RT/13/A

TRANSPORT AND WORKS ACT 1992

RAILTRACK (THAMESLINK 2000) ORDER 1997
RAILTRACK (THAMESLINK 2000)(VARIATION) ORDER 1999

Proof of evidence
of

R.M. Thornely-Taylor

Fellow of the Institute of Acoustics
Consultant in Acoustics and Noise Control

CONTENTS

1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is Rupert Maurice Thornely-Taylor. I am a Fellow of the Institute of Acoustics and have specialised exclusively in the subjects of noise, vibration and acoustics for more than thirty-five years. I have been an independent consultant in these subjects for the past thirty-one years, and head the practice known as Rupert Taylor F.I.O.A. and am a director of the associated company Rupert Taylor Ltd. I was a member of the Noise Advisory Council chaired by the Secretary of State for the Environment for ten years and was a member of the Scott Committee on whose report the noise sections of the Control of Pollution Act 1974 were based. I was chairman of the Working Group on Noise Monitoring and deputy chairman of the Working Group on Noise as a Hazard to Health.

1.2 I have carried out consultancy contracts for a large number of government and local government clients, and promoters or objectors to many major infrastructure projects in the United Kingdom and overseas. I have been expert witness in many High Court and County Court actions, in a large number of public inquiries and Parliamentary Select Committees, and have been called to give evidence to the Royal Commission on Environmental Pollution. I am the author and joint author of several books, published in countries from Russia to Japan as well as the United Kingdom, and many articles and papers on noise, and have been an invited speaker in many international conferences on the subject.

1.3 Between March and August 1996 I was under contract to the Department of the Environment to study the application of Planning Policy Guidance PPG 24 PLANNING AND NOISE, to identify any need for additional guidance and to make recommendations on possible methods that could be developed and adopted in the guidance.

1.4 A large part of my work over the past 30 years has been concerned with noise and vibration from railways. I have had consultancy commissions from railway undertakings, objectors to railway proposals, rolling stock builders and equipment suppliers, and have carried out studies of noise and vibration on, among others, Tyne and Wear Metro, Glasgow Underground, London Underground, British Railways, Kowloon-Canton Railway, Hong Kong Mass Transit Railway, Netherlands and Norwegian Railways, railways in Cologne, Rotterdam, Berlin, Munich, San Francisco, Washington D.C., and Seoul, South Korea. I prepared the terms of reference for the Environmental Impact Study of the Taipei Rapid Transit Systems in the Republic of China. I have been engaged in noise studies of Manchester Metro, Nottingham and South Hampshire Light Rapid Transit systems. I have been noise and vibration consultant to the Docklands Light Railway (DLR) and was involved in the City, Beckton and Lewisham Extension projects. I prepared the noise and vibration parts of the Environmental Statement for Croydon Tramlink. I was expert witness in both Houses of Parliament during the committee stages of all the DLR and Croydon Tramlink Bills.

1.5 I have been noise and vibration consultant to (and expert witness in Parliament for) the CrossRail and Jubilee Line Extension Projects, and was expert witness in the House of Commons committee on the Channel Tunnel Rail Link Bill on behalf of Union Railways.

1.6 I was engaged in the design of the Kowloon-Canton Railway West Rail project in Hong Kong, and am a consultant to the Citytunnel project in Malmö, Sweden, having completed a major study on ground-borne noise from the proposed system.

1.7 In 1989 I carried out noise and vibration studies of the designs for the bridges carrying the Eurotunnel railway over the A20 and M20 bridges. In 1992 I carried out a study of noise and vibration in the design of the Waterloo International Terminal for British Rail.

1.8 A substantial part of my experience relating to noise and vibration from railways has been in the field of the acoustical design of rolling stock. I carried out a noise study of the TGV as part of the acoustical design of the British Rail East Coast Main Line (Intercity 225) Mk IV Coaching Stock. I was noise consultant in the design of the GEC-Alsthom (Metro-Cammell) Networker Class 465, and in other Electric Multiple Unit (EMU) designs such as the Class 323 built by Hunslet. I also was engaged in acoustical design work on Channel Tunnel Shuttle vehicles in 1987/88, and provided computer software to a French company involved in those vehicles.

1.9 I have been engaged as noise and vibration consultant in the Thameslink 2000 project and its predecessors since 1990.

2 SCOPE AND STRUCTURE OF EVIDENCE

2.1 The objectives of the Thameslink 2000 project have been set out in the Statement of Case. The means of delivering those objectives include operational measures (provision of more frequent services and longer trains) and works to the infrastructure (new or modified structures and alterations to stations) to enable those services to be operated.

2.2 The evidence presented in this proof is concerned with noise and vibration arising from both these phases of the project: the construction phase during which the necessary changes to the infrastructure will be made, and the operating phase when any effects of longer and more frequent trains, and of running trains on the new infrastructure, will be apparent.

2.3 The project as currently proposed is described in two Transport and Works Act Order applications: the first was made in 1997, the second in 1999 after further project development. Environmental Statements were prepared and deposited with each of these order applications. Those Environmental Statements (and the Technical Annexes on which they were based) dealt with the works set out in the respective Order applications. This evidence draws on the Technical Annexes produced in 1997 and 1999, but does not divide the works between the 1997 proposals and those of 1999.

2.4 The evidence deals with noise and vibration from all aspects of the scheme (excluding those areas for which powers were granted in the Channel Tunnel Rail Link Act). However, at the time the environmental work was carried out, the same level of detail was not available for all aspects of the scheme. Consequently, the scope of the assessment, and hence this evidence, differs between elements. The approach to the different components of the scheme is set out in Table 4.0 of the 1999 Technical Annex and reproduced in Appendix 1 of this proof.

3 NOISE AND VIBRATION UNITS

Noise

3.1 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. 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 and a ten fold increase in energy is certainly not a tenfold increase in loudness.

3.2 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 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. In 'A-weighted decibels' both sounds would have the same decibel, or dB(A), level. 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. Judgment 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 which 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.

3.3 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 r.m.s. 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 present context, the dB(A) levels to which I refer are to be measured using the 'S' response.

3.4 The basic dB(A) scale can only measure the instantaneous level of sound, and 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 L_{Aeq}, is employed. L_{Aeq} (which in some documents is referred to as L_{eq}

rather than L_{Aeq} - the two terms have the same meaning) is a long term average of the amount of energy in the fluctuating sound, expressed in dB(A). In the case of a continuous, unchanging sound, its L_{Aeq} level is the same as its sound level in dB(A). 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 L_{Aeq} level will go up or down by 3 dB just as it would if the amount of energy in the sound, rather then the duration of the sound, had doubled or halved.

3.5 The consequence is that the L_{Aeq} 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 L_{Aeq} 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 L_{Aeq} 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.

Vibration

3.6 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. (The low frequency airborne effect to which I have referred is not normally caused by electric railways.)

3.7 Wave propagation in the ground takes several forms. Some waves spread out underground in a manner analogous to sound waves in air (although there exist both compressional and shear waves), others 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.

3.8 In the case of trains running on the surface, surface waves are important. For railways in tunnel, body waves are of prime importance since these transmit ground-borne noise which may be radiated inside noise-sensitive buildings.

3.9 The basic units of vibration measurements relate to the movement of the surface which 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/s^2). For small values millimetres may be used instead of metres.

