what matters is the extent to which people are annoyed or disturbed e.g. by interruptions to conversation, and to assess that it is necessary to balance the loudness of the event against the number of times the events of different loudness occur. Unfortunately, there is no established guidance against which to weigh these factors in isolation. Whereas these factors are fundamental components of the LAeq,t index which has been correlated with the subjective impact of aviation noise via extensive research. As a consequence in the UK, the LAeq,t index was adopted following the 1985 report of the United Kingdom Aircraft Noise Index Study (ANIS).

Except for SEL and LAmax for sleep disturbance, there is no current official UK guidance on how to use indices other than Leq,t to assess aviation noise (all though use of supplementary indices such as LAmax is allowed for in the EU directive and UK transposing legislation for strategic noise mapping). Whereas, as described above, the appropriateness of the use of the Leq,t index for assessment of aviation noise has been tested and used extensively in the UK and around the world for several decades.

Conclusions

Aviation noise can cause significant disruption to many who live near to airports and under flight paths and can have health impacts, to say nothing of its effect on the value of land and property beneath.

The effects of noise can be difficult to separate from other environmental stressors and the individual sensitivity to aviation noise is highly variable and significantly influenced by non-acoustic factors, and is probably volatile over time.

Proposals for changes to airports, such as increasing the number of flights, have to include descriptions of how they will change noise exposure and impacts. In the UK this has conventionally been achieved by establishing noise contours around airports using an index called Leq,t i.e. the Equivalent Continuous Sound Level, which is essentially the total noise energy received on the ground averaged over time. It is measured in decibels, takes into account both the noise levels of aircraft, the duration of their noise and their number, and logarithmically averages the sound energy from all aircraft movements, based on average modes of use of the airport, in a certain area over a 16 hour period, between 0700 hrs and 2300 hrs each day, which covers the operations of the designated airports.

Whilst the LAeq,t has been reasonably well correlated to the subjective impact of aircraft noise in the UK and abroad, with its use for aviation noise being derived through extensive study of the disturbance ratings of people and communities exposed to aircraft noise. There remain criticisms of its sole use for the assessment of aviation noise; with strong cases being made for the use of the peak noise levels and the number of noise events as well, although there is no current UK guidance specifically on the noise implications of changes in numbers of air movements or the significance of peak aviation noise levels. However, this information appears to be useful in articulating potential noise impacts to those who are not familiar with the LAeq,t index.

Supplementary indicators, such as flight paths and numbers and N70 can assist in articulating the impact of aircraft noise; but are also subject to limitations and do not replace LAeq type indicators that remain the basis of aircraft noise impact assessment in the UK.

A recent re-examination of the impact of aviation noise in the UK and the introduction of the Aviation Policy Framework has not led to a change in the Government Policy of using LAeq, noise index to assess and manage aviation noise overall; although the use of supplementary indices is recognised in the APF.

Consequently, the this study recommends using the LAeq,16 hr and N60 indices to quantify and assess the impacts of aviation noise on the Heritage sites. This allows the assessment of the likely impacts on heritage sites against the current minimum statutory and established policy requirements and guidelines.

