TRANSPORT AND WORKS ACT 1992

TOWN AND COUNTRY PLANNING ACT 1990

PLANNING (LISTED BUILDINGS AND CONSERVATION AREAS) ACT 1990

PROPOSED LONDON UNDERGROUND (NORTHERN LINE EXTENSION) ORDER

PROOF OF EVIDENCE

OF

Rupert Thornely-Taylor
Noise and Vibration

FOR

TRANSPORT FOR LONDON (TfL)

DOCUMENT TFL3/A

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Contents

GLOSSARY AND ABBREVIATIONS

Abbreviation	**Definition**
ANC	Association of Noise Consultants
Ambient	Background levels
A-weighted sound pressure level	A logarithmic measure of sound pressure which takes into account the human auditory system's response to the size of changes in sound pressure and differential sensitivity to sounds of different pitches (or frequencies)
BPM	Best Practicable Means
BS	British Standard
BSI	British Standard Institute
Baseline	Existing environmental conditions present on, or near a site, against which future changes may be measured or predicted
Benchmark	A standard by which something can be measured or judged
Breakers	Pneumatic hammer for breaking through concrete
CoCP	Code of Construction Practice. Document providing mitigation to reduce or eliminate adverse effects and enhance beneficial effects
COPA	Control of Pollution Act, 1974
CRTN	Calculation of Road Traffic Noise
Cumulative Impacts	Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions
dB	Decibel. The ratio of sound pressures, which we can hear, is a ratio of 10^6 (one million: one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound pressure level' (L_p) and the associated measurement unit is the decibel (dB). As the decibel Is a logarithmic ratio, the laws of logarithmic addition and subtraction apply
dB(A)	The unit of noise measurement (measured on a logarithmic scale), which expresses the loudness in terms of decibel (dB) scale and the frequency factor (A)
Free-Field Noise Levels	Levels which are at least 3.5m away from any hard reflecting surface other than the ground

GLOSSARY AND ABBREVIATIONS

Abbreviation	Definition
Frequency (Sound)	The rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the Hertz (Hz), which Is identical to cycles per second. A thousand hertz is often denoted kHz, e.g. 2 kHz: 2000 Hz. Human hearing ranges approximately from 20 Hz to 20 kHz. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For more detailed analysis, each octave band may be spilt into three one-third octave bands or in some cases, narrow frequency bands
Grade II Listed Building	Buildings of special architectural or historic interest
HGV	Heavy Goods Vehicle
HM	Her Majesty
Hz	Hertz
Head house	The above ground structure which is associated with and either directly above or off set from a below ground shaft
Hoarding	A temporary board fence set up on the perimeter of a building site
IoA	Institute of Acoustics
ISO	International Organisation for Standardisation
JLE	Jubilee Line Extension
L_{A10}	The noise level exceeded for 10% of the measurement time
$L_{A90,T}$ (or L_{A90})	The A weighted noise level exceeded for 90% of the specified measurement period. (T) In B84142: 1990 It is used to define background noise level
$L_{Aeq,T}$ (or L_{Aeq})	Equivalent continuous sound level. Another index for assessment for overall noise exposure is the equivalent continuous sound level,

GLOSSARY AND ABBREVIATIONS

Abbreviation	Definition
L_{eq}	This is a notional steady level, which would, over a given period of time, deliver the same sound energy as the actual time varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level
L_{Amax}	Maximum value that the A-weighted averaged sound pressure level reached during a measurement period. L_{AmaxF}, or Fast, indicates that the sound pressure level is averaged in 0.125 second slices.
LOAEL	Lowest Observable Adverse Effect Level
OECD	Organization for Economic Co-operation and Development
L_P	Sound Pressure Level
L_W	Sound Power Level
NIR	Noise Insulation Regulations 1988
NLE	Northern Line Extension
NOEL	No Observed Effect Level
NPPF	National Planning Policy Framework (published 27th March 2012)
NPSE	Noise Policy Statement for England
NSR	Noise Sensitive Receptors
OGV	Other Goods Vehicle
OS	Ordnance Survey
PPG	Planning Policy Guidance
PPGN	Pollution Prevention Guidance Notes (Environment Agency)
PPS	Planning Policy Statement
PPV	Peak Particle Velocity in metres per second. The vibration measurement parameter that based on a form of acceleration that is frequency weighted to reflect human sensitivity to various frequencies
R_W	Single number quantity that categorises the airborne sound insulating properties of a material or building element over a range of frequencies

GLOSSARY AND ABBREVIATIONS

Abbreviation	Definition
Receptor	(Sensitive) A component of the natural created or built environment such as human being, water, air, a building, or a plant that is affected by an impact
Residual Impacts	Those impacts of the development that cannot be mitigated following implementation of mitigation proposals
SCL	Sprayed Concrete Lining
SI	Statutory Instrument
SOAEL	Significant Observed Adverse Effects Level
SPD	Supplementary Planning Document
SPG	Supplementary Planning Guidance. Non-statutory guidance that supplements Unitary Development Plan (UDP) policies
Sound Power	The sound power level (Lw) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its volume or mass), which is not affected by the environment within which the source is located
Statistical Noise Levels	For levels of noise that vary widely with time, it is necessary to employ an index that allows for this variation. For example, L1 0 is the level exceeded for ten per cent of the time period. A weighted statistical noise levels are denoted LA10, dBLA90 etc. The reference time period (T) is normally included, e.g. dBLA 10, 5min or dBLA90, 8hr
Step Plate Junction	A junction where two tunnels lined with plates of different diameters meet, and vertical plates are used to close the vertical faces, to form a step
TBM	Tunnel Boring Machine
TWAO	Transport and Works Act Order. Can authorise railways, tramways, guided transport schemes and certain other types of infrastructure project in England and Wales
Tender	A bid for a contract
UK	United Kingdom

GLOSSARY AND ABBREVIATIONS

Abbreviation	Definition
URS	URS Infrastructure and Environment UK Limited. Authors of the Environmental Statement
VDV	Vibration dose values in metres per second. The vibration measurement parameter that based on a form of acceleration that is frequency weighted to reflect human sensitivity to various frequencies, (the scale is $m/s^{1.75}$).
WHO	World Health Organisation

S1. SUMMARY PROOF OF EVIDENCE

S1.1 Scope of Evidence

S1.1.1 My evidence covers the noise and vibration effects from the construction and operation of the Northern Line Extension scheme in accordance with Method B in the Draft Order (and consequently there will be no surface level sites at Radcot Street or Harmsworth Street).

S1.1.2 I describe the nature of noise and vibration and the scales used to quantify them, review current practice in construction noise control, and then set out the controls on noise and vibration that would be used in the Northern Line Extension scheme. I summarise the environmental impact of the scheme, taking account of these controls, following which I address issues raised by objectors. I then set out my conclusions.

S1.1.3 My evidence addresses the Statement of Matters insofar as it relate to noise and vibration.

S1.2 The Nature of Noise and Vibration

S1.2.1 The kind of decibel scale most commonly used for overall noise assessment is known as the ‘A-weighted decibel’ or dB(A). A fluctuating noise is measured using as the equivalent continuous sound level, or LAeq.

S1.2.2 Vibration can be measured either in units of velocity or acceleration. The scale used to assess human sensitivity to non-continuous vibration is the peak particle velocity (PPV) or vibration dose value (VDV). Vibration can give rise to re-radiated airborne noise which can been assessed using the maximum value of the re radiated noise level measured with ‘S’ or ‘F’ time weighting (LAmax,S. or LAmax,F).

S1.3 Summary Of Work Carried Out

S1.3.1 Effects from airborne and structure-borne noise and from vibration during the construction and operating phases of the Northern Line Extension project have been assessed at noise sensitive buildings in the vicinity of the worksites and along the routes of traffic diversions.

S1.3.2 Ambient noise levels were monitored in April and May 2008, during July – August 2010, and in January and March 2013 at locations representative of the closest noise sensitive receptors to the works.

S1.3.3 The evaluation of noise and vibration effects is based upon criteria developed following a review of criteria and policies adopted by other major rail projects and current best practice.

S1.4 Basis of the Adopted Criterion for Groundborne Noise from the Northern Line Extension

S1.4.1 The design of the Northern Line Extension will follow the precedents set by recent new underground railway projects in the UK in seeking to achieve an operating railway that does not cause significant disturbance as a result of vibration or groundborne noise.

S1.4.2 Current LU guidance uses the F (fast) rather than the S (slow) dB Max scale and so the design aims are more stringent than those for the JLE and Crossrail though the numerical values are the same.

S1.4.3 These aims also sit well within the range of international guidance on GBN levels and fully accords with the aims of the Noise Policy Statement for England and thereby the National Planning Policy Framework.