3.10 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).

3.11 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 (up and down the spine), horizontal (front to back) and lateral (side to side) directions. The most sensitive is the vertical direction (known as 'z-axis'). Weighted acceleration of 'z-axis' in units of m/s^2 is approximately equal to velocity in units of m/s multiplied by 50, provided that the frequency of the vibration is greater than 8 cycles per second (8 Hz).

3.12 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 L_{Aeq} 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 now forms the basis of advice given in the 1992 edition of British Standard 6472.

3.13 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 $L_{Amax,S}$ has been adopted as the assessment index.

4 ASSESSMENT CRITERIA

4.1 Noise and vibration can result in a range of impacts. These include indirect impacts such as the consequences of having to avoid opening windows facing the noise source, and direct impacts such as annoyance, reduced speech intelligibility, and interference with task performance. The thresholds of significant noise effect indicate cases where inconvenience arises from, for example, the need to sleep with windows closed and provide ventilation from other windows not directly facing the noise source, because sleep disturbance could occur with wide open windows. In such cases, mitigation in the form of acoustic glazing may need to be installed. This issue is discussed in more detail below.

4.2 There are two basic approaches to setting evaluative criteria. They may be based on absolute levels (of noise or vibration) or on relative levels - i.e. the level of the new noise or vibration compared to the ambient levels at the receptor. In this study, the appropriate basis for criteria has been selected according to the circumstances. Thus, in practice, both approaches are used for different situations.

4.3 Except where otherwise stated, the criteria apply to residential buildings, and to occupied non-residential buildings using daytime thresholds only. Special buildings, e.g. churches, theatres etc., were considered individually.

4.4 Changes in road traffic flow may occur during either construction or operation and the same criteria are used for this topic in each case (**Table A.1**). Criteria relating to other sources of noise or vibration are specific to either the construction phase (**Tables A.2** to **A.4)** or to the operating phase (**Tables A.5** to **A.7**).

Power Reinforcement Installations, Lineside Signalling Equipment and Vent Shafts

4.5 These sources are assessed using the methodology of BS 4142. Consideration needs to be given to the question of character correction, background noise level appropriate to the source, and the acceptable value of the rating level in the light of the operating duty of each item of the equipment.

Public Address Systems

4.6 No formal assessment criteria have been developed for public address systems, which are likely to be annoying if announcements are regularly clearly audible at noise-sensitive receptors. Effectively this means that L_{Aeq} levels during and due to announcements should not be greater than the background noise in terms of L_{A90}. This is a similar approach to that used for the prediction of complaints about industrial and commercial noise as set out in BS 4142.

4.7 Railtrack has developed a policy for the design of public address systems for the purpose of avoiding problems of noise annoyance. Where public address systems are to be installed as part of Thameslink 2000 works

Railtrack proposes to utilise modern public address system technology to keep noise intrusion to a practicable minimum whilst maintaining the audibility and intelligibility of announcements to required standards. This will be done by:-

a) Using distributed arrays of loudspeakers operating at relatively low sound power levels;

b) Using the minimum sound power levels required to achieve the desired intelligibility; and

c) Using modern design techniques and technologies to ensure that the performance of the public address system is tailored to the acoustic characteristics of the station and the requirements for minimum sound level outside the station.

4.8 A similar policy was adopted by the Jubilee Line Extension for its at-grade stations (Canning Town, West Ham and Stratford).

5 THE THAMESLINK 2000 NOISE AND VIBRATION POLICY

5.1 The Thameslink Noise and Vibration Policy is reproduced in Appendix II in RT/13/B. It includes a policy for the provision of Noise Insulation and Temporary Re-Housing in cases where construction noise exceeds set thresholds. Noise insulation (or grant) will be offered where the predicted noise level exceeds either the trigger level for insulation set out in the table in Appendix II or a figure 5dB above the existing airborne noise level for the corresponding times of day, whichever is the higher, for more than 10 out of 15 consecutive working days or for a total of days exceeding 40 in any six month period. Temporary re-housing will be offered where the predicted noise level exceeds either the trigger level for temporary re-housing set out in the table in Appendix II or a figure 10dB above the existing airborne noise level for the corresponding times of day, whichever is the higher, for more than 10 out of 15 consecutive working days or for a total of days exceeding 40 in any six month period.

6 INTERPRETATION OF SIGNIFICANT EFFECTS

6.1 While the time periods used in the table of trigger levels in Appendix II contain more subdivisions than those in the ES assessment criteria, it is true to say that the trigger levels for noise insulation are generally up to 10 dB higher than the thresholds of significance, and the temporary re-housing trigger levels are 5 to 10 dB above the insulation trigger levels.

6.2 The reason for these differences are as follows. Significance is not an absolute state, and the degree of effect of noise above the significance threshold increases as the level increases. Clearly the purpose of identifying significant effects is to assist in the broad process of weighing the advantages and disadvantages of a project. In so doing, due weight must be given to adverse effects, and this is not simply a process of counting effects, but of assigning weight to different effects. The position is further complicated by the fact that if a noise effect is great enough to trigger noise insulation or temporary re-housing, then the actual noise effect may be completely mitigated (and an alternative “effect” such as the disruption and inconvenience of having secondary windows and alternative ventilation installed, or the disruption of temporary re-housing, substituted).

6.3 The weight to be attached to a significant effect will depend not only on the extent to which the noise exceeds the significance threshold, but also or alternatively on the duration of the exceedance (e.g. in days or nights). The weight to be attached to a major exceedance of the night significance threshold for ten nights out of fifteen would no doubt be greater than a similar situation where the exceedance was for eleven nights and noise insulation or temporary re-housing was offered, and had been installed or provided.

6.4 The criteria for significant effects are a combination of tests for changes in noise level relative to the baseline, and tests for exceedance of noise levels above limits (in some cases set having regard to the baseline).

6.5 The operational signficance criteria are set in terms of noise changes, which principally indicate the short term public response to increases in noise due to the coming into operation of new transport infrastructure. The significance threshold which is a change of 3 dB or more in the value of the L_{Aeq} index for day or night equates to the point at which such a change is noticeable. It does not necessarily have any other effect besides causing people to notice that train noise has increased, and possibly thereby causing annoyance. Specific effects such as sleep disturbance are more closely related to absolute levels than to changes, and the significance criterion includes an additional test which is exceedance of an external maximum noise level of 85 dB L_{Amax}. At this level source-specific noise disturbance of sleep may be expected irrespective of the L_{Aeq} level if the number of such events is more than about 20 per night[i].

6.6 The construction noise significance criteria are tests against absolute levels set according to one of three categories. The category is dependent on the baseline noise climate. The category with the lowest level is category A, and the night-time threshold is an outdoor level of 45 dB $L_{Aeq\ (2200\text{-}0700)}$. With a partially open window this is equivalent to an internal level of 30 dB $L_{Aeq\ (2200\text{-}0700)}$, and if related to noise spread fairly evenly through the period satisfies the World Health Organisation's recommendation for preserving the restorative process of sleep. Exceeding this level does not necessarily mean sleep disturbance, but can in any event be mitigated by the house occupier closing the window. The effect is then one of reduced ventilation, which can often be replaced by opening windows in another facade of the house. An alternative effect, is the necessity for the householder to sleep in a room with windows in a different façade, if there is such alternative accommodation available in the house.