Appendix 3: Listed Buildings Within the Case Study Area

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
MAUSOLEUM OF THE DUCHESS OF KENT	I	1117780	Neo-classical mausoleum c.1850. Set within Frogmore Gardens.	A
THE ROYAL MAUSOLEUM	I	1117781	Romanesque mausoleum c.1862-71. Set within Frogmore Gardens. Burial place of Queen Victoria and Prince Albert.	A
FROGMORE HOUSE	I	1319304	The three-storey, stucco-faced central block (c.1680), flanked by early 19th century bow-fronted pavilions, with a Tuscan colonnade running along the ground floor of the central block overlooking the main lawn. Located in the north-east of Frogmore Gardens.	A
PRINCE ALBERTS DAIRY AND COTTAGE	II*	1272281	The Dairy Cottage dates back to circa 1830-40 but was refaced circa 1850-60 with the erection am decoration of dairy itself. Elaborately decorated in picturesque style. Within Frogmore Gardens.	N/A
ADELAIDE COTTAGE	II*	1319270	Formerly known as Adelaide Lodge. Incorporating part of John Nash's original Royal Lodge, built for the Prince Regent. Re-erected in this part of the Home Park, east of the Castle in 1831. On the edge of Home Park golf course and within Home Park RPG.	N/A
GOTHIC RUIN OF TEMPLE BY LAKE IN FROGMORE GARDENS	II*	1319305	c. 1793 by James Wyatt, as garden house with extensions in ruinous manner. Within Frogmore Gardens	A
1-3, TRINITY PLACE	II	1117678	Circa 1850 2 storey stock brick block of 3 houses. On minor road on the edge of Windsor centre. Residential area.	N/A
6-9, TRINITY PLACE	II	1117679	Circa 1850 2 storey stock brick block of 3 houses. On minor road on the edge of Windsor centre. Residential area.	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
10 AND 11, TRINITY PLACE	II	1117680	Circa 1840-50 pair of 3 storeys red brick houses. On minor road on the edge of Windsor centre. Residential area.	N/A
14 AND 15, TRINITY PLACE	II	1117681	Circa 1840-50 double gabled pair of red brick houses. On minor road on the edge of Windsor centre. Residential area.	N/A
CHURCH OF HOLY TRINITY	II	1117682	1842-44 by Edward Blore. Located on an island site as designed, closing vista up Trinity Place. At junction of a number of minor roads on the edge of Windsor Centre.	N/A
18 AND 19, TRINITY PLACE	II	1117683	Circa 1840-50 pair of 3 storeys red brick houses. On minor road on the edge of Windsor centre. Residential area.	N/A
39-51, ST LEONARDS STREET	II	1117696	Circa 1890-1900, symmetrically designed row of 2 storey and attic red brick houses with original shop fronts. Located on a busy, minor road on the edge of Windsor centre.	N/A
85, ST LEONARD'S STREET	II	1117697	Built as projecting terminal house of otherwise much altered, c. 1830 terrace. Located on a busy, minor road on the edge of Windsor centre.	N/A
EDWARD VII STATUE IN HOSPITAL FORECOURT	II	1117698	1912 memorial statue with bronze figure of the King. Located in the centre of a car park to the front of the hospital.	N/A
THE STAG AND HOUNDS PUBLIC HOUSE AND ADJOINING COTTAGE	II	1117700	C17 timber building, considerably altered early C19th and C20th. Located on a major road on the edge of Windsor centre.	N/A
BRUNSWICK TERRACE	II	1117710	Nos 65 to 79 King's Road. Circa 1800, row of 2 storey (+ attic) brick terrace houses. Located on quiet minor road. Gardens to the rear back onto The Long Mile. Residential area.	N/A
BRUNSWICK TERRACE	II	1117711	Part of Brunswick Terrace. Located on quiet minor road. Garden to the rear backs onto The Long Mile. Residential area.	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
81, KINGS ROAD	II	1117712	Nos 29 to 37 King's Road. Circa 1800, row of 2 storey (+ attic) brick terrace houses. Located on quiet minor road. Gardens to the rear back onto The Long Mile. Residential area.	N/A
QUEEN ANNE'S COTTAGE	II	1117713	Early C19 recasing/remodelling of late C17 or early C18 building. Located on major road (A322) to the south of the centre of Windsor. One the edge of Windsor Great Park	N/A
QUEEN ANNE'S GATE LODGE	II	1117714	c. 1830-36 lodge to Windsor Great Park. Located on major road (A322) to the south of the centre of Windsor. Within Windsor Great Park RPG.	N/A
PICKETS HOUSE	II	1117715	Early C19 2 storey stucco faced villa set back from road with flank on Grove Road. Located on minor road on the edge of centre of Windsor. Residential area.	N/A
THE ROYAL ADELAIDE HOTEL	II	1117716	c. 1830 late Regency classical style hotel, on the corner of two minor roads on the edge of the centre of Windsor. Residential area.	N/A
ADELAIDE TERRACE	II	1117717	Nos 58 to 72 (even) King's Road. Symmetrical terrace of 8 houses dated 1831 with central pediment. Located on minor road on the edge of centre of Windsor. Residential area. Has direct views across the The Long Mile.	N/A
GATEPIERS AND FORECOURT WALL OF QUEENS TERRACE	II	1117718	Tall brick gate piers and forecourt wall of Queen's Terrace. Located on minor road on the edge of centre of Windsor. Residential area.	N/A
CROWN COTTAGES	II	1117719	Nos 7 to 12 King's Road. Estate cottages. By Teulon probably and dated 1855. Set back slightly from major road (A322) to the south of the centre of Windsor. Within Windsor Great Park RPG.	N/A
76 AND 78, OSBORNE ROAD	II	1117724	c.1850 pair of three storeys, attic and basement, stock brick houses. Set back from major road. Residential	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