S1.5 Review of Current Policy and Practice in Noise Control

S1.5.1 National and local policies on the approach to controlling noise are addressed in the evidence of John Rhodes; my evidence describes the Noise Policy Statement for England and its relationship to the overall national planning policy.

S1.5.2 The Northern Line Extension project will apply the protocol developed as part of the Crossrail project.

S1.5.3 Noise and vibration impacts from the construction of the development will be controlled by the Northern line Extension CoCP.

S1.6 Proposed Controls On Noise And Vibration

S1.6.1 Noise and vibration from the NLE scheme will be controlled in the following ways:

i. An updated CoCP
ii. The Project Noise and Vibration Policy for Airborne Noise during Construction
iii. Prior consents under Section 61 of the Control of Pollution Act 1974
iv. The facilities associated with the Northern Line Extension will be designed to control noise and vibration to levels no greater than the thresholds of significance established for the project.

S1.7 Overview Of Assessment

S1.7.1 Airborne noise from surface construction activity on worksites (including the construction and use of the jetty) will cause significant effects (SEs), and/or lead to an offer of noise insulation (NI), and/or further mitigation (FM) under the project's noise policy at residential accommodation in the vicinity. There would be no residual SEs, taking into account the mitigation provided under the NLE Policy.

S1.7.2 Vibration from surface construction activity at worksites (and the jetty) will not cause any SEs for buildings or their occupants.

S1.7.3 Groundborne noise (GBN) from the tunnel boring machine (TBM) will not cause significant effects but unmitigated GBN from the use of the underground construction railway could cause significant effects at dwellings in the vicinity of Aulton Place and De Laune Street. These effects will be mitigated by the requirement to use Best Practicable Means to reduce GBN from the temporary railway.

S1.7.4 There are no significant effects on noise-sensitive buildings arising from the use of the highway by construction traffic.

S1.7.5 The project's approach to operational noise and vibration is such that there will be no significant effects.

S1.7.6 More detailed information in relation to premises associated with objectors is provided in Appendix 6.

1. QUALIFICATIONS AND EXPERIENCE

1.1.1 My name is Rupert Maurice Thornely-Taylor

1.1.2 I am a Fellow of, and was a founder member of, the Institute of Acoustics, a Member of the Institute of Noise Control Engineering of the USA and a Member of the International Institute of Acoustics and Vibration. I have specialised exclusively in the subjects of noise, vibration and acoustics for more than 49 years. I have been an independent consultant in these subjects for the past forty five years, and head the practice known as Rupert Taylor FIOA.

1.1.3 I am a past President and Honorary Member of the Association of Noise Consultants and a Director of the International Institute of Acoustics and Vibration. I was for ten years a member of the Noise Advisory Council chaired by the Secretary of State for the Environment, and was chairman and deputy chairman of two of its working groups; I was a member of the Scott Committee, which drafted the basis of the noise section of the Control of Pollution Act 1974.

1.1.4 I am the author of the Pelican book NOISE, and editor or co-author of many other books including the Association of Noise Consultants Guidelines Measurement and assessment of Groundborne Noise and Vibration". I was a member of the Working group that produced the recent ISO Standard 14837-1:2005 "Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General guidance". I have prepared reports on noise for the OECD.

1.1.5 I have extensive experience of construction noise and vibration, and have carried out construction noise studies of the Jubilee Line Extension, Crossrail, Dublin Metro North, Thameslink 2000 and have been expert witness on construction noise in inquiries into several major infrastructure developments including Victoria Station Upgrade. I was expert witness in the House of Commons Select Committee on the Channel Tunnel Rail Link Bill, and in the House of Commons and House of Lords Select Committees on the Crossrail Bill. I have been consultant to the Crossrail Project since 1991.

1.1.6 I have been consultant to London Underground Ltd and/or TfL (and their predecessors) for over 35 years, having advised on projects, in addition to Jubilee Line Extension, Crossrail and Croydon Tramlink, such as the initial Docklands Light Railway, Green Park Station, Westminster District and Circle Line Station, Camden Town Station, and Tottenham Court Road Station. I have also carried out vibration surveys at King's Cross Underground Station. For Network Rail and the predecessors, in addition to Thameslink 2000 I have been involved in vibration studies at St Pancras Chambers, the Clerkenwell Tunnels, London Bridge and Waterloo International Terminal.

1.1.7 I have, as a sub-consultant to URS, been advising TfL on the Northern Line Extension Scheme since 2012.

2. SCOPE OF EVIDENCE

2.1 Overview

2.1.1 My evidence covers the topics of noise and vibration, from the construction and operation of the Northern Line Extension scheme. It includes or refers to information contained in the Environmental Statement (the ES) (NLE/A19) dated April 2013 including Appendix E (Noise and Vibration) (NLE/A20).

2.1.2 At the time of the preparation of the ES and the Draft Order, TfL had provided for two potential methods of constructing the works proposed in the vicinity of Kennington Station (referred to as Construction Methods A and B) in the draft Order submitted in April 2013 pending further investigation of the methods.

2.1.3 At that time, under Method A, it was proposed to have two temporary shafts to allow work to stabilise the ground (through the injection of grout) around the sites where the two new running tunnels are propose to be connected to the Kennington loop by means of step plate junctions. The temporary shaft sites assessed in the ES were at Radcot Street and Harmsworth Street. Powers to use these sites were included in the draft TWA Order submitted with TfL's application in April 2013.

2.1.4 During TfL's review of the scheme in 2012, another potential means of connecting the extension to the Kennington loop was identified which would not require temporary shafts. Instead, underground 'gallery tunnels' would be constructed in order to undertake the ground treatment works (through the injection of grout from inside the 'gallery tunnels'). This method, known as Construction Method B, was also provided for in the draft TWA Order submitted with TfL's application in April 2013.

2.1.5 Since the publication of the Environmental Statement, TfL has decided to adopt Method B. The use of the underground 'gallery tunnels' to inject grout to stabilise the ground means that the surface level sites at Radcot Street and Harmsworth Street are not required to be used. My evidence is therefore confined to addressing the effects of Method B and consequently does not examine the potential noise impacts arising from Method A and the use of the surface level sites at Radcot Street and Harmsworth Street.

2.2 Structure of proof

2.2.1 I first describe the nature of noise and vibration and the scales used to quantify them. I next review current practice in construction noise control, and then set out the controls on noise and vibration that would be used in construction and operation of the Northern Line Extension scheme. I summarise the environmental impact of the scheme, taking account of these controls, following which I address the specific noise and vibration related issues raised by objectors. I also provide a corrected version of an incorrect table in Chapter 9 and Appendix E the ES.

2.2.2 I set out my conclusions in Section 9

2.2.3 My evidence addresses the following topics included in the Statement of Matters:

4. The extent to which the scheme would be consistent with the National Planning Policy Framework, Mayoral Plans and Strategies for London and with local planning authority policies.

5. The likely impact on local residents, others visiting or passing through the area, businesses and the environment of the scheme during construction and operation, including;

a) noise and vibration;

6. The effects of the construction of a permanent shaft and head house in Kennington Park and Kennington Green.

9. The measures proposed by TfL for mitigating any adverse impacts of the scheme, including:

a) the proposed Code of Construction Practice;

b) any measures to avoid, reduce or remedy any major or significant adverse environmental impacts of the scheme; and

11. The conditions proposed to be attached to the deemed planning permission for the scheme, if given, and in particular whether those conditions meet the tests of the DOE Circular 11/95 of being necessary, relevant, enforceable, precise and reasonable.

3. THE NATURE OF NOISE AND VIBRATION ISSUES RAISED IN OBJECTIONS

3.1 Noise Levels and Scales

3.1.1 The noise levels to which I will refer are expressed using the decibel scale. The decibel scale has the characteristic that it measures proportions rather than absolute quantities, so that, for example, doubling the amount of energy in a sound (for example by putting two identical sound sources close together) always causes an increase of 3 decibels, whether it is a doubling of a large or of a small amount of noise energy. However, as I shall explain, the perceived loudness of a doubling of noise energy is quite small, and certainly much less than a doubling of perceived loudness. A tenfold increase in the amount of energy gives an increase of 10 decibels, although, once again, the perceived increase in loudness is not nearly as great as the increase in energy would suggest; a ten fold increase in energy is certainly not a tenfold increase in loudness.

3.1.2 The kind of decibel scale most commonly used for overall noise assessment is known as the ‘A-weighted decibel’ or dB(A). The ‘A-weighting’ is a method of causing measuring instruments to respond in approximately the same manner as does the human ear, which is comparatively insensitive to low-pitched and very high-pitched sound. For example, two sounds which are perceived as having the same loudness may have widely differing physical magnitudes if one is a low rumble and the other is a whistle. Without ‘A’ weighting, the low rumble would measure some 30 decibels more than the whistle, even though they both sound equally loud to the human ear. In ‘A-weighted decibels’ both sounds would have the same decibel, or dB(A), level. In some documents dB(A) is written as dBA.