6.7 In cases where the baseline L_{Aeq} is elevated, the significance criteria and the insulation/temporary re-housing criteria are also raised. The reason for this is that if the pre-existing noise climate is high, then the occupants of the receptor are likely to have come to terms to some extent with the exigencies of living in a less than quiet environment. For example occupants of houses fronting main roads may have organised their living arrangements to avoid the necessity to open the windows facing the road, or may already have secondary or acoustic double glazing installed (with or without acoustic ventilators).

6.8 The World Health Organization (WHO) has recently published a document "Guidelines for Community Noise"[iii]. This contains a set of guideline values for community noise in specific environments, according to specific health effects. An adverse health effect of noise refers to any temporary or long-term deterioration in physical psychological or social functioning that is associated with noise exposure. The guideline values are set at the lowest adverse health effect (called the critical health effect), and they represent values for the onset of health effects. It is explained in the report that the authors would have preferred to establish guidelines for exposure-response relationships. Such relationships would indicate the effects to be expected if standards were set above the WHO guideline values and would facilitate the setting of standards for sound pressure levels (noise immission[1] standards). However, exposure-response relationships could not be established as the scientific literature is very limited.

6.9 It follows that the WHO guidelines are not intended for the setting of noise standards, and that they merely indicate the level at or below which virtually no effect occurs at all.

7 EXISTING NOISE AND VIBRATION LEVELS

7.1 Baseline noise levels were derived from a series of attended and unattended measurements taken over the short, medium and long term.

[1] Immission standards relate to noise levels received by receptors; emission standards relate to the noise emitted by noise sources.

Surveys were undertaken in 1992, 1996, 1997, and 1999. Vibration measurements were also taken at locations where vibration levels were already thought to be significant by the local authority.

7.2 Given that Thameslink 2000 is a development of an existing railway, the baseline noise and vibration environment is largely dominated by railway noise during the hours of operation from existing Thameslink services, although road traffic noise is also significant in the inner London area and this has been taken into account where applicable.

7.3 Many of the outer areas are rural in nature and background noise levels, particularly at night, are low, subject to the noise from trains on the existing network. There are also sites located in the centre of towns, and urban areas, where comparatively high levels of road traffic noise exist together with railway noise.

7.4 In relation to construction noise, one must also consider the fact that outside normal operating hours for the existing railway (i.e. the middle part of the night), baseline noise levels are low owing to the absence of rail and road traffic outside façades facing railways. Furthermore, there is the potential for noise and/or vibration from construction activities to affect façades which do not face directly onto an existing railway and may therefore currently experience lower noise levels than façades which do overlook the railway even during daytime hours.

Farringdon Station

7.5 Existing noise levels in the vicinity of Farringdon Station are moderately high, due to the proximity of roads and existing railway operations. Locations that may be considered noise sensitive are office uses in the daytime and residential accommodation (on the upper floors of several buildings in the area), both by day and by night.

7.6 At the rear of No. 66 Cowcross Street, train noise predominates; this is due not only to existing Thameslink through services and Thameslink

Moorgate trains, but also the London Underground trains, which are closer and run more frequently than the Thameslink services.

7.7 At Nos. 34/35 Cowcross Street, which is shielded from the existing underground lines by intervening buildings, noise levels are only marginally less than those at 66 Cowcross Street because of the influence of the noise of road traffic in Cowcross Street and Turnmill Street.

7.8 The noise survey results show that the representative façades used in this assessment are in category C, for the purposes of construction noise.

7.9 Vibration monitoring carried out at 66 Cowcross St indicates that there are no appreciable levels of existing vibration.

Blackfriars Station

7.10 Existing noise levels in the vicinity of Blackfriars Station are high, due to the proximity of major roads and the existing railway operations. Daytime noise levels are largely dominated by road traffic and north of the Thames the façades are in construction assessment category C.

7.11 The residential façades facing the Thames on the south bank are less affected by traffic noise by day and by night and the 1996 noise monitoring results for Falcon Point indicate that the location is in construction assessment category B.

7.12 There is no appreciable vibration at this location.

Blackfriars station to Blackfriars Junction and Ewer Street

7.13 The principal receptors are Friars Close, a block of flats 7m from the viaduct whose roof level is at approximately the same elevation as the parapet of the railway viaduct, and residential properties on the north side of Union Street. There are also residential properties in Scoresby Street and Chancel Street, and a public house at 22 Great Suffolk Street.

7.14 There is a recording studio at 100 Union Street, on the opposite side of the viaduct to the eastern end of Ewer Street.

7.15 In the Ewer Street area, the existing noise environment is determined by traffic on Union Street, Great Suffolk Street, and Southwark Street for those façades with road frontages. For façades facing the railway viaducts, the L_{Aeq} levels are low for a central London site.

7.16 A noise survey carried out at Friars Close indicated that noise levels outside the façades facing the viaduct are comparatively low for a central London location. This is due to the fact that the façade does not receive appreciable levels of road traffic noise, and being of comparable height to the viaduct benefits from a noise barrier effect provided by the edge of the viaduct. It is therefore in Category A.

Metropolitan Junction to London Bridge

7.17 For residential properties on Redcross Way, Park Street, Stoney Street, and Bedale Street, existing noise levels are generally typical of a busy urban area bisected by major roads and railway viaducts. Even at locations away from the main roads, there is considerable noise during daytime hours. In addition, night-time activity at The Borough Market results in considerable night-time noise levels in the immediate area.

7.18 Commercial premises on Park Street, Stoney Street, Bedale Street, and Borough High Street, offices in the Hop Exchange and No.5 London Bridge Street are all subject to noise and vibration from the existing railway viaduct. At Southwark Cathedral, noise and vibration, which is substantial, is due to the existing railway viaduct as well as road traffic in Borough High Street.

7.19 Most of the area is in Category C but Park Street is in Category B.

7.20 There is appreciable vibration from trains in this area.

London Bridge Station

7.21 The noise climate of the area immediately surrounding London Bridge Station is dominated by road traffic noise and railway noise. Nevertheless, residential facades which could be affected by night-time working are not adjacent to the station and they are likely to be in Category A.

7.22 There is appreciable vibration from trains in this area at buildings adjacent to the railway.

New Cross station

7.23 The noise climate in areas surrounding New Cross Station has contributions from railway noise on the Railtrack and East London Lines, from local road traffic and also from New Cross Road.

St John's (Tanners Hill)

7.24 The residential areas surrounding Tanners Hill and St John's have little local traffic and ambient noise levels are low, subject primarily to the effect of train services. They are likely to be in category A.

Hither Green station

7.25 The noise climate in areas surrounding Hither Green Station has contributions from railway noise and from local road traffic of which there is little.

Bermondsey

7.26 Train noise is the principal determinant of noise levels in the area surrounding the proposed works. To a lesser extent both Silwood Street and Bolina Road are sources of traffic noise and there are significant movements of goods vehicles, skip lorries and heavy traffic associated with the employment uses in the arches. SELCHP is a noise source in the area, subject however to noise limits. Activity in the under-arch premises also tends to create impulsive noise, for example from loading of construction materials.