			area.	
84 AND 86, OSBORNE ROAD	II	1117725	c. 1850 similar detached villas of two storeys, stock brick with red brick quoins. Set back from major road. Residential area.	N/A
7 AND 8, CLAREMONT ROAD	II	1117731	Circa 1840-50 pair of similar 3 storey houses with basement. Slightly set back from road which forms part of the busy minor road around Trinity Church. Residential area.	N/A
9-14, GLOUCESTER PLACE	II	1117738	c. 1830 sequence of three pairs of cottage/villas. Set back from road which is a quiet minor road on the edge of the centre of Windsor. Residential area.	N/A
58 AND 60, GROVE ROAD	II	1117739	c. 1830-40 part of terrace but altered and stuccoed with large pilastered shop front of later C19 date. On quiet minor road on the edge of the centre of Windsor. Residential area.	N/A
SHAW FARMHOUSE	II	1117753	c. 1850 Italianate house. Not always a farmhouse? Set within Home Park set back from busy Albert Road to the south, however, screened by a large number of modern agricultural buildings.	N/A
1-29, ADELAIDE SQUARE	II	1117760	Nos 1 to 29. c. 1835-40, two storey London stock brick terrace, symmetrical design with 2nd houses from each end (Nos 3, 15 and 27) projecting and pediment. On minor road on the edge of the centre of Windsor. Residential area.	N/A
18 AND 20, ADELAIDE SQUARE	II	1117761	c.1835-40 pair of two storeys stock brick houses. Set back from road, which is a minor road on the edge of the centre of Windsor. Residential area.	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
PRINCE CONSORT COTTAGES	II	1117762	Completed 1855. Architect Henry Roberts for the Royal Windsor Society in consultation with Prince Albert. Group of small simple gabled red brick cottages ranged around a green. Surrounded by residential dwellings and minor roads to the south of the centre of Windsor.	N/A
PRINCE CONSORT COTTAGES	II	1117763	Completed 1855. Architect Henry Roberts for the Royal Windsor Society in consultation with Prince Albert. Group of small simple gabled red brick cottages ranged around a green. Surrounded by residential dwellings and minor roads to the south of the centre of Windsor.	N/A
ROMAN CATHOLIC CHURCH OF ST EDWARD	II	1117764	c. 1867-8 ragstone rubble church by C A Buckler. Within a residential setting, surrounded by quiet and busy minor roads on the edge of the centre of Windsor.	N/A
1-6, CLAREMONT ROAD	II	1117775	Three pairs of circa 1840-50 houses. Slightly set back from road which forms part of the busy minor road around Trinity Church. Residential area.	N/A
FROGMORE HOUSE STABLES	II	1117777	c.1792 two storey stucco faced stables. Within Frogmore Gardens and associated with Frogmore House.	N/A
FROGMORE COTTAGE IN FROGMORE GROUNDS	II	1117778	Early C19 plain 2 storey house with parapet. Within Frogmore Gardens.	A
TEA HOUSE TO SOUTH OF FROGMORE HOUSE IN FROGMORE GROUNDS	II	1117779	c. 1860 tea house with Japanese and Tudor (!) design influences. Within Frogmore Gardens.	A
LODGE NORTH OF LYCH GATE FROM DRIVE TO THE ROYAL MAUSOLEUM IN FROGMORE GROUNDS	II	1117782	Italianate lych date c.1850-60. Within Frogmore Gardens. Associated with Royal Mausoleum.	N/A
THE HOME FARMHOUSE	II	1117783	Designed with the other farm buildings by S A Dean, c. 1850's for Prince Albert. Located within Home Park, and adjacent to Frogmore Gardens and Frogmore House.	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
THE AVIARY	II	1117784	Late 1830's and 40's Gothic/Picturesque aviary. Located within Home Park, and adjacent to Frogmore Gardens and Frogmore House.	A
ADELAIDE LODGE	II	1117785	Formerly known as Adelaide Cottage , former service wing to Adelaide Cottage. On the edge of Home Park golf course and within Home Park RPG.	N/A
62-96, GROVE ROAD	II	1204438	c. 1830-40 main part of terrace of small 2 storey and basement houses. On quiet minor road on the edge of the centre of Windsor. Residential area.	N/A
26-34, KINGS ROAD	II	1205258	c. 1830-40, forms part of Brunswick Terrace. Set back slightly from a quiet minor road. Residential area.	N/A
48, KINGS ROAD	II	1205260	Corner site balancing Royal Adelaide Hotel and of the same date, c. 1830. On the corner of two minor roads on the edge of the centre of Windsor. Residential area.	N/A
ALBERT TERRACE	II	1205267	Nos 100 to 110 (even) King's Road. c. 1850-60 slightly Gothicised terrace 3 storeys and basements, red brick with some grey headers.	N/A
KING EDWARD VII MEMORIAL HOSPITAL (MAIN FRONT BLOCK)	II	1205473	c. 1909 by A W West, early C18 in style. Looks out onto a number of major roads to the south of the centre of Windsor. A number of modern buildings to the rear.	N/A
ELM PLACE	II	1205482	54 St Leonard's Road. c. 1760-80 2 storey stucco faced house, set back from street the right hand part of front partly obscured on ground floor by addition of projecting shop front. Located on a busy, minor road on the edge of Windsor centre.	N/A
YORK PLACE	II	1205507	Nos 51 to 71 (odd) Sheet Street. Early C19 buff brick terrace of 3 storey houses. Set back from busy major road to the south of the centre of	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
			Windsor.	