3.1.3 Noise levels in dB(A), like the basic decibel scale, measure proportions so that a 10 dB(A) increase is a doubling of loudness and a 10 dB(A) decrease is a halving of loudness. Judgement of loudness is subjective, and dependent on the characteristics of the sound, but the ‘10 dB(A) increase is a doubling of loudness' rule is a useful general guide. For example, ten motor cycles close together sound only about twice as loud as one motor cycle, and certainly not ten times as loud; the same is true of one motorcycle that emits ten times as much sound power as another. As a further guide, one may say that a sound level of less than 20 dB(A) is virtual silence, 30 dB(A) is very quiet. 50 dB(A) is a moderate level of noise, 70 dB(A) is quite noisy and in a noise level of 90 dB(A) one has to shout to be understood.

3.1.4 The measurement of sound levels in decibels involves a kind of averaging process in which the fluctuating pressure signal is squared, averaged, and the square root obtained. This process is known as rms. averaging, and it takes place over a defined time. There are two standard averaging times, 1/8 second, known as ‘F' response and 1 second, known as ‘S' response. In the assessment of groundborne noise levels relating to the proposed Northern Line Extension, the dB(A) levels have been ,measured and assessed using the ‘F' response. Maximum noise levels measured with either of these two time weightings, as they are known, are labelled LASmax or LAFmax. In some documents this is written as LAmax,S or LAmax,F. The subscript “p” is also sometimes inserted to make clear that the “L” represents sound pressure level, i.e. LpASmax or LpAFmax.

3.1.5 The basic dB(A) scale can only measure the instantaneous level of sound. Where the level of sound fluctuates up and down, as it normally does in the environment, the dB(A) level also fluctuates. When it is necessary to measure a fluctuating noise environment by means of single number, an index known as equivalent continuous sound level, or LAeq, is employed, also having units expressed in decibels, or dB. LAeq (which in some documents is referred to as Leq in units of dB(A) rather than LAeq in units of dB – the two conventions have the same meaning) is a long term average of the amount of energy in the fluctuating sound over time, expressed in dB(A). In the case of a continuous, unchanging sound, its LAeq level is the same as its sound level in dB(A).

3.1.6 Because a 3 decibel change is caused by a doubling or halving of sound energy, then it follows that if the sound energy entering an ear or a microphone over a particular period of time is doubled or halved, because the same sound went on for twice or half as long as it did previously, then the amount of energy received will be doubled or halved. The result is that the LAeq level will go up or down by 3 dB just as it would if the amount of energy in the sound, rather than the duration of the sound, had doubled or halved.

3.1.7 The consequence is that the LAeq scale will measure either the level of sound, or the duration of sound, or a combination of both such as the number and noise level of a series of train passages. Since the LAeq index is based on the dB(A) scale, it will measure loudness in the same way, that is, an increase of 10 units on the LAeq scale sounds like a doubling in loudness if the increase is due to the same sound just getting louder. Alternatively, a 10 unit increase could be due to a tenfold increase in the number of sounds all of the same individual loudness and duration, or a tenfold increase in the duration of the same number of sounds within the measurement period.

3.1.8 Another example of the effect of the decibel scale is in relation to noise levels from road traffic. Historically, road traffic noise has, in the UK, been assessed using the LA10,18 hr noise scale. Since this is a decibel scale it also has the characteristic that a doubling of the source of the sound energy will cause an increase of 3 units on the scale. Road traffic noise is now often assessed using the LAeq scale. (There are means of converting between these two scales in many cases.)

3.1.9 As a consequence of the decibel scale, in order for noise levels from road traffic to increase by 3 dB there must be a doubling of the source of sound energy from the traffic . If the speed and composition of the traffic is constant then, for a given section of road (on which the physical factors are unchanged) a doubling of the sound energy can only be achieved by a doubling of the traffic flow (ie over the same period). It is for this reason that a large change in traffic flow is necessary to produce a significant change in noise levels alongside the roads in question.

3.2 Vibration Levels and Scales

3.2.1 Although low frequency airborne noise from sources such as heavy lorries can cause perceptible movement of building elements, such as rattling of windows, which is described by people as vibration, in my evidence the term ‘vibration' is restricted to displacement of the ground or of structures due to the propagation of waves through the ground.

3.2.2 Wave propagation in the ground takes several forms. Some waves spread out underground in a manner analogous to sound waves in air, although in solids there are also shear waves which behave in a more complex manner than the compressional waves that occur in both fluids (including air) and solids. Other wave types travel on the surface in a manner more analogous to the surface ripples of a pool of water. These waves travel at different speeds and are attenuated at different rates. The underground waves, or body waves as they are sometimes called, may undergo reflection from underground features such as rock strata.

3.2.3 In the case of vibration sources at ground (ie street) level, surface waves are important. For underground sources (eg railways in tunnel), body waves are of prime importance since these transmit ground-borne noise which may be radiated inside noise-sensitive buildings above.

3.2.4 The basic units of vibration measurements relate to the movement of the surface that is vibrating. This can be measured either in units of velocity in metres per second (m/s) or of acceleration in metres per second per second (m/s2). For small values, millimetres may be used instead of metres.

3.2.5 In fact, the decibel scale is sometimes used for the measurement of vibration as well as of noise, and for example, when velocity is measured in decibels above a reference level of one billionth of a metre per second then a velocity level of 120 dB is 1 millimetre per second (1 mm/s).

3.2.6 Again, as with noise, human sensitivity to vibration depends on the frequency of the vibration. There are weighting curves like the ‘A-weighting' of noise measurements in dB(A). The sensitivity of a person to vibration depends to some extent on the direction of the vibration relative to their posture at the time – for example vertical vibration in the floor is perceived differently by a standing person and a person lying down. There are therefore different weighting curves for vibration in the vertical, horizontal and lateral directions. In British Standard 6472:2008:Part 1 (NLE/E2) there are two weightings, one for vertical and another for either of the two horizontal directions.

3.2.7 As is the case with noise, it is necessary to take account of the effect of intermittency on human response, when vibration is not continuous. Whereas with noise this is done using the LAeq index, for vibration the method used is to sum the fourth power of the weighted acceleration, and express the fourth root of the result as an index known as vibration dose value or VDV, which forms the basis of advice given in British Standard 6472:2008:Part 1.

3.2.8 Vibration can also give rise to re-radiated airborne noise. In this case the noise is measured using the dB(A) scale, and for all recent railway projects where ground-borne noise has been an issue, the maximum value of the re radiated noise level measured on ‘S’ response, known as LASmax has been adopted as the assessment index. As explained above, however, for the proposed NLE the more sensitive index LAFmax has been adopted.

4. SUMMARY OF WORK CARRIED OUT

4.1.1 The activities considered that could give rise to noise and vibration effects, the locations and types of premises, the periods of assessment, the baseline, and the criteria for assessing effects are described below.

4.2 Noise and Vibration Issues Considered

4.2.1 Noise and vibration effects could arise from the following activities during construction:

i. noise and vibration from activities carried out at surface worksites;
ii. secondary groundborne and structure-borne noise and vibration from underground works including tunnelling; and
iii. noise associated with construction traffic using the public highway.

4.2.2 During operation, noise and vibration effects could arise from:

i. noise and vibration from the operation of plant and machinery,; and
ii. groundborne noise and vibration from the operation of underground trains.

4.3 Geographical Scope

4.3.1 The areas within which noise and vibration has been assessed include:

i. areas near enough to construction/work sites where significant activities will affect sensitive receptors (the location and extent of the worksites are shown in Figures 9-3 to 9-6 of the Environmental Statement (NLE/A19) which are reproduced in Appendix A1 to this proof;
ii. construction traffic routes, and routes subject to changes in traffic flow which will experience changes in flows where sensitive receptors will potentially be affected;
iii. areas in the vicinity of the stations and ventilation shafts that will operate after construction and they correspond to the locations identified in paragraph i; and
iv. buildings close to the alignment of the NLE have also been assessed as regards noise and vibration during the operating phase and these locations are shown Figure E4-1 in Part 4 of Appendix E in ES Volume II: Part E4 (NLE/A20) which is reproduced as Figure A1.6 in Appendix A1 of this proof.

4.4 Temporal scope

4.4.1 For the construction phase, the period considered is the duration of the construction programme which is expected to run from late 2014 or early 2015 to – 2020 (**NLE/A19/8**, Section 4 - Description of the NLE as amended by the Environmental Statement Addendum paragraph 33 and 34), and approximately 22 months for construction of the main running tunnels.

4.4.2 For the operational phase, the period considered extends to the lifetime of the system.

4.5 Receptors considered

4.5.1 The resources and receptors have been identified as residential properties the locations of the receptors assessed are shown in Figures 9-3 to 9-6 of the ES (**NLE/A19**) and Figure E4-1 in Annex B of *ES Volume II: Appendix 4* (**NLE/A19**) which are reproduced in Appendix A1 of this proof. In addition, schools have also been considered as noise sensitive receptors.