7.27 Noise levels at the façades of the higher buildings on Silwood Street (e.g. Gillam House) fall into assessment category C while the lower buildings in Goldsworthy Gardens and Sketchley Gardens are in category A

Outer Areas

7.28 In outer areas locations clearly comparable with previously surveyed locations in Category A, the worst-case assumption has been made that they are in Category A. In other areas the baseline noise environment has been measured at representative façades of noise-sensitive receptors in the outer areas. In the outer area north, survey results previously made at Leagrave and Flitwick have been taken as surrogates for Arlesey and Sandy which have similar environments. The assessment categories for construction are summarised in **Table A.8**.

7.29 There is, in general, no appreciable vibration from trains in the outer areas.

8 CONSULTATION

8.1 For the Inner Area, meetings were held, attended by representatives of all the London Boroughs and the City of London, for the purpose of agreeing the evaluation criteria as well as the methodology, monitoring locations and results of the Inner Area baseline survey.

8.2 For the Outer Areas, discussions were held with local authorities (districts, boroughs and counties).

9 PREDICTION METHODS

Construction Phase

9.1 On-site noise and vibration predictions were made taking account of the factors set out in BS 5228[iii] and in the case of vibration, supplementary information was used.

9.2 The predictions of construction noise are based on a set of construction activity schedules prepared by Thameslink 2000 engineers. These schedules set out an inventory of noise emitting plant, the locations, and durations for which it would be used. Plant sound power data have been derived from a combination of sources including the results of recent measurements, the relevant tables in BS 5228[iv], and information from the project.

9.3 Predictions of construction vibration, which is likely to be significant primarily as a result of piling, have been carried out based on case studies published in BS 5228, and data which has been provided by TRL[v].

Operating Phase – Railway

9.4 Prediction of noise from the operating railway was made using the Department of Transport publication "Calculation of Railway Noise"[vi], supplemented where necessary with measured data obtained during the baseline survey. Since existing maximum noise levels already exceed 85 dB L_{Amax} in areas where significant effects would be likely to occur, L_{Amax} predictions for future train services were not necessary. Some preliminary calculations have been carried out to assess whether properties would be eligible for sound insulation in accordance with the Noise Insulation Regulations for New Railways[vii].

9.5 The prediction of noise and vibration from elevated structures and existing tunnels was made using techniques developed for other railway projects involving numerical models.

9.6 Prediction of changes in noise levels due to changes in traffic flows was made in accordance the Department of Transport publication "Calculation of Road Traffic Noise"[viii].

9.7 As a result of the Thameslink proposals there would be changes in the level of train noise due to changes in the number and length of train movements and to the introduction of new rolling stock. Many of the existing Charing Cross services are operated by "slam-door" stock, which is tread-braked and equipped with traction equipment noisier than that on modern stock. The proposed Thameslink 2000 services would comprise either Class 319 electric multiple units (EMUs) in 4-car, 8-car, or 12-car formations or Class 365 (or similar build) EMUs in 4, 8 or 12-car formations. They would replace or supplement services operated by a range of EMUs, from "slam-door" types such as Class 421 and Class 422 to Class 465 sliding door stock and Class 319. Class 365 stock already operates on London to Cambridgeshire and Kent coast services.

9.8 New rolling stock being introduced in the area (such as the class 375, similar to the class 357 operating on the London, Tilbury and Southend line) is disc braked, which means that brake shoes are not repeatedly roughening the wheel tread, and the brakes discs are attached to the wheel webs which reduces wheel noise radiation. The principal difference is that the traction equipment is electronically controlled, giving rise to the "gear-changing" sound that characterises modern electric multiple units.

9.9 Reference single vehicle SEL_V values given in the Department of Transport publication "Calculation of Railway Noise" (CRN) indicate that the tread-braked slam-door stock such as Class 421 and 422 are, surprisingly, 0.5 dB quieter than Class 319 EMUs. The Class 465 EMU is listed as 2.4 dB quieter than a Class 422 or 421 EMU. Vehicles on the existing Gatwick Express, BR Mark II, are listed as 4 dB noisier than

Class 421/2 vehicles. The Class 365 is not listed in CRN but, although dual-voltage, is very similar to the Class 465.

9.10 The noise characteristics of the existing dual-voltage rolling stock operating on Thameslink, the Class 319, have been used for the noise assessment in the Environmental Statement (CD/34). It is, however, nearly 3 dB(A) noisier than the Networker (Class 465) according to the Department of Transport booklet "Calculation of Railway Noise". Noise levels from future types such as the Class 375 are likely to be more like those of the Class 465, with the result that the Environmental Assessment is very much a worst case.

9.11 The surveys in the inner areas supported the data indicating that Class 421, 422, 319 and 465 vehicles have SEL values that are within a range of the order of 3 dB. Since the noise assessment has primarily been made by calculating the effect of changes in train formation, speed, and frequency, it has been assumed that there will be no change in average SEL_v across all vehicles currently using the system. Effectively this means that the Class 319 vehicle has been used as "best proxy" for existing and future EMU stock. Studies carried out in the outer areas have indicated that the difference between Class 465 (and similar modern EMU types) and slam door stock such as Class 422 or 421 is greater in the outer areas where the track is ballasted at-grade, than it is in the inner areas where the track tends to be on viaduct. The "best proxy" assumption is therefore a worst case for the outer areas.

Operating Phase – Power Supply Reinforcement Installations

9.12 There are three types of equipment in this category that will generate noise when the railway is operational. The first of these is transformers, which will generate a constant noise (i.e. throughout the day and night). The second source is contactors, which are associated with track sectioning and consequently only generate a short-term noise during the passage of a train. Four contactors may be housed together and generate intermittent noise over a period of 30 – 60 seconds. The third source of noise is contact breakers. These will only operate occasionally when fault conditions arise, necessitating changes to the routing of power supply connections. They are designed to operate up to 3 times in 3 minutes after which they will not operate further until the fault is cleared. They may also be operated manually but then generate less noise than when tripped by a fault.

9.13 Insufficient data are available from which noise from the latter two sources can be predicted. Transformer sound power level has been estimated by reference to the Railtrack specifications for transformer noise[ix] and assuming a maximum physical size of approximately 3m x 3m[x]. Sound pressure levels for a single transformer were then estimated assuming hemispherical, isotropic radiation. These data were then used to identify locations at which mitigation (in the form of enclosures) was likely to be necessary in order to achieve an acceptable noise level at the nearest dwelling having regard to the conclusions of British Standard 4142:1997.[xi]

Operating Phase – Signalling Equipment

9.14 Lineside signalling equipment falls into two categories: track circuits, and track axle counters. Track circuits emit high frequency noise that can be mitigated by a variety of methods (e.g. fitting a silencer). Track axle counters do not emit noise but are several times more expensive. Decisions on which types of system would be used at specific locations have not yet been made. Where equipment is located in a lineside building, an additional source of noise is the ventilation system. No predictions of noise have been made for these installations since it has been assumed that any noise that is emitted can be mitigated if necessary.

Operating Phase – Vent Shaft

9.15 The project includes vent shafts at Blackfriars Station. The vent shafts are now likely to rely on natural ventilation in which case there will be no requirement to carry out predictions of fan noise. Train noise emitted from the shaft is not likely to give rise to a significant effect.