4 AND 5, TRINITY PLACE	II	1205837	c. 1840-50 pair of two storeys and basement stock brick houses. On minor road on the edge of Windsor centre. Residential area.	N/A
20 AND 21, TRINITY PLACE	II	1205959	c. 1840-50 pair of three storeys and basement stock brick houses with red brick dressings. On minor road on the edge of Windsor centre. Residential area.	N/A
GOLF COTTAGE	II	1244624	c. 1840 built as kennels, enlarged subsequently. Barge boarded Tudor style. Set alongside treelined Queen Elizabeth's Walk and other minor route ways within the parkland. Within Home Farm RPG. Close to golf course	N/A
LODGES EACH SIDE OF ALBERT ROAD SOUTH WEST OF SHAW FARM INCLUDING GATES	II	1272282	By Wyatville c. 1820-30. Stock brick with stone dressings. Located adjacent to Albert Road, a busy major road. Within Home Park RPG.	N/A
16 AND 17, TRINITY PLACE	II	1280441	c. 1840-50 pair of houses with three storeys and basement, stock brick above stucco ground floor. On minor road and busy roundabout close to Trinity Church, on the edge of Windsor centre. Residential area.	N/A
12 AND 13, TRINITY PLACE	II	1280478	c. 1840-50 pair of houses with three storeys and basement, red brick and stock brick. Slightly set back from road which forms part of the busy minor road around Trinity Church. Residential area.	N/A
THE MERRY WIVES OF WINDSOR	II	1280711	C17 timber framed building considerably altered. Ground floor built out with public house front c. 1900. Located on a busy, minor road on the edge of Windsor centre. Commercial area.	N/A
80 AND 82, OSBORNE ROAD	II	1280762	Circa 1850 pair of 2 storeys and attic, stock brick houses. Set back from	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
			major road. Residential area.	
HAMILTON LODGE	II	1280813	c. 1860-70 Gothic large red brick house with sandstone dressings. On corner of two semi-busy minor road (set back), with garden to the rear. Views towards The Long Mile.	N/A
3-8, GLOUCESTER PLACE	II	1281221	Three pairs of circa 1830-40 small cottage/villas. Set back from road on a quiet minor road. Residential area.	N/A
15-16, GLOUCESTER PLACE	II	1281224	c.1831-5 pair of Roman cement faced houses. Set back from road on a quiet minor road. Residential area.	N/A
BRIDGE FROM ISLAND LEADING TO DUCHESS OF KENT'S MAUSOLEUM	II	1319267	c.186l, designed in conjunction with terraced steps of mausoleum. Within Frogmore Gardens.	A
LYCH GATE FROM DRIVE TO ROYAL MAUSOLEUM IN FROGMORE GROUNDS	II	1319268	Humbert am Gruner c. 1862-71, ashlar Romanesque style lych gate. Within Frogmore Gardens.	A
RANGE OF COWSHEDS STABLING ETC TO WEST OF THE HOME FARMHOUSE	II	1319269	Principal north-south range with returns and inner wings ranging back to the farmhouse. c. 1850's for Prince Albert. Located within Home Park, and adjacent to Frogmore Gardens and Frogmore House.	N/A
THE CRISPIN PUBLIC HOUSE	II	1319287	No 56 Grove Road. circa 1830-40 terminal house of terrace. On quiet minor road on the edge of the centre of Windsor. Residential area.	N/A
CLOCK COTTAGE WITH WAGON SHED AT SHAW FARM	II	1319293	c.1850. Italianate style two storey stock brick cowshed with central belvedere tower porch. Set within Home Park set back from busy Albert Road to the south, however, screened by a large number of modern agricultural buildings.	N/A
4 AND 6, ADELAIDE SQUARE	II	1319298	c. 1835-40 pair of two storey stucco faced houses. On minor road on the edge of the centre of Windsor. Residential area.	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
22-32, ADELAIDE SQUARE	II	1319299	c. 1835-40, two storey London stock brick terrace, symmetrical design with 2nd houses from each end projecting and pedimented. On minor road on the edge of the centre of Windsor. Residential area.	N/A
KIOSK TO SOUTH EAST OF COTTAGE IN FROGMORE GROUNDS	II	1319306	Indian Kiosk, all of marble. Taken from the Kaiserbajh at Lucknow and brought over in 1858 by Viceroy Earl Canning. Within Frogmore Gardens.	A
1, KINGS ROAD	II	1319312	c. 1800-20 narrow corner block. Set at junction of two roads, one of which is a busy, major road south of the centre of Windsor.	N/A
BRUNSWICK TERRACE	II	1319313	Nos 39 to 63 (odd) King's Road. A terrace of 13 houses c.1800. Located on quiet minor road. Garden to the rear backs onto The Long Mile. Residential area.	N/A
BRYN BRITH	II	1319314	c. 1830-40 2 storey buff brick house, mid C19 extension to garden front. et back slightly from major road (A322) to the south of the centre of Windsor. Within Windsor Great Park RPG.	N/A
CROWN COTTAGES	II	1319315	1 to 6 King's Road. Inter-linked L-plan group of estate cottages. By Teulon probably and dated 1855. Set back slightly from major road (A322) to the south of the centre of Windsor. Within Windsor Great Park RPG.	N/A
22, KINGS ROAD	II	1319316	c. 1830-50 3 storey stock brick house set at right angle to road. Located on quiet minor road. Residential area.	N/A
50 AND 52, KINGS ROAD	II	1319317	c. 1830-40 pair of three storey stucco faced houses. Set back from a quiet minor road. Residential area.	N/A
QUEENS TERRACE	II	1319318	Bold Jacobean design - terrace of three storey houses set back with forecourt. Teulon architect, exhibited at the Royal Academy 1849. Located on minor road on the edge of centre of Windsor. Residential area. Has direct views across the The Long Mile.	N/A