4.5.2 Representative receptors assessed as being potentially affected by effects due to construction works are listed in 9-18 to 9-21 and 9-24 of the ES. Representative receptors assessed as being potentially affected by the construction and operation of the tunnels and the system are listed in tables 9-26 to 9-29 of the ES.

4.6 Baseline noise levels

4.6.1 Ambient noise levels were monitored during April and May 2008, during July – August 2010, and in January and March 2013. The monitoring locations were chosen to be representative of the closest noise sensitive receptors to the proposed works.

4.6.2 Measured ambient noise levels at these monitoring locations are summarised in Table A2.1 in Appendix 2 of this proof. The locations of the monitoring locations are illustrated in Figure 9-2 of the ES (NLE/A19) which is reproduced as in Appendix A1.6 of this proof).

4.7 Evaluation Criteria

4.7.1 The evaluation of noise and vibration effects due to surface construction works is based upon criteria that have been developed following a review of criteria and policies adopted by other, recent major rail projects together with current best practice. The criteria that have been adopted are set out below and use the "ABC" method, Method 1, included in BS5228-1:2009. This method was originally developed in the assessment of construction noise impacts for the Channel Tunnel and was further implemented in the ES for the Thameslink 2000 project. It is similar to the Method 2 given in BS 5228-1 which is based on the approach used in the Crossrail ES. Both methods assess significance according to the degree of noise change, taking an increase in the overall noise (ambient and construction) of 5 dB L_{Aeq} as significant with a lower cut-off of 65 dB (day), 55 dB (night) and 45 dB (night). This type of assessment method has now been used for many projects in the UK over several decades and in practice has been found to be a realistic and successful way of assessing the potential effects of surface construction noise. This is why the British Standards Institution chose to provide examples of the method in the 2009 revision of BS 5228.

4.7.2 The basis for the adoption of the criterion for groundborne noise is described in Section 5 of this proof.

4.8 Construction – Noise and Vibration

4.8.1 For airborne noise from surface construction activity, levels generated by construction activities will be considered significant if they exceed the threshold values in Table A3.1 of Appendix 3.

4.8.2 Changes in road traffic flow have been assessed on the basis of the degree of change in noise level adjacent to a given section of road based on the approach adopted by the Highways Agency's "Design Manual for Roads and Bridges". This comparison takes into account construction traffic using the highway and non-construction traffic diverted from its normal route. The criteria are shown in Table A3.2 of Appendix 3.

4.8.3 Potential vibration effects are of three kinds:

i. effects on buildings
ii. 'feel able' vibration experienced by occupiers of buildings; and
iii. groundborne noise (also termed secondary noise or re-radiated noise).

4.8.4 Criteria for assessing these three effects are as follows:

i. criteria for effects on buildings are set out in Appendix A3,Table A3.3. These are based on the guidance given in BS 5228-2:2009.
ii. criteria for 'feel able' vibration experienced by residents are set out in Appendix A3,Table A3.4. These criteria are based on the advice given in BS 6472:2008.
iii. for secondary noise radiated into sensitive spaces by vibrating wall, floor and/or ceiling surfaces, the effect thresholds in Appendix A3, Table A3.7 have been used but when assessing the impact of groundborne noise from the passage of the Tunnel Boring Machine (TBM) the limited duration of exposure anticipated has been taken into

account 1. Unlike the effects of vibration the effects of secondary noise, also called re-radiated noise, groundborne or structure-borne noise are not subject to guidance in a British or International Standard, and as explained in section 5 below the assessment approach that has been adopted for the proposed NLE is based on the accumulated experience and practice developed in a sequence of underground railway projects in the UK, also having regard to other approaches used around the world.

4.9 Operation – Fixed Plant

4.9.1 The significance criteria utilised in assessing operational noise from fixed plant such as ventilation shafts are set out in Appendix A Table A3.5. These criteria are derived from the advice given in BS 4142:1992 Method of Rating Industrial Noise Affecting Mixed Residential and Industrial Areas. Mechanical and electrical services forming part of the NLE project will be designed and constructed to ensure that, at locations relevant to neighbouring residential or other noise sensitive development, the Rating Level of all the NLE plant in normal operation will be 10 dB less than the L_{A90} (background noise level) in its absence assessed in accordance with BS 4142:1997 (NLE/E3) and hence will have a negligible effect.

4.9.2 The potential effects arising from vibration of fixed plant on buildings during the operational phase use the same criteria as those referred to in i above.

4.9.3 The criteria for effects of 'feel able' vibration from fixed plant on people in buildings during the operational phase are set out Table A3.6 in Appendix 3.

4.9.4 For secondary noise radiated into sensitive spaces by vibrating wall, floor and/or ceiling surfaces, the effect thresholds are set out in Appendix A3,Table A3.7.

4.10 Operation – Underground Rail Traffic

4.10.1 The potential effects arising from vibration of underground rail traffic on buildings during the operational phase use the same criteria as those referred to in i

[1] **See ES viz -**9.168 **The results of the Crossrail measurements show that measured groundborne noise levels are 35 to 40 dB L_{ASmax} during TBM cutting activities. These results ... are expected to be more representative of the levels that will occur from the construction of the NLE tunnels.** 9.169 **The conclusion of the Crossrail report was that groundborne noise from the TBM would be audible inside properties above the line for no more than one day. Based on this, it is expected that the significance of groundborne noise from TBM use during construction of the tunnels will be minor adverse.**

4.10.2 The criteria for effects of ‘feel able’ vibration from underground rail traffic on people in buildings during the operational phase are set out Table A3.6 in Appendix 3.

4.10.3 For secondary noise radiated into sensitive spaces by vibrating wall, floor and/or ceiling surfaces, the effect thresholds are set out in Appendix A3,Table A3.7.

4.10.4 An explanation of the interpretation of the tables mentioned above in order to determine the significance of a potential effect is set out in Appendix A3,Table A3.8.

5. BASIS OF THE ADOPTED CRITERION FOR GROUNDBORNE NOISE FOR THE NORTHERN LINE EXTENSION

5.1 The Modern Approach to the control of Groundborne Noise

5.1.1 The design of the Northern Line Extension will follow the precedents set by recent new underground railway projects in the UK in seeking to achieve an operating railway that does not cause significant disturbance as a result of vibration or groundborne noise.

5.1.2 The Jubilee Line Extension was the first major underground railway project in the UK which was specifically designed for the control of vibration and groundborne noise, followed by the Docklands Light Railway extensions to Lewisham and to Woolwich Arsenal, and more recently by The Channel Tunnel Rail Link (now known as High Speed 1). Crossrail is the most recent example, now under construction. In the course of gaining the powers for these projects either in Parliament or Transport and Works Act inquiries, the topic of groundborne noise and vibration was raised by petitioners and objectors and decisions on the issues were reached by the Parliamentary select committees and the Secretary of State. The most recent and comprehensive position is set out in Crossrail Information Paper D10 (**NLE/G5**).

5.1.3 Crossrail Information paper D10 sets out an approach which was the subject of scrutiny by both Houses of Parliament and approved by them.

5.1.4 The projects have followed broadly the same approach to the mitigation of noise impacts through design. The approach is one that goes beyond simply identifying a simple numerical noise limit value; instead, it has involved a complete procurement approach that aims to secure a satisfactory outcome system-wide without imposing an unreasonable cost burden on the project.

5.1.5 The approach requires the designers of the railway, who, under the modern approach to procurement, will be initially tenderers for a design and build contract, to select a system-wide track support design which is predicted to achieve, in the locations likely to receive the highest levels of groundborne noise and vibration (colloquially referred to as “pinch-points”), a noise level which is below known complaint thresholds in London.

5.1.6 In any particular location where that noise level cannot be achieved using a track support system appropriate for system-wide use, special systems may be used in those special cases. For example, this has happened on Crossrail where it passes under recording studios or close to a concert hall such as the Barbican Hall. The important feature of this approach is that tenders will not be accepted that seek to install a sequence of different track forms chosen to be the lowest cost design that will just meet the design noise level at each location. This would in any event be unacceptable for maintenance reasons because of the impracticability of having to maintain a range of different track components.

5.1.7 Tenderers, and in due course contractors, will be required to employ state-of-the-art methods of predicting, through numerical modelling, the performance of vibration isolating track forms, using the best available data concerning the parameters that control the generation and transmission of vibration and groundborne noise.