Operating Phase – Public Address Systems

9.16 Further work is in progress to study the acoustical performance of the proposed new public address systems.

10 MITIGATION

10.1 The project is committed to ensuring construction and operational noise and vibration effects are kept to a practicable minimum. In particular:

a) During the design process every opportunity has been taken to review the adequacy of noise and vibration mitigation and incorporate additional mitigation where this is practicable. Moreover, in many areas, acoustic consultants have been an integral part of the design teams.

b) Highly sophisticated acoustic modelling techniques have been used to help assess the effects and explore mitigation options.

c) Where residual effects remain these will be looked at as part of the detailed design process to see if these effects can be reduced still further.

d) A number of policy documents have been developed by Thameslink 2000 specifically to address noise and vibration e.g. Noise and Vibration Policy (this includes provision for noise insulation and temporary re-housing), Public Address Systems.

e) A Planning and Environmental Management Strategy (PEMS) has been produced by the project which sets out Railtrack's strategy for controlling and managing the planning and environmental issues relating to construction of the Thameslink Project. Amongst other things, this strategy refers to the contractual arrangements that will be put in place to implement the works.

10.2 Under the terms of the contract between Railtrack and the contractor, the latter will be required to prepare a Noise and Vibration Management Plan as part of the overall Environmental Management Plan which is also a contract requirement. The Noise and Vibration Management Plan will identify

a) those activities likely to generate noise and vibration;

b) the levels of noise and vibration likely to be generated;

c) any sensitive receptors close enough to the Works to receive noise and vibration; and

d) the mitigation measures to be adopted.

10.3 The Contractor will also be required to demonstrate and implement Best Practicable Means (BPM), as defined under Section 72, Part III of the Control of Pollution Act (COPA) 1974 and in most cases, to seek local authority consent under Section 61 of COPA.

10.4 The Noise and Vibration Management Plan will also set out the monitoring regime to be adopted to ensure that compliance with BPM and any consented noise levels are adhered to and that these can be audited.

10.5 The complete mitigation of construction noise is not always possible, but significant effects can be reduced by a combination of the selection of quiet methods of working and types of plant, limitation on the times when work is carried out, and the construction of temporary noise barriers. These measures have been assumed as incorporated mitigation and include operating equipment in an appropriate manner (e.g. closed covers) and ensuring that it is properly maintained (e.g. no defective silencers).

10.6 Railtrack have successfully imposed requirements to limit noise in a number of construction projects, details of which are given in other evidence.

Technical Measures

10.7 Technical measures include firstly the use of alternative methods of working or types of plant which are inherently quieter, secondly the application of acoustical engineering to plant to minimise its noise output, and thirdly the erection of noise barriers. Quiet methods of breaking concrete are available, including bursting using expanding grout, nibbling rather than using jackhammers or hydraulic breakers. Other measures include the use of mains power supplies in place of portable generators, and using longer piping to enable concrete pumps to be located remotely from noise sensitive working areas. Acoustical engineering involves the fitting of improved exhaust silencers to internal combustion engines and acoustic enclosures to plant.

10.8 Noise barriers are only effective when they extend above a direct line drawn through the barrier from noise source to noise receiver, and when they are close to either the source or the receiver. Their effectiveness is dependent on the extent to which the length of the shortest line from source to receiver over the top of the barrier is greater than that of the direct line, known as the path difference.

10.9 Noise barriers would be erected where shown on the significant effects maps to a height of 3m, to be removed once the construction work at the site is completed. Portable barriers would also be used during construction activities, where practicable, to reduce the noise levels from particularly noisy items of plant and machinery.

Compensatory measures

10.10 The principal compensatory measures available to residential properties are the provision of noise insulation, and in cases where the external noise level would be too high for noise insulation to give reasonable internal noise conditions, temporary re-housing. Railtrack will act at its discretion under Section 28 of the Land Compensation Act 1973. Buildings which are not eligible but which are particularly sensitive to noise will be subject to individual consideration by Railtrack. The Thameslink 2000 Noise and Vibration Policy deals with these aspects.

11 PREDICTED NOISE AND VIBRATION EFFECTS - CONSTRUCTION

Site-Specific Effects: The Inner Area

Works to Stations and New Viaduct

11.1 This section describes impacts, significant effects, and mitigation options for specific locations in the Inner Area arising from works to the stations and the civil works associated with the viaducts between Metropolitan Junction and London Bridge.

11.2 For the major works in the central part of the core area (Farringdon Station, Blackfriars Station, Metropolitan Junction to London Bridge, and London Bridge Station) both daytime and night-time periods have been considered. For works near stations at other locations (New Cross, St John's, Hither Green), only night-time has been considered.

Farringdon Station

11.3 By day, façades directly facing the railway between Farringdon Station and Charterhouse Street, and in Turnmill Street, will experience noise and vibration impacts due to construction. At night, noise will affect residential occupancy on the upper floors of a small number of buildings including the public houses in Cowcross Street, together with the new residential development of Dickens Court.

11.4 There will be only a limited amount of percussive piling consisting of some trench sheeting, and the installation of end-driven piles for the construction of the interchange bridge. This may produce perceptible vibration in nearby buildings.

11.5 There would be increased traffic in Farringdon Road and Turnmill Street but this would have a negligible effect.

11.6 The façades likely to experience significant noise effects are as follows:

11.7 Properties in Turnmill Street, Cowcross Street, Greenhill's Rents and The Smokery, Charterhouse Street and Farringdon Rd are predicted to receive noise levels above the significant effect threshold by day, and approximately 20 residential properties and 100 commercial properties, including Lincoln Place, Smith New Court House and Cardinal House, would be affected for up to 150 weeks. At night there would be a significant effect at approximately 20 residential properties during night possessions over a period of up to 71 weeks.

11.8 In addition to the matters discussed in section 8 above, the principal option for mitigation of the night-time effects would be to carry out the work during the day rather than at night. This is likely to be impracticable for work on an operating railway.

Blackfriars Station

11.9 Noise from construction work within the confines of the existing station would have a transitory impact on station users. The areas within which construction work would take place would be boarded off but it is likely that at times noise levels would be intrusive. It should be noted that within the station noise levels are already high due to train movements.

11.10 Activity at the worksites on the south bank of the river and the construction of the new station entrance would involve demolition work, concreting works, steel erection and vehicle movements.

11.11 There would be a noise impact for commercial property in the vicinity of Blackfriars Station concourse. Construction works on the river bridge platforms, and on the bridge reconstruction works are predicted to result in noise impacts at Falcon Point and River Court, particularly at night, and on adjacent commercial properties.

11.12 No percussive piling will be used, which will avoid significant vibration impacts from piling in this area.

11.13 The façades likely to experience significant noise effects are as follows:

11.14 North of the river, there would be significant noise effects for properties in Puddle Dock, Bridge House, Queen Victoria Street and Victoria Embankment, including the Mermaid Theatre, over 92 weeks.

11.15 South of the river, the construction works are predicted to result in noise levels which exceed the daytime and night-time significant effect thresholds for approximately 165 properties over 92 weeks. There would also be significant effects during the day for the adjacent commercial building at 245 Blackfriars Road.

11.16 In addition to the matters discussed in section 8 above, the principal mitigation option for effects on residential premises would be to carry out the work during the day rather than at night. This is likely to be impracticable for work on an operating railway.

Metropolitan Junction to London Bridge

11.17 Overall, construction of this stretch of the route has considerable potential for noise intrusion due to the existence of residential and commercial property very close to the alignment and the significant amount of night-time and weekend working required. Some properties will, however, be unoccupied during this period.