Listed Buildings Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
9 AND 10, CLAREMONT ROAD	II	1319322	c. 1840-50 pair of two storey brick houses. Slightly set back from road which forms part of the busy minor road around Trinity Church. Residential area.	N/A
CHURCH OF ALL SAINTS	II	1319326	c. 1862-4 by Sir Arthur Blomfield. Red brick with blue brick banding. Red, yellow and blue brick polychromy. Surrounded on two sides by, though slightly set back, from a busy road to the south of the centre of Windsor.	N/A
25, FRANCES ROAD	II	1392972	Detached house in a Domestic Revival style of 1888 by Thomas Edgington, architect, for himself. C20 alterations and additions. Facing onto a, though slightly set back, a busy road to the south of the centre of Windsor.	N/A

Scheduled Monuments Within Study Area			
Name	**List Entry**	**Brief Description**	**Methodology Grouping**
Moated site at Moat Park, New Windsor	1013358	The monument includes a small sub-rectangular moated site situated in a low- lying area at the northern end of Windsor Great Park and bisected from north- west to south-east by the Bourne Ditch (not included within the scheduling). The site appears on a map of 1607 as a moated lodge.	C

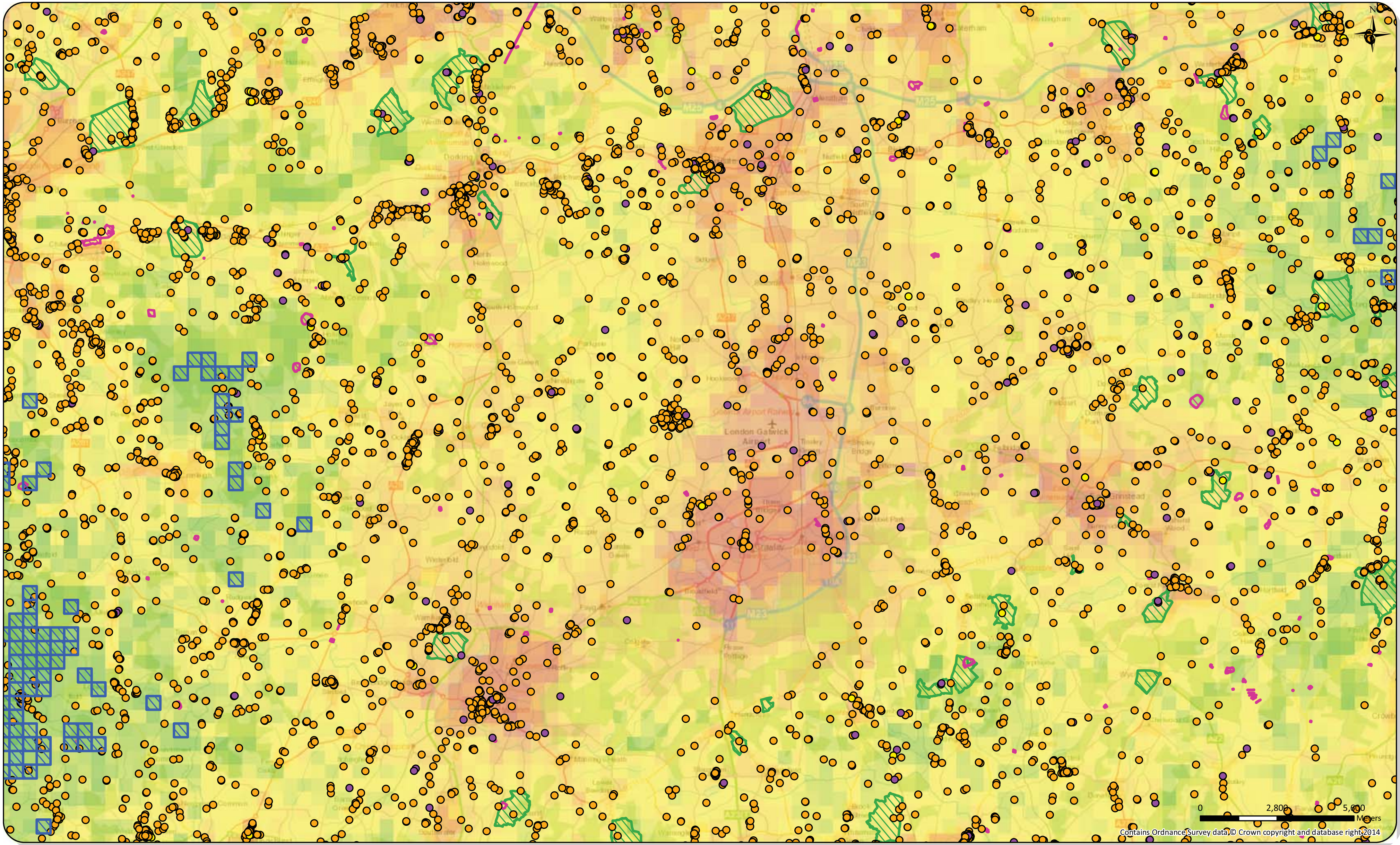
Registered Parks and Gardens Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**

Registered Parks and Gardens Within Study Area				
Name	**Grade**	**List Entry**	**Brief Description**	**Methodology Grouping**
FROGMORE GARDENS	I	1000587	Picturesque landscape garden, laid out in the 1790s for Queen Charlotte on the site of an earlier C18 formal garden, and further developed in the C19 by Queen Victoria. Also includes kitchen garden. Principal house is Frogmore House (GI). Set within Windsor Home Park and part of the Royal Estate, Windsor.	A
WINDSOR GREAT PARK	I	1000592	A royal park of medieval origin created out of Windsor Forest as a royal hunting park from the C11, and by c 1365 had evolved approximately to its present, late C20, size and shape. Containing many ancient trees. The park was later landscaped, and contains gardens attached to four principal residences within the park: Cumberland Lodge, Royal Lodge, Cranbourne Lodge and Forest Lodge. Lies immediately to the south and south-west of the town of Windsor and Windsor Home Park. Part of the Royal Estate, Windsor.	A
WINDSOR CASTLE & HOME PARK	I	1001434	England's premier castle with moat garden (used as a garden from the C15; remodelled late C19/early C20) and a terrace garden by Sir Jeffry Wyatville (mid 1820s) surrounded by pleasure grounds and a landscape park (in origin a medieval deer park), with intimate associations with the British Royal Family since the C11.Part of the Royal Estate, Windsor.	N/A

Conservation Areas Within Study Area		
Name	**Description**	**Methodology Grouping**