5.1.8 Many of these parameters are within the control of the engineers, including rolling stock characteristics, rail section, resilient rail support components, track support and tunnel design. Parameters such as ground conditions and the nature of underground structures and building foundations are obtainable through geotechnical studies and archive searches. The contractors are required to submit their prediction results to demonstrate that in all reasonably foreseeable circumstances the design noise level will be achieved at the "pinch-points". It follows that at other locations (i.e. locations other than the "pinch-points" lower levels of vibration and groundborne noise will occur, for example due to greater depth of ground cover, lower speeds, absence of deep foundations. Thus in these locations the predictions will show outcomes considerably better than the design noise level.

5.1.9 The contractor's designs, if approved by the employer, will be made available to the local authorities. The local authorities will then have the opportunity to satisfy themselves that all reasonably foreseeable circumstances have been taken into account and that a track form and associated design features are proposed which will achieve the design aim. Any concerns raised by local authorities will be reviewed by the project and addressed either by the provision of further information or design modification if appropriate.

5.1.10 When the railway becomes operational, should there be any cases where the design aim is not achieved in practice, investigations will be carried out to establish the cause. The reason may be found to be a fault in a component, which can be rectified, or a design fault and a consequent use of an incorrect component which, if practicable can be replaced. There may be a want of maintenance which can be rectified.

5.1.11 There is also the possibility, however, that a design aim is not achieve due to circumstances that were not reasonably foreseeable, such as a buried structure between the tunnel and the building above which has the effect if increasing transmission of groundborne noise and vibration. In such circumstances which are very rare in my experience, it may not be possible or reasonably practicable to rectify the problem and exceedance of the design aim may remain. My understanding is that in such circumstances a person with a relevant interest in land may be able to make a claim in compensation.

5.1.12 As set out in section 7 below, TfL has proposed conditions to give effect to the approach set out above.

5.1.13 The draft condition relating to groundborne noise in section 7 is based on designing to achieve stated noise levels in “all reasonably foreseeable circumstances”. Should such an incident occur, any steps reasonably practicable at that stage in the design would be taken to offset the effect of the unforeseen features discovered, such as the identification of a previously unidentified pile, the resilient components on the track form would be optimised to meet the requirements of the site.

5.1.14 It follows from the above that the choice of the numerical value of the appropriate design noise level is but one part of the whole approach to procuring an underground railway that will achieve a satisfactory outcome.

5.2 Selection of design noise level for the Jubilee Line Extension and Crossrail

5.2.1 The selection of the design noise level originally dates from information gathered by London Underground after the opening of the first part of the Jubilee Line in 1979, linking Baker Street and Charing Cross. This was the last London Underground line to be designed using old-style track support without vibration isolation, and levels of vibration and groundborne noise in buildings above it are similar to those above the older deep tube lines. There were complaints from residents living above the line, and London Underground found that most of those complaints occurred where the maximum sound level measured using the standard “slow” response of a sound level meter, called L_{ASmax} was greater than 40 dB L_{ASmax}.

5.2.2 This information was the starting point for the choice of a design noise level when the Jubilee Line Extension was planned at the beginning of the 1990s. At that time the original Crossrail project was also being planned, and a small scale social survey was carried out to study the relationship between groundborne noise levels and public response. The important finding in that study was that people’s response to noise from underground railways was dependent on whether the groundborne noise, or “rumble”, was accompanied by vibration which could be felt using the tactile senses. Where there was “feel able” vibration as well as noise, there was a greater likelihood of annoyance. Where there was negligible “feel able” vibration, the noise heard was less likely to cause annoyance.

5.2.3 An important feature of the vibration and groundborne noise which results from a modern underground railway constructed using resilient rail support is that “feel able” vibration is almost always absent, and audible noise is the only manifestation of vibration transmitted up from the tunnel. This is because modern railways use continuously welded rail. The few joints that are necessary are of high quality. Further, the alignment of the track is set to close tolerances. The running surfaces of the wheels and the rails are also of good quality.

5.2.4 The Jubilee Line Extension was designed to achieve a design aim for rooms inside residential premises of 40 dB L_{ASmax} The system-wide track support system used consists of a resilient baseplate design, although there were some locations where there were high-sensitivity uses such as lecture theatres, or where there were deep foundations coming close to the tunnel, where concrete slab track supported on rubber bearings was employed.

5.2.5 Recent measurements carried out in properties above the Jubilee Line tunnels, where the track is supported by resilient baseplates, have shown maximum noise levels of the order of 28-30 dB L_{AFmax}, several dB better than predicted at the time the Jubilee Line Extension was designed. The occupants were reported to be unaware that there was an underground railway tunnel beneath their dwelling.

5.2.6 The Jubilee Line Extension was operating successfully by the time the Crossrail Bill came before Parliament. The local authorities sought to achieve a better design aim than 40 dB L_{ASmax} advised by their own experts that a figure of 35 dB L_{ASmax} was reasonably achievable. As a result, the Crossrail Information Paper D10, which governs the design and procurement process in the Crossrail Project with regard to the subject of groundborne noise, included a requirement to use reasonable endeavours to adopt mitigation measures that will further reduce any adverse environmental impacts caused by Crossrail, insofar as these mitigation measures do not add unreasonable costs to the project or unreasonable delays to the construction programme. This requirement is applicable to any residential property in which the level of groundborne noise arising from the operation of the Crossrail passenger service near the centre of any noise-sensitive room is predicted to equal or exceed 35dB $L_{Amax,S.}$

5.3 Derivation of the groundborne noise design aim for the NLE

5.3.1 When each new underground railway project is planned, the topic of groundborne noise design level criteria naturally comes under review, as it has done in the case of the Northern Line Extension. Once again, reference has been made to London Underground’s experience in responding to complaints about groundborne noise, and an important change is that in recent times it has been the practice of LUL to use the L_{AFmax} scale rather than the L_{ASmax} scale when investigating complaints. A sound level meter set to "F" or "Fast" response follows fluctuations in sound level much more readily than does a meter set to "S" or "Slow " response. "F" response more closely matches the response of the human ear, while "S" response is more repeatable and predictable.

5.3.2 Where there are rail joints or discontinuities the difference between an "F" and "S" based measurement can be as much as 5 dB. Above an underground railway without rail joints and with resilient rail support the noise may be less peaky and the difference between "F" and "S" may be less.

5.3.3 The London Underground Noise and Vibration Asset design guidance, informed by the experience of LUL, states:

"3.4.2 The noise from sub surface and underground railways should not be considered to be significant if the groundborne noise as measured in a residential dwelling does not give rise to an average maximum noise level exceeding 40dB LAFmax . This is based on an assessment of at least 10 trains for the line being assessed (Note: the two directions of a line would be assessed separately).

3.4.3 In recognition that the sensitivity of people to noise can vary significantly the designers should use reasonable endeavours to meet a more stringent requirement of 35dB LAFmax."

5.3.4 This document is referred to in the draft planning conditions for the Northern Line Extension.

5.4 NLE design noise level in the context of national and international guidance

5.4.1 The design aim clearly needs to be considered in the context of national and international guidance on matters relating to noise and development. The Noise Policy Statement for England (**NLE/E6**), referred to by the National Planning Policy Framework (**NLE/E1**) advises

"There are two established concepts from toxicology that are currently being applied to noise impacts, for example, by the World Health Organisation. They are:

NOEL – No Observed Effect Level

This is the level below which no effect can be detected. In simple terms, below this level, there is no detectable effect on health and quality of life due to the noise.

LOAEL – Lowest Observed Adverse Effect Level

This is the level above which adverse effects on health and quality of life can be detected.

2.21 Extending these concepts for the purpose of this NPSE leads to the concept of a significant observed adverse effect level.

SOAEL – Significant Observed Adverse Effect Level

This is the level above which significant adverse effects on health and quality of life occur.

2.22 It is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. Consequently, the SOAEL is likely to be different for different noise sources, for different receptors and at different times. It is acknowledged that further research is required to increase our understanding of what may constitute a significant adverse impact on health and quality of life from noise. However, not having specific SOAEL values in the NPSE provides the necessary policy flexibility until further evidence and suitable guidance is available.

5.4.2 The first aim of the NPSE states that significant adverse effects on health and quality of life should be avoided while also taking into account the guiding principles of sustainable development. The second aim is to mitigate and minimise adverse impacts on health and quality of life from environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development. The second aim of the NPSE refers to the situation where the impact lies somewhere between LOAEL and SOAEL. It requires that all reasonable steps should be taken to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development (paragraph 1.8). This does not mean that such adverse effects cannot occur.