11.18 The principal areas of potential noise impacts are as set out below.

a) Offices on the north side of the Hop Exchange would be within a few metres of demolition, piling, and construction operations. These premises are screened from traffic noise on Southwark Street, but currently experience train movements at about five metres distance.

b) The rear facade of residential properties in Park Street (which would be partly demolished and will be empty) would be in very close proximity to the viaduct construction.

c) In addition, during the partial demolition of Nos 6 and 8 Stoney Street, neighbouring buildings including residential premises at No.9, The Market Porter, would be subject to disturbance from the demolition as well as from the viaduct construction.

d) There would be noise impacts at night for some residential properties in Redcross Way.

e) Commercial, retail and office buildings in Bedale Street would be affected by adjacent demolition work, rotary bored piling, concreting operations and bridge construction.

f) At Southwark Cathedral, there would be noise impacts during construction activity on the new viaduct.

g) Occupants of No. 5 London Bridge Street and New London Bridge House near the station would overlook the new viaduct works. The north façade of No. 5 London Bridge Street would, at its nearest point, be about one metre from the construction works. These offices presently experience high daytime noise levels from train movements and traffic, and are double glazed/air conditioned.

11.19 There would be vibration impacts arising from vibration impulses that occur during rotary bored piling operations. Perceptible vibration impacts would occur at properties (some of which would be partly demolished as part of the project) in Bedale Street, the Globe public house, Stoney Street, Southwark Street, Railway Approach (including. New London Bridge House), London Bridge St, Southwark Cathedral, and Redcross Way.

11.20 The façades likely to experience significant noise effects are as follows:

11.21 Significant noise effects would occur at approximately 30 residential properties at night for 67 weeks, namely 2-4b Redcross Way, 5-24 Cromwell Flats, 21 and 23 Park St, 11 Stoney St, the Globe public house and 19-21 Borough High Street, and also at the hotel at 8 London Bridge Street.

11.22 Significant noise effects would occur at the following commercial properties by day for up to 75 weeks: 2 Park Street, 1-5 Stoney St, 9 Stoney Street (The Market Porter), 22 Southwark St, the Hop Exchange, 2-18 Southwark St (even nos. only), 1 and 5 Bedale St, the Globe public house, 4-8 London Bridge St, and 1 and 5 Railway Approach (including New London Bridge House). Properties on the south side of Park Street would be affected except that they are likely to be unoccupied.

11.23 In addition to the matters discussed in section 8 above, the principal mitigation option for effects on residential premises would be to carry out the work during the day rather than at night. This is likely to be impracticable for work on an operating railway.

11.24 At Southwark Cathedral, external noise levels in the range 65 to 75 dB L_{Aeq} are predicted during construction activity on the new viaduct. These would affect the upper part of the Cathedral facade. Measurements have been made of the sound reduction provided by the facade. When the noise source is trains on the existing viaduct, these show that there is a reduction of 17 dB between outside and inside noise levels. The spectrum of construction noise differs slightly from that of train noise, but a similar reduction is likely to occur. The internal noise level is therefore expected to be up to 58 dB L_{Aeq}, which likely to be intrusive. The levels will be in the range 53 to 58 dB L_{Aeq} during approximately 30 weeks of the construction programme. It may be possible to arrange for the noisiest activities to take place during times of minimum activity in the cathedral although the opportunities in this respect are likely to be limited. Apart from the practicality of any such treatment, the Cathedral authorities would need to approve any scheme involving treatment to the cathedral.

11.25 There would be significant vibration effects arising from vibration impulses that occur during rotary bored piling operations. Perceptible vibration impacts would occur at the properties identified as likely to receive significant noise effects by day.

11.26 There is little that can be done to mitigate these vibration effects since the piling method proposed is likely to produce lower levels of vibration than any other practicable system. It is therefore unlikely that this effect can be avoided and some residual effects, particularly for those in the immediate vicinity of the piling are likely to remain.

London Bridge Station

11.27 Guys Hospital and London Bridge Hospital are the principal noise sensitive receptors in the area of the London Bridge Station works, together with residential property to the south and east. Night-time work will cause significant effects at these locations. Because of the height of many of the receptors, noise barriers would be ineffective.

11.28 With appropriate mitigation measures it would be possible to avoid a significant effect from the demolition of Fielden House.

11.29 The façades likely to experience significant noise effects are as follows:

11.30 Approximately 15 residential properties will receive significant effects from the London Bridge Station works at night for 63 weeks and a further 60 properties will receive significant effects for 25 weeks. The tower block and medium-rise block at Guys Hospital will receive significant effects at night for 112 and 92 weeks respectively. London Bridge Hospital will receive a significant effect at night for 98 weeks.

New Cross station

11.31 The significant works at New Cross Station would consist of a 3m extension to London end of Platform A, and a 31m extension to the London end of platform B to serve the up and down fast lines.

11.32 The noise-sensitive receptors are residential properties on the west side of the railway in Exeter Way, Pagnell Street, Railway Grove, Edward Street, Achilles Street and New Cross Road. There are also residential buildings on the east side of the railway in Amersham Grove and Amersham Vale.

11.33 A significant effect would occur at facades in all the above streets. This would occur during night possessions, mainly at weekends, over the 12-week construction period. It is estimated that up to about 165 dwellings could be affected for 2 nights. The maximum number of nights worked is about 18, but not all those 165 dwellings would be affected for all these periods of night working.

St John's (Tanners Hill)

11.34 There is a high retaining wall on the western edge of the Tanners Hill Junction. Nevertheless, there would be noise impacts for properties in Albyn Road, Ashmead Road and Cliff Terrace during construction works in night possessions.

11.35 The three principal works which will emit noise are the reconstruction of St Johns' Vale road bridge, widening of the embankment on the south side of the station, and works on the permanent way south of the station. A substantial amount of this work will have to be carried out at night.

11.36 The area is predominantly residential and consequently all the surrounding roads contain noise-sensitive receptors.

11.37 The only piling activity is confined to the use of a small piling rig to carry out alterations to the southern side of the footbridge. This location is approximately 45m from the nearest dwellings and so significant effects are unlikely.

11.38 At St John's station the railway is in a cutting but south of the station it is on an embankment.

11.39 The facades at which a significant effect would occur during night possessions, on both weekdays and at weekends, over the 6 month construction period are as follows:

11.40 It is estimated that up to about 300 dwellings could be affected for 3 weeks (at night). The maximum number of weeks worked at night is about 22, but not all the 300 dwellings would be affected for all these periods of night working. About 70 dwellings, mainly in Albyn Road, Ashmead Road, Cliff Terrace and St John's Vale, may qualify for noise insulation under the Thameslink 2000 Noise & Vibration Policy.

Hither Green Station

11.41 The significant works at Hither Green Station would consist of a 42m extension to the Country end of platform 5 and a 40m extension to the London end of platform 6.

11.42 The noise-sensitive receptors are residential properties in Fernbrook Road and Leahurst Road on the north side of the railway and in Springbank Road and Nightingale Grove to the south.

11.43 The track is elevated relative to Fernbrook Road (on an embankment of approximately 3m).

11.44 No piling works are proposed and so no vibration impacts are anticipated.

11.45 A temporary 3m high noise barrier is incorporated along the edge of the railway land on the north side of the track near the works adjacent to Staplehurst Road.