Conservation Areas Within Study Area		
Name	**Description**	**Methodology Grouping**
Windsor Town Centre	Windsor Town Centre Conservation Area, amended to its current extent in 1991, is focused upon the historic core of the town and the built environment surrounding Windsor Castle, including: the High Street; Peascode Street; Windsor and Eton Central Station and Windsor Bridge. Elements of the Conservation Area which contribute to its significance include the historic built fabric and the historic street planning; both of which demonstrate the historic development of the settlement and its relationship with both the Castle and the River Thames.	N/A

Appendix 4: Examples of the Spatial Scope of the Study Area



Document Path: D:\JF Working\08052014\Tranquility over heritage.mxd | User Name: john.fisk | Date: 12/05/2014

Project: **T2407 Heritage Assets Aviation Noise Metric**

Client: **English Heritage**

Title: **CPRE Tranquility Data overlyed by Heritage Assets**

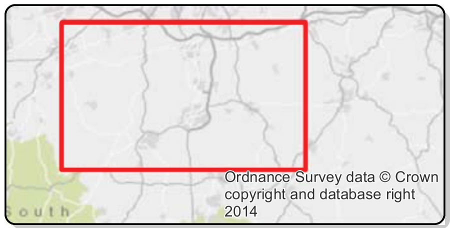
Legend

CPRE Tranquility
Value
High : 148.699
Low : -140.517

National top 20% most tranquil

20140502_ListedBuildingPoints
Grade
- I
- II
- II*

- 20140502_CertificateOfImmunityPoints
- 20140204_BuildingPreservationNoticePoints
- 20140204_WorldHeritageSite
- 20140417_ScheduledMonument
- 20140204_Battlefield
- 20140404_ProtectedWreck
- 20140417_ParkAndGarden



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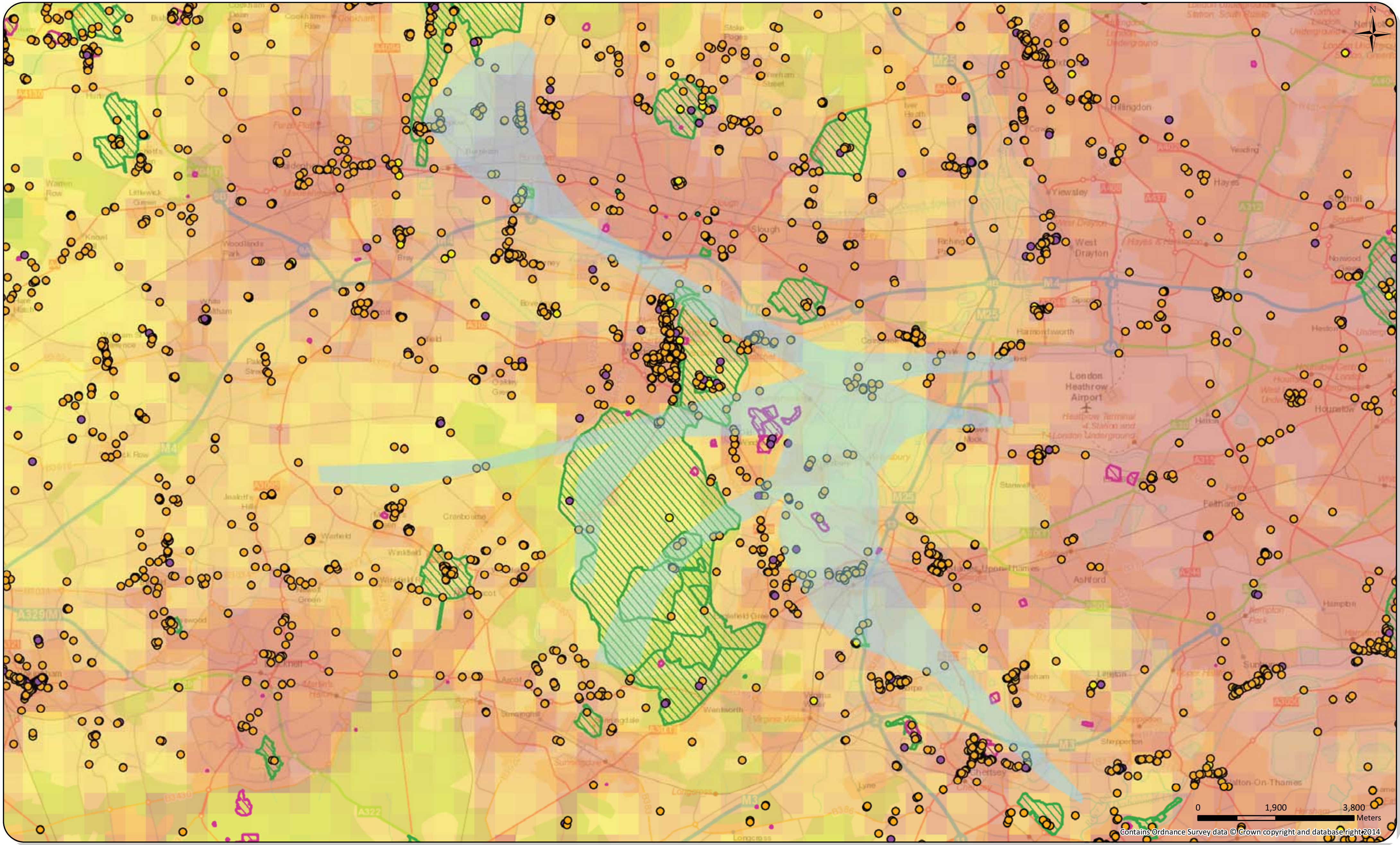