5.4.3 Guidance on what noise level might be associated with the NOEL and LOAEL concepts in the case of transportation noise is found in the Night Noise Guidelines for Europe on page 99 (see Appendix 4 of this Proof) in a discussion on health effects:

"However, noise-induced motility is a sign of arousal, and frequent (micro-) arousal and accompanying sleep fragmentation can affect mood and functioning next day and lead to a lower rating of the sleep quality. Therefore, motility is relevant for adverse health effects, but more than a few intervals with noise-induced motility are needed for inducing such effects. Although additional, more sophisticated analyses could be performed to refine this estimate, we propose LAmax = 32 dB(A) as the currently best estimate of the threshold for motility induced by transportation noise. The threshold found for EEG awakening was LAmax = 35 dB(A), that is, only a little higher than the 32 dB(A) found for noise-induced awakenings. This would mean that the NOELAmax for transportation noise events is most likely at most 32 dB(A), and definitely not higher than 35 dB(A). It is important to note that the above given NOELAmax ~ 32 dB(A) and NOELAmax ~ 42 dB(A) are indoor levels, in the sleeping room. Although events below 32 dB(A) are audible, and, hence, further research may show more sensitive effects than motility, on the basis of the present available evidence we propose to assume that NOELAmax = 32 dB(A) and set a health-based night-time noise limit that is tolerant for transportation noise events with LAmax 32 dB(A). On the other hand, since adverse health effects need to be prevented by health-based limits and even though vulnerable groups may require lower limits, on the basis of the present available evidence we propose to assume that

NOAELAmax = 42 dB(A) and set a health-based night-time noise limit that does not tolerate transportation noise events with LAmax > 42 dB(A)."

5.4.4 Thus, for transportation noise in general the NOAEL is higher than the Design Guidance for NLE, and therefore LOAEL will be higher still.

5.4.5 The Night Noise Guidelines go on to consider the concept of L_{night} which is the annual energy average in terms of the L_{Aeq} index between the hours of 2300-0700.

"On the basis of the above proposal, it would be possible to derive a night-time noise guideline value in terms of Lnight. Such a guideline value would indicate the level below which no short-term effects are to be expected that would lead to temporary reduced health or chronic disease. Such a guideline value needs to be compared with guideline values derived directly with a view to preventing temporary reduced health and chronic diseases. In particular, for self-reported sleep disturbance, which is an expression of reduced well-being and may be an indication of effects that could contribute to cardiovascular disease, exposure–effect relationships have been derived on the basis of an extensive set of original data from studies from various countries (Miedema, Passchier-Vermeer and Vos, 2003; Miedema, 2004 [See Appeinx 4 of this Proof]). The percentage of people reporting high noise-induced sleep disturbance (%HS) levels off at 45 dB(A) but at a non-zero effect level. The remaining effect may be caused by events not incorporated in the exposure assessment and it appears that if all noise contributions would be incorporated in the exposure metric, high noise-induced sleep disturbance would vanish between 40 dB(A) and 45 dB(A), say at 42 dB(A). Since values found for other temporary reduced health effects or chronic diseases, in particular cardiovascular diseases, will be higher, and considering self-reported sleep disturbance as an adverse effect, this would suggest Lnight = 42 dB(A) as the NOAEL to be compared with the value derived from the short-term effects. Note that this is an outdoor level, which would, assuming partly opened windows and an actual insulation of 15 dB(A), correspond to an indoor equivalent night-time sound level of 27 dB(A). The above discussion is based on motility, EEG awakenings, and conscious awakening. In addition, EEG micro-/minor arousals, and autonomic reactions have been discussed above."

5.4.6 The L_{Aeq} index, and therefore the L_{night} index, are functions of the noise level, duration and number of events. For the Northern Line Extension, on the unlikely assumption that a receptor would receive the 35 dB L_{AFmax} from both tunnels, i.e. from 36 trains per hour, the value of $L_{night,\ inside}$ is 21 dB, 6 dB better than the Night Noise Guidelines for Europe recommendation that NOAEL is 27 dB.

5.4.7 The NLE design aim is compared against international benchmarks in Appendix E of the Environmental Statement Appendix E as follows.

5.4.8 Internationally, a range of limits and design specifications have been adopted for groundborne noise. Malmö Citytunnel was required by the Swedish Environmental Court not to exceed 30 dB L_{ASMax} (with 30 dB L_{AFMax} as a goal) in housing, hospitals and churches. Australian guidance is found in "Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects" which provides for 40 dB L_{ASmax} (day) and 35 dB L_{ASmax} (night). The Austrian Önorm S 9012 sets values, for satisfactory protection, of 40 dB L_{ASmax} for night where the train service ceases for four of the night hours and 35 L_{ASmax} otherwise. The figures for good protection are 5dB lower. Italian regulations set a limit of 35 dB L_{ASmax}. Norwegian Technical Regulation TEK 97 is satisfied is 32 dB L_{AFmax} is achieved in bedrooms. Västlänken in Gothenburg has a guideline value of 30 dB L_{ASmax} for bedrooms. Switzerland has a directive BEKS 1999 with a guideline value of 25 dB $L_{Aeq\ 1h}$ at night, for new construction, in residential area. The US Federal Transit Administration has impact criteria of 35 dB L_{ASmax} for residences where there are more than 70 events per day, increasing by 3 dB where there are between 70 and 30 events per day and by 8 dB where there are fewer than 30 events per day. In Ireland, both Metro North and Dart Underground have limits of 35 dB L_{ASmax} for residential area.

5.4.9 Given that the NLE aim is stated in terms of L_{AFmax} and is up to 5 dB better than figures expressed in terms of L_{ASmax} it sits well within the range of international practice. It also fully accords with the aims of the Noise Policy Statement for England and thereby the National Planning Policy Framework.

6. REVIEW OF CURRENT POLICY AND PRACTICE IN NOISE CONTROL

6.1.1 The National Planning Policy Framework (NPPF) (NLE/E1) was published in March 2012 and replaced Planning Policy Guidance Note 24: ‘Planning and Noise’ (PPG24).

6.1.2 The NPPF (paragraph 109) states that the planning system should contribute to and enhance the natural and local environment by:

“preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by unacceptable levels of soil, water or noise pollution or land instability”.

6.1.3 The NPPF does not define what it considers to be an ‘unacceptable risk’ or an ‘unacceptable level’. To this end, it is the role of assessors and decision makers to determine what is and is not acceptable in each case.

6.1.4 The national policy on the approach to noise is set out in The Noise Policy Statement for England (NPSE) (NLE/E6) published in 2010 and the local polices are contained in various documents issued by the relevant local authorities. These policies are addressed in more detail in the proof of Mr John Rhodes and consequently are only briefly referred to in my evidence.

6.1.5 The Noise Policy Statement for England (NPSE) sets out the long term vision of Government noise policy. The Noise Policy Vision is to:

“Promote good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development”.

6.1.6 The NPSE draws on two established concepts from toxicology that are currently being applied to noise effects namely NOEL ‘No Observed Effect Level’ and LOAEL ‘Lowest Observed Adverse Effect Level’. The NPSE extends these concepts and introduces the concept of a SOAEL ‘Significant Observed Adverse Effect Level’. This is the level above which significant adverse effects on health and quality of life occur.

6.1.7 The second aim of the NPSE refers to the situation where the effect lies somewhere between LOAEL and SOAEL. It requires that all reasonable steps should be taken to mitigate and minimise adverse effects on health and quality of life while also taking into account the guiding principles of sustainable development (paragraph 1.8 of the NPSE). This does not mean that such adverse effects cannot occur.

6.1.8 The third aim seeks, where possible, to positively improve health and quality of life through the pro-active management of noise while also taking into account the guiding principles of sustainable development, recognising that there will be opportunities for such measures to be taken and that they will deliver potential benefits to society. The protection of quiet places and quiet times as well as the enhancement of the acoustic environment will assist with delivering this aim.

6.2 Construction Activities

6.2.1 Noise and vibration impacts from the construction of the development (including demolition) will be subject to the construction noise provisions of the Control of Pollution Act, 1974 (Sections 60 and 61, reproduced in Appendix 4 of this Proof), and to the Code of Construction Practice (CoCP) (NLE/A23, Section N1). To the extent set out in the CoCP, the Contractor will be obliged to apply to the Local Authority for formal consent in accordance with Section 61 of the Control of Pollution Act.

6.2.2 The Section 61 procedure has the effect of securing the “best practicable means” (BPM) for reducing noise. “Best Practicable Means” is defined in Section 72 of the Control of Pollution Act 1974 (reproduced in Appendix 4 of this Proof). ‘“Practicable” means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications. The means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and acoustic structures’.

6.2.3 The project also has in place a Construction Noise and Vibration Mitigation Scheme (NLE/A23 ,Part N2) which sets out façade noise limits for occupied dwellings (Table 1 in Appendix A of NLE/A23 ,Part N2). The contractor will be required to comply with these noise limits where it is reasonably possible to do so, in addition to any requirements in the Section 61 consent. These limits are included in Appendix 5 (Table A 0.1) of this proof.

6.2.4 The limits in Appendix 5 are based around a figure of 75 dB LAeq ,10-hr, measured or calculated one metre in front of exposed windows, for the core weekday working period of 0800-1800.