11.46 A significant effect would occur at up to about 200 facades in the above roads. This would occur during night possessions, at weekends during the 9-week construction period. Most properties would be affected for 2 to 6 nights, though some may be affected for up to 10 nights.

Changes to the Permanent Way

11.47 There is the potential for significant noise effects from this work, which would involve night-time possessions, but an assessment of this feature has not yet been conducted.

11.48 Works to the permanent way at London Bridge and Blackfriars stations might not affect more premises than are expected to be affected by other works (e.g. to the station) at those locations.

11.49 Other permanent way works (east of London Bridge Station, and at New Cross Gate and North Kent East junctions) have the potential to affect premises which have not been identified in relation to other works.

11.50 As further data becomes available these works will be assessed to determine the extent of any significant effects.

Power Supply Installations

11.51 Installation of power supply infrastructure is expected to be carried out mainly during the daytime. Night-time delivery of plant by rail during 6 hour possessions is anticipated for the installations at Kentish Town, Bricklayers Arms and New Cross. For the first of these locations, one such possession would be required: at Bricklayers' Arms and at New Cross, two such night-time possessions would be necessary. However, civil works (i.e. construction) would be carried out during the daytime.

11.52 There is thus the potential for a significant construction effect to occur at dwellings near the Kentish Town installation. However, the number of properties affected has not been determined at this stage owing to lack of data (e.g. ambient noise levels and topography).

11.53 The area surrounding the Bricklayers' Arms is commercial and so significant noise effects are not anticipated.

11.54 The works at New Cross Station are not expected to affect premises which have not been identified as receiving a significant noise effect as a result of the works to the station.

11.55 Noise from this activity will be kept under review as further information regarding night-time possessions emerges or changes.

Signalling Equipment

11.56 Installation of signalling equipment will require night-time possessions at some locations and hence has the potential to cause significant noise effects. As further data becomes available these works will be assessed to determine the extent of any significant.

Site Specific Effects: The Outer Area

Overview – Works to Stations

11.57 This section reports significant noise and vibration effects associated with the night-time construction activity at Stations in the Outer Areas.

Vibration

11.58 The only piling works proposed in the Outer Areas are at Balcombe and Dartford Stations where works are required to an existing bridge in the vicinity of each station. The piling method is in each case low headroom system, and at Dartford a continuous flight auger is proposed. The nearest dwellings are approximately 60m from the piling works at each site. On the basis of that data it is not anticipated that significant vibration effects will occur at those locations. Since piling is not proposed at other stations, there will, consequently, be no significant vibration effects in the Outer Areas.

Noise

11.59 Two aspects need to be understood regarding the reporting of significant noise effects in the following tables.

Dwelling Counts and Durations

11.60 The first is the basis for the numbers of properties identified as receiving significant effects and the duration of those effects.

a) The number of properties in each case is the estimate of the maximum number of dwellings that are expected to experience a significant effect even if this would occur for only one or two nights in the construction period.

b) The number of nights on which significant effects might occur represents the total number of nights on which works would be carried out at night. It does not necessarily mean that all properties would experience a significant effect on each of those nights. The total number of nights represents an upper limit to the number of nights on which properties nearest the works might experience a significant effect.

c) Noise survey personnel have visited many of the sites to collect topographical data and check the heights of residential buildings. However, a detailed study of land-use and numbers of residences within particular buildings potentially affected has not been carried out at this stage. (That will be undertaken when Section 61 consents are applied for.) Currently, therefore, housing counts are approximate.

11.61 The above factors also apply to the numbers of dwellings shown as potentially qualifying for sound insulation under the Thameslink 2000 Noise & Vibration Policy.

Mitigation

11.62 Incorporated mitigation is shown for those stations at which temporary 3m noise barriers will be provided.

11.63 All stations will benefit from the procedures that will require, for example, liaison between the contractor and the Local Authority to determine appropriate mitigation for each location. The strategy for mitigating the effects of noise and vibration is described in Section 8.

11.64 The numbers of dwellings for which significant noise effects (for one or more nights) are predicted, and the numbers of dwellings which might qualify for noise insulation (under the Thameslink 200 Noise & Vibration Policy) are summarised for the Outer Areas in **Table A.9**.

Outer Areas North and South – Power Infrastructure Works

Overview of Works

11.65 At most locations work on providing new power supply installations and upgrading existing equipment will be carried out during the daytime. However, at some locations night-time work will be required. This will be of two kinds: delivery of plant (e.g. transformers), and civils works where the particular installation requires it and daytime working is not possible.

11.66 In practice, only a few locations will require night-time working on more than one night for civils works. **Table A.13** identifies those locations. The table also shows locations at which night-time possession for delivery of plant (but no civils works) would be required, and, where there are dwellings in the vicinity, their approximate distance from the works.

11.67 It is considered that there is the potential for a significant effect from night-time construction work at:

a) Potters Bar (North) (possible);

b) Potters Bar (South) (probable)

c) Riddlesdown (probable); and

d) Follyhill (possible).

11.68 At Riddlesdown there are about 45 dwellings within 100m of the site, the closest being approximately 50m away. At Potters Bar (South) the nearest dwellings are also about 50m away. Consequently, the potential for a significant effect is greatest at those locations. At Potters Bar (North) and at Folly Hill the distance between the works and the nearest dwelling is further (i.e. 120 – 150 m). There is therefore less likelihood of a significant effect at these two sites than there is at Riddlesdown. There are more dwellings in the vicinity of the works at Potters Bar than there are at Folly Hill where the only dwelling Folly

Farm. Thus, if there are significant effects at the latter two sites, more dwellings would be affected at Potters Bar (North) than at Folly Hill.

11.69 At Hurst Green no night-time civils works are proposed, and only one night-time delivery of plant is expected. However, owing to the proximity of the works to the dwellings, there is the potential for a significant effect at this location (there are about 30 dwellings within 50m of the works).

12 SUMMARY OF SIGNIFICANT EFFECTS - CONSTRUCTION

12.1 **Tables A.10 and A.11** summarise the significant noise effects identified in this study. The numbers refer to dwellings receiving effects at night.

12.2 Note that the property counts and durations should be interpreted in the way described in **paragraph 11.60**.

13 OPTIONAL MITIGATION MEASURES - CONSTRUCTION

13.1 Further mitigation options are limited to finding ways of carrying out work by day that is currently expected to be necessary at night, within the severe constraints of working near an operating railway.

13.2 There is little in practice that can be done to mitigate vibration effects given that, except at a limited number of locations, percussive piling will not be used in the project, and the vibration impacts are from the use of rotary bored piles. It is therefore unlikely that vibration effects can be avoided and some residual effects, particularly for those in the immediate vicinity of the piling are likely to remain.

13.3 Additional measures will be discussed with the Local Authority as the detailed design and the construction arrangements are refined further. These measures will be incorporated into the Environmental Planning and Environmental Method Statements required under Railtrack contract documentation to ensure that significant effects will be reduced to a practicable minimum.

14 PREDICTED NOISE AND VIBRATION EFFECTS - OPERATION

Site-Specific Effects: Inner Areas

Impacts on particular resources/receptors

14.1 Potential noise and vibration impacts caused by the operation of Thameslink 2000 are described below; first dealing with railway operations and then other features (e.g. power re-inforcement).