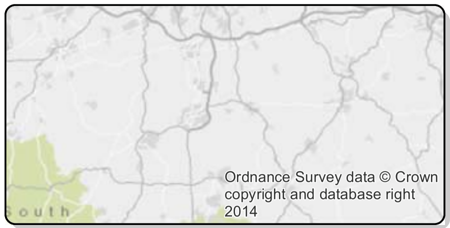

Project: **T2407 Heritage Assets Aviation Noise Metric**

Client: **English Heritage**

Title: **CPRE Tranquility Data and Heathrow Westerly Departures overlyed by Heritage Assets**

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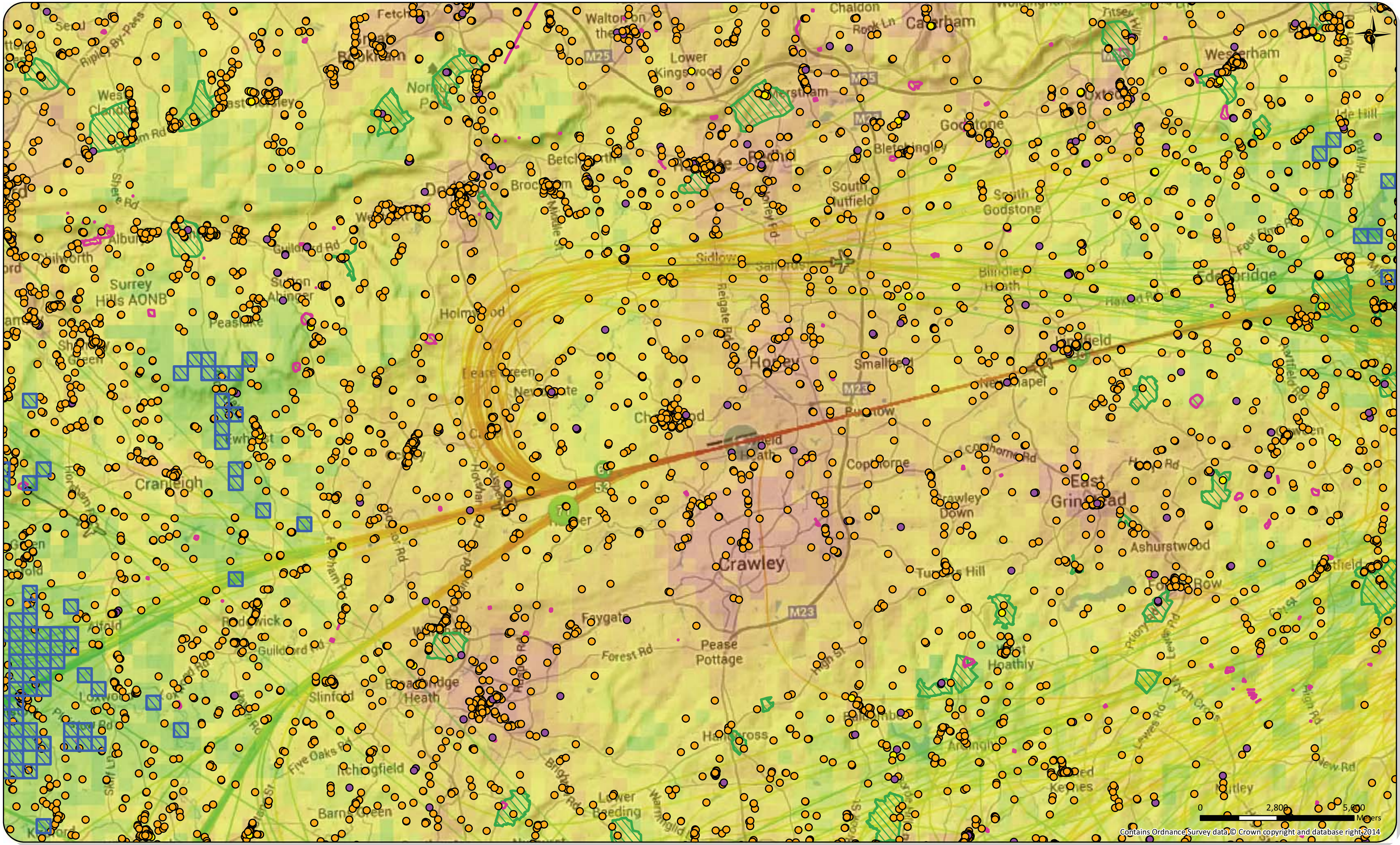


Project: **T2407 Heritage Assets Aviation Noise Metric**

Client: **English Heritage**

Title: **CPRE Tranquility Data overlyed by Heritage Assets and Gatwick westerly departure flight paths**