6.2.5 Clearly where pre-existing noise levels are greater than those emitted from the construction site, the effect is small. As the construction noise levels become greater relative to the pre-existing ambient, so the significance increases, and it becomes necessary to evaluate the effect of the construction noise as well as comparing it with the ambient.

6.2.6 It must be borne in mind that the effect of noise exceeding a desirable façade level is not necessarily a noise-related effect such as annoyance. The first effect is caused by the fact that people’s first action in response to external noise, which is disturbing them, is to close the window. This gives at least 10 dB noise reduction depending on the nature of the window. The adverse effect is the need to achieve ventilation through, for example, a window in a quieter façade, rather than a direct noise effect. Many residents in London, particularly with windows facing major roads, rarely open the windows facing the road.

6.2.7 The basis of the 75 dB limit is that at this limit conversation inside rooms with windows shut would not be difficult. In the event that after application of best practicable means a higher level than this occurred as a result of the construction works then noise insulation in the form of secondary glazing and noise attenuated alternative ventilation (ie works of the kind provided under the Noise Insulation Regulations) are appropriate.

6.2.8 Should construction noise levels exceed 75 dB(A) by a margin greater than the benefit of the sound insulation, then consideration has to be given to temporary re-housing.

6.2.9 The noise insulation and temporary re-housing policy is set out in Appendix A to the Mitigation Scheme (NLE/A23, Part N2).

6.2.10 Vibration is also subject to control by the mechanisms of Section 61[2].

[2] See s73 of CoPA in Appendix 4 of this proof

7. PROPOSED CONTROLS ON NOISE AND VIBRATION

7.1.1 Noise and vibration from the NLE scheme will be controlled in the following ways.

7.2 Construction

Project Noise and Vibration Policy for Airborne Noise during Construction – Code of Construction Practice

7.2.1 A CoCP has been prepared that applies the key principles of minimising noise at the source and also reducing noise transmitted to the receiver. The CoCP (**NLE/A19/9** Appendix NA) commits the projects to using Best Practicable Means in respect of all activities.

7.2.2 The CoCP incorporates a range of mitigation measures to control noise and vibration and their effects during construction and makes provision for the management of noise effects arising during the construction phase, including appropriate monitoring. It includes the following steps to control noise and vibration at source and on the transmission path as described below.

Selection and Use of Equipment

i. Each item of plant used on the project will comply with the noise limits quoted in the relevant European Commission Directive 2000/14/EC/United Kingdom Statutory Instrument (SI) 2001/1701 The Noise Emission in the Environment by Equipment for Use Outdoors Regulations (as amended).

ii. TfL will adopt the recommendations for the control of noise, as set out in BS 5228-1:2009 section 8, and for the control of vibration, as set out in BS 5228-2:2009 section 8. Where alternative authoritative guidance and procedures are thought to be more reasonable and have been agreed in advance with the relevant local authority, these may be adopted in place of the aforementioned.

iii. Plant and equipment liable to create noise and/or vibration whilst in operation will, as far as reasonably practicable, be located away from sensitive receptors. The use of barriers to absorb and/or deflect noise away from noise sensitive areas will be employed where required and reasonably practicable.

iv. All plant, equipment, and noise control measures applied, shall be maintained in good and efficient working order and operated such that noise emissions are minimised as far as reasonably practicable. Any plant, equipment, or items fitted with noise control equipment found to be defective will not be operated until repaired.

v. Where reasonably practicable, fixed items of construction plant shall be electrically powered in preference to being diesel or petrol driven.

vi. Vehicles and mechanical plant utilised on site for any activity associated with the construction works will be fitted with effective exhaust silencers and shall be maintained in good working order and operated in a manner such that noise emissions are controlled and limited as far as reasonably practicable.

vii. Machines in intermittent use will be shut down or throttled down to a minimum during periods when not in use. Static noise-emitting equipment operating continuously will be housed within suitable acoustic enclosure, where appropriate.

7.2.3 In addition, for underground activities, and for conveyors above surface level, the following measures will be adopted where reasonably practicable:

Conveyors

i. The mounting for any conveyors used to remove excavated material from the works (underground, sub-surface or surface) will be designed and installed so as to mitigate the transmission of noise and vibration;

ii. A maintenance programme will be implemented to ensure that the noise generation of any conveyor does not deteriorate over time.

iii. The surface conveyor systems will be of similar standard to underground conveyors and will be acoustically enclosed where they run through, or adjacent to, noise sensitive areas. They too will be subject of a maintenance programme. (Note: the conveyer will be covered throughout its length to prevent material spillage.)

Temporary Construction Railway

i. The alignment, jointing and mounting of the temporary construction railway will be installed, maintained and operated in a manner so as to minimise the transmission of vibration and ground borne noise from the passage of rail vehicles.

ii. Any diesel locomotives used will be fitted with efficient exhaust silencers.

Temporary Tunnel Ventilation

i. All tunnel ventilation plant with connections to the atmosphere in any noise-sensitive location will be subject to mitigation measures appropriate to its local environment.

Notifications

i. Occupiers of nearby properties shall be informed in advance of the works taking place, including the duration and likely noise and vibration effects. In the case of work required in response to an emergency, the relevant local authority and local residents shall be advised as soon as reasonably practicable that emergency work is taking place. Potentially affected residents will also be notified of the helpline number.

Reversing Alarms

i. TfL will, as far as reasonably practicable, ensure that the noise from reversing alarms is controlled and limited. This will be managed through the following techniques.
ii. the site layout will be designed to limit, and where reasonably practicable, avoid the need for the reversing of vehicles. TfL will seek to ensure that drivers are familiar with the worksite layout;
iii. banksmen will be utilised to avoid, as far as reasonably practicable, the use of reversing alarms;
iv. reversing alarms incorporating one or more of the features listed below or any other comparable system will be used where reasonably practicable: highly directional sounders, use of broadband signals, self adjusting output sounders, and flashing warning lights.
v. reversing alarms will be set to the minimum output noise level required for health and safety compliance.

Project Noise and Vibration Policy for Airborne Noise during Construction – Provision of Noise Insulation and Further Mitigation

7.2.4 Mitigation of airborne noise from worksites using the COCP has been described above. Where despite the application of the procedures in the COCP specified the façade noise levels are exceeded for certain time periods then the project's Construction Noise and Vibration Mitigation Scheme will be applied (NLE/A23, Part N2). Under this scheme noise insulation (or a grant therefore) or further mitigation may be offered where the predicted or actual noise levels exceed the prescribed levels defined in the TfL NLE Construction Noise and Vibration Mitigation Scheme (reproduced in Table A 0.1 of Appendix 5 of this Proof).

7.2.5 The Scheme is based on similar schemes used on major projects from the Jubilee Line Extension onwards, and have been found to be practicable and effective

Interaction of COCP, Section 61 of CoPA and the Draft Planning Conditions.

7.2.6 Through the CoCP, LUL will ensure that prior consents are obtained under the provisions of Section 61 of the Control of Pollution Act 1974 (see Appendix 4 of this Proof). This will enable the local authority to ensure that the best practicable means for the control of noise and vibration are used in the carrying out of the construction work. The CoCP commits the project to using best practicable means of mitigating noise in respect of all activities.

7.2.7 The contractor will also be required to adopt, operate, and comply with the COCP which is two parts. The first part – known as Part A – has been described above and applies project-wide. In addition there will be a second part – known as Part B – which will be developed in conjunction with the relevant local authority to suit the particular circumstances of individual worksites.

7.2.8 The implementation of these procedures will be further secured by the (draft) planning conditions which are reproduced in Appendix 4. Those conditions are as originally proposed by TfL within its s.90(2A) planning direction application (Appendix 2 of NLE/A2) except the condition 11 on groundborne noise from the operation of trains, which is now being proposed by TfL as a replacement for the original condition 11, and in relation to which discussions with the local authorities and residents are continuing.

7.2.9 Condition 11(a) refers to the noise from “a train”, and given that there are locations where a train passing in each of the two tunnels may be audible the effect of combined noise from two trains arises.

7.2.10 There are two considerations. The first is that because the assessment index is LAFmax, the “F” subscript means that the level varies rapidly as the averaging time is only 125 milliseconds. The maximum value from one train noise level will rarely happen at precisely the same moment as the maximum value from the other, so while two identical steady noises combined have a combined sound level 3 dB higher then each individual level, two time-varying noises will typically have a combined sound level less than 3 dB higher. The second consideration is that locations where noise from each tunnel will be at the same level are not close to either tunnel.

7.2.11 Groundborne noise predictions have been carried out for two trains passing at once for the specific locations contained in the ES. There are locations located centrally between the tunnels which have the potential to experience an increase of up to 3 dB compared to a measurement from a single train passing, but from a base which, because the locations are some distance from both the tunnels, is less than the maximum for either individual tunnel. Thus, even with this 3dB increase, expected ground borne noise levels of no more than 30dB are expected at these locations. For locations such as Meadows Road which is located approximately 25m from the furthest tunnel, the contribution will be sufficiently low that an increase of less than 1dB is expected. Since the tunnels diverge to the north of the Claylands Road area, the distance to the second receptor will be such that no measureable increase will be caused by two trains passing simultaneously. This will be the case for receptors such as Claylands Road, Hanover Gardens and Henry Fawcett Junior School.

7.2.12 It follows that the use of a condition tied to the passage of a single train will be sufficient in relation to this project to ensure that the proposed NLE will not give rise to significant impacts in all reasonably foreseeable circumstances.

Groundborne Noise and Vibration Effects on Buildings

7.2.13 For the construction railway, the alignment, rail jointing and mounting of the railway will be installed, maintained and operated in a manner so as to minimise the transmission of vibration and groundborne noise from the passage of rail vehicles. (Vibration during construction will cause no damage to property, but will be perceptible in the nearest houses.)

7.3 Operation

7.3.1 The facilities associated with the NLE will be designed to control noise and vibration levels no greater than the thresholds of significance set out in Appendix A3.

8. OVERVIEW OF ASSESSMENT

8.1.1 This section summarises the significant residual effects of the scheme. More detailed information in relation to premises associated with objectors is provided in Appendix 6 of this proof.

8.1.2 The preceding sections of this proof have explained the following aspects of the assessment:

i. activities considered;
ii. area considered and identification of noise sensitive premises;
iii. selection of evaluation criteria by reference to published sources and experience and established practice on past major projects;
iv. confirmation of the mitigation measures to be incorporated into the scheme;
v. mitigation to be applied at the receptor under the Project Noise and Vibration Policy for Airborne Noise during Construction (NLE/A23, Part N2); and
vi. draft planning conditions to control noise and vibration.

8.1.3 During the course of meetings with objectors and local residents, and number of issues have been raised and answers provided.

8.2 Findings of assessment of construction phase

8.2.1 From this basis, airborne noise from construction activity on worksites during the main construction phase has been predicted and assessed to identify significant effects during the main works (during the initial part of which some of the utilities works will also be carried out), and in the period before the main works start when highways and utilities works will be undertaken.

8.2.2 The use of the Section 61 process will ensure, where practicable, that works are carried out on site to meet the target noise levels provided in Table 1 of Appendix A of the Construction Noise and Vibration Mitigation Scheme.

8.2.3 Where it is not practicable to meet the target construction noise thresholds the Northern Line Extension Construction Noise and Vibration Mitigation Scheme will provide off-site mitigation to remove residual significant effects that cannot be mitigated through on-site measures. Therefore, the use of the defined mitigation measures will ensure that airborne construction noise effects from worksites are not significant (negligible to minor adverse effects).

8.2.4 In comparison to the traffic noise assessment criteria in Appendix A3, Table A3.2 it is predicted that construction road traffic is likely to provide a negligible to minor significance for all assessed road links. The only location where the construction traffic is predicted to provide a minor effect is Wandsworth Road due to the Nine Elms station works.

8.2.5 Construction vibration has been predicted for diaphragm walling and tunnel boring activities. There is an error in table 9-26 of Chapter 9 of the ES, and the equivalent table 22 in Appendix E-2 of the ES. The correct table is provided in Appendix 5, Table A5.4 to this proof of evidence. The corrected vibration predictions, when compared with the significance criteria in table 9-4 of the ES reproduced as Table A3.4 in Appendix 3 to this proof of evidence, all fall in the category "moderate adverse effect". The effects of construction vibration are not predicted to be significant for their effects on structures. The groundborne noise predictions are also high, but it is explained in the ES that the results of measurements of the passage of a Crossrail TBM show much lower levels, and the conclusion drawn from the Crossrail data in the ES is that noise from the TBM will be audible inside properties above the line for no more than one day, and as the same is likely to be true for perceptible vibration it is expected that the significance of noise and vibration from the passage of the TBM will be minor adverse. Therefore there is no change in the assessment of significance as reported in the ES.

8.2.6 Groundborne noise due to tunnel boring activities is expected to be audible (ie, in the range of 35 – 40 dB of LASmax) inside properties above the line for no more than one day (and so is predicted to cause a minor adverse effect).

8.2.7 The construction of the gallery tunnels from the two permanent shafts to the step plate junctions will involve the excavation of two additional tunnels of approximately 3.5m diameter at a shallower depth than the running tunnel. Excavation will be by mechanical means, though not involving a tunnel boring machine and the construction and/or insertion of tunnel linings will not involve percussive work such as the breaking out of concrete. The noise effects are likely to be similar in magnitude to those of the main tunnel drive, but will, in duration terms, be additional. The tunnels will be back-filled on completion of the works which may result in some audible noise, although the linings will be left in place and not broken out. Work to construct the gallery tunnels will be subject to the commitment to use best practicable means which is contained in the CoCP.

8.2.8 Groundborne noise from the construction railway is predicted, using highly robust assumptions, to have a maximum noise level of 45 dB LAFmax. The use of the construction railway will be a less frequent event than the passage of an underground train in service, with about 60 train movements per day. The significance of the use of the construction railway will be minor to moderate adverse (ie, at the upper end of this range it will be a significant effect).

8.2.9 The construction assessment shows that the worst-case predicted noise level from the other consented developments are not increased as a result of the NLE, except for the Battersea Power Station development, where the increase is such that the significance criteria are not exceeded.

8.2.10 The road traffic noise assessment shows that the conclusion in the ES of negligible road traffic noise effects is correct and that for the predicted scenarios, the NLE will have a negligible effect on road traffic noise levels during both construction and operation.

8.3 Findings of assessment of operational phase

8.3.1 The approach to operational noise and vibration is that the development will be designed to comply with the evaluation criteria and hence cause no significant effects.

8.3.2 The operational noise due to fixed installations at stations and ventilation shafts has been predicted to provide a negligible effect with the predicted noise levels no greater than 10 dB below the background noise levels. This meets the project design target.

8.3.3 The operational groundborne vibration levels have been assessed and it is expected that levels will provide a negligible effect during the day and a minor adverse effect during the night. Therefore, no mitigation is required specifically for operational groundborne vibration.

8.3.4 The operational groundborne noise levels have been predicted to provide a moderate adverse effect without the use of a modern track form. To reduce the effects of the groundborne noise, it has been assessed that a vibration isolating track form is required in the running tunnels. The use of a vibration isolating track form that provides the same degree of isolation as the JLE baseplate system is predicted to reduce the predicted groundborne noise plevels to no more than 35 dB LAFmax which is a negligible effect. This also has the effect of reducing the operational groundborne vibration effects to negligible for both the day and night. The use of the proposed mitigation meets the design guidance for groundborne noise and vibration.

8.3.5 Apart from the topic of groundborne noise from the operation of trains in the tunnels of Works 1, 2 and 3, there is also the matter of changes in noise levels from trains using the existing northern line tunnels. At present, trains not continuing to Morden use the loop and travel round it at low speed. As part of the NLE project, step-plate junctions will be constructed one in either side of the loop which will enable trains, after entering the start of the existing loop tunnel, to turn out from the loop on to the new running tunnel of the NLE, and vice-versa on the return journey. Over a short length of the existing tunnel which will not have the benefit of a mitigated track support system train speeds will potentially be slightly higher than they are at present. There is currently a speed limit on the loop of 15 mph/24 km/h.

8.3.6 Measures will be taken to ensure that the noise level from trains using the loop will not be increased. This will be done either by maintaining a speed limit of 15 mph on this section of track or by installing resilient rail support to provide noise reduction which offsets any increase in noise caused by an increase in speed. As far as the middle section of the loop is concerned, between the step plate junctions, there will be a substantial reduction in the number of trains using this section of tunnel as most trains will continue to Battersea and will not turn back at Kennington. The few trains which do use the loop will continue to be limited to the existing low speed.

9. CONCLUSIONS

9.1.1 My evidence to this inquiry addresses the issues raised in the statement of matters.

9.1.2 My conclusions are that there will be no significant impact on local residents, others visiting or passing through the area, businesses or the environment of the scheme during operation.

9.1.3 As regards those significant effects that are currently predicted to occur during the construction phase, controls under both the project's Code of Construction Practice and Section 61 of the Control of Pollution Act (enforced by the relevant Local Authorities) will ensure that the best practicable means will be used to control noise and vibration thereby minimising these effects.

10. Witness Declaration

I hereby declare as follows:

This proof of evidence includes all facts which I regard as being relevant to the opinions that I have expressed and that the inquiry's attention has been drawn to any matter which would affect the validity of that opinion;

I believe the facts that I have stated in this proof of evidence are true and that the opinions I have expressed are correct; and

I understand my duty to the inquiry to help it with matters within my expertise and I have complied with that duty.