Legend

CPRE Tranquility

Value

High : 148.699

Low : -140.517

National top 20% most tranquil

20140502_ListedBuildingPoints

Grade

- I
- II
- II*

20140502_CertificateOfImmunityPoints

20140204_BuildingPreservationNoticePoints

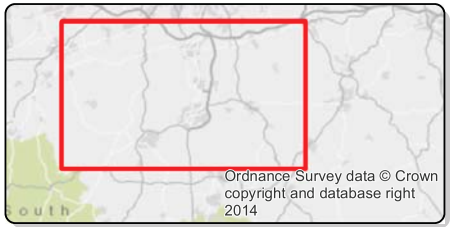
20140204_WorldHeritageSite

20140417_ScheduledMonument

20140204_Battlefield

20140404_ProtectedWreck

20140417_ParkAndGarden



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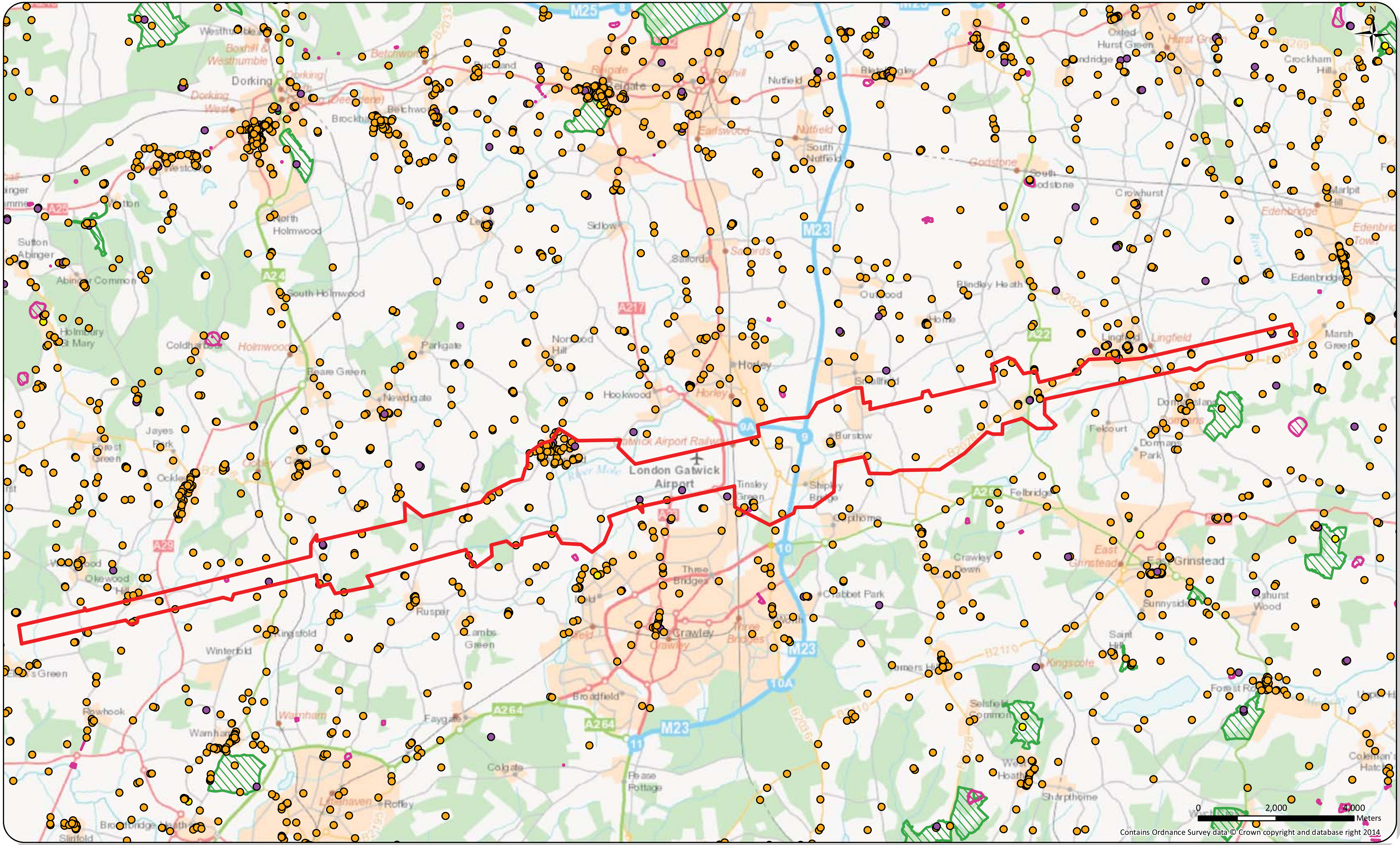


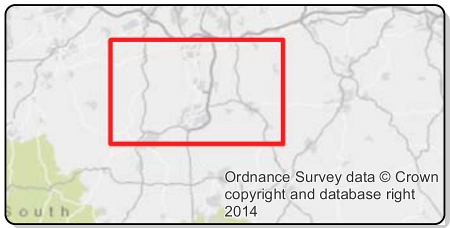
Project: **T2407 Heritage Assets Aviation Noise Metric**

Client: **English Heritage**

Title: **Gatwick Noise Insulation Boundary overlyed by Heritage Assets**

Legend

- Gatwick Noise Insulation boundary
- **20140502_ListedBuildingPoints**
- **Grade**
  - I
  - II
  - II*
- 20140502_CertificateOfImmunityPoints
- 20140204_BuildingPreservationNoticePoints
- 20140204_WorldHeritageSite
- 20140417_ScheduledMonument
- 20140204_Battlefield
- 20140404_ProtectedWreck
- 20140417_ParkAndGarden



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