14.2 Predicted vibration levels in all cases are such that it is highly unlikely that any structural damage would arise.

14.3 Permanent traffic management changes as part of the Project are generally insignificant in terms of noise effects, with the exception of the closure of Cowcross Street in the Farringdon area, discussed below.

Farringdon Station

14.4 The existing train service of 222 trains in both directions (0700-2300) and 28 two-way trains (2300-0700) would be increased approximately threefold. This is partly offset by the discontinuation of Thameslink Moorgate service, and the significant contribution from London Underground services to overall noise levels, to the extent that no significant noise impacts are expected to occur at this location. The discontinuation of the Thameslink Moorgate service will lead to an improved noise climate, for properties in close proximity to the line over this section, which will be a noticeable benefit but not significant in the context of the evaluative criteria thresholds.

14.5 The closure of part of Cowcross Street through the re-routing of existing road traffic would result in an significantly improved noise environment for 48-60 and 36-42 Cowcross Street.

14.6 The closure of part of Cowcross Street would result in a significant positive effect on noise levels in the immediate locality.

Blackfriars Station to Blackfriars Junction

14.7 The existing service of 366 two-way trains (0700-2300) and 39 two-way trains (2300-0700) would be increased to approximately 782 and 100 respectively, and train lengths would be greater so the number of railway vehicles passing during the relevant time periods would be more than doubled.

14.8 Locations that may be sensitive to noise from train operations comprise:

a) office premises close to the track (e.g. Puddle Dock, Bridge House, Express Newspapers, Lloyds Bank);

b) the amenity areas of Riverside Walk and Paul's Walk;

c) residential properties at Falcon Point and River Court.

d) residential properties near Blackfriars Junction including Friars Close, Quadrant House and Edward Edward's House.

14.9 There are some residential properties adjacent to the viaduct between Blackfriars Station and Blackfriars Junction. The resulting change in noise levels from train movements would be just over the threshold of significance with a predicted increase in the region of 3-5 dB in the L_{Aeq} (0700-2300). An increase of 3-5 dB is classed as a "slight increase" in table A.5. The increase in the L_{Aeq} (2300-0700) index depends on the formations of off-peak trains, but in the extreme case of increasing all off-peak trains from 4-car to 8-car the L_{Aeq} (2300-0700) would be increased by 7 dB, i.e. a "moderate increase".

14.10 This potential significant effect would only occur for façades close enough to the railway for the existing L_{Aeq} levels to be dominated by railway noise, and This limits the extent of the moderate increase to Friars Close. Because this property is below the level of the viaduct, the noise is influenced by re-radiated structure-borne noise from the viaducts, and mitigation by installing higher parapets or noise barriers may not be effective. The façades of Quadrant House and Edward Edward's House overlooking the railway are slightly more distant and their baseline noise environment is less dominated by railway noise, so that the overall noise change will to be in the "slight increase" category. In the absence of qualifying permanent way works in this area, no entitlement to statutory noise insulation is likely to arise.

14.11 No significant vibration impacts or effects have been identified in the Blackfriars Station to Blackfriars Junction section.

Blackfriars Junction to Metropolitan Junction

14.12 Railway noise in this area is determined by train movements on the Charing Cross lines as well as Thameslink, and by noise from trains crossing points and by the occurrence of wheel squeal on curves. The existing service of 724 two-way trains (0700-2300) and 111 two-way trains (2300-0700) would be increased by approximately 60%, and train lengths would be longer. The resulting change in noise in the L_{Aeq} noise index is a mathematical function of the increase in the number of rail vehicles passing during each time period. This 60% increase in train movements results in a noise change of less than 3 dB and is therefore not significant.

Metropolitan Junction to London Bridge

14.13 The level of noise due to train movements would change due to changes in: track re-alignment and position, train frequency, train speed and train length, and the introduction of new rolling stock. In addition, the design of the new structures is likely to give rise to different noise characteristics to those of the existing viaducts. One of the objectives in this design process would be to reduce noise and vibration levels to a practicable minimum.

14.14 The existing service of 896 two-way Charing Cross trains and 113 two-way Thameslink trains (0700-2300) and 113 two-way Charing Cross trains and 13 two-way Thameslink trains (2300-0700) will change as follows. The Charing Cross trains will be transferred to the new viaduct; approximately 529 two-way Thameslink trains (0700-2300) and

73 two-way Thameslink trains (2300-0700) will operate on the old viaduct. The Thameslink trains will be 12-car in the peak and 8-car in the off-peak, compared with the existing services of 8-car and 4-car trains respectively.

14.15 Potential noise and vibration sources from railway viaducts in general include:

a) airborne noise radiated by rails and train wheels ("normal" railway noise);

b) wheel squeal on short radius curves caused either by slip-stick motion of axles negotiating curves because the two rails are of unequal radius or by flange contact with the running rail or a check rail;

c) airborne low-frequency noise ("rumble"), i.e. re-radiated structure-borne noise caused by vibrating viaduct surfaces;

d) ground-borne noise, re-radiated inside buildings by building surfaces receiving vibration at acoustic frequencies from the viaduct via the foundations and the ground; and

e) tactile vibration transmitted into buildings via the foundations and the ground, typically at very low frequencies.

14.16 Existing train noise levels in this area are dominated by the occurrence of "wheel squeal" caused by the relatively tight curve radii.

14.17 At the Hop Exchange and Park Street, construction of the new viaduct would reduce the distance between tracks and building facade with a consequent potential increase in noise levels. However, the new viaduct will be designed to minimise structure-borne noise, and will incorporate noise barriers.

14.18 Adjacent to Bedale Street, and Stoney Street, Charing Cross trains through the Borough Market would transfer from the old viaduct, where the tracks are fixed directly to the structure, to the new viaduct, which is planned to have non-ballasted resiliently supported track, and noise barriers. Overall, changes in noise levels due to individual train movements are expected to be negligible. However, the new viaduct would be close to No 5 Stoney Street and close to the office, commercial, and retail premises at the southern ends of Stoney Street and Bedale Street.

14.19 In the case of Southwark Cathedral, the changes in alignment have the effect of offsetting any increase in noise due to the change in numbers of train movements. There is not expected to be any increase in traffic on the tracks nearest to the Cathedral (i.e. those to Cannon Street) and while the services from London Bridge to Blackfriars would increase, the Charing Cross trains would transfer onto the new viaduct (i.e. further from the Cathedral). There is not therefore expected to be any change in train noise levels at the Cathedral.

14.20 At No.5 London Bridge Street, the new viaduct would be in closer proximity and this, together with changes in train frequency, length, and stock, means that there is a potential for a significant impact in terms of noise and vibration although this can be mitigated by appropriate maintenance measures.

14.21 For Cromwell Flats in Redcross Way, adjacent to Metropolitan Junction, the increase in noise caused by a combination of the realigned tracks and the increase in traffic (particularly 2300-0700) will cause a significant effect in the "slight increase" category. The top floor flats may be likely to be eligible for sound insulation according to the Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996.

14.22 Between Metropolitan Junction and Stoney Street, the overall maximum increase in train airborne noise levels for the upper floors of the nearest buildings with line-of-sight to the track over the top of the noise barriers is predicted to be approximately 4 dB L_{Aeq}, i.e. a "slight" noise increase. This applies only to the nearest (4-storey) part of the Hop Exchange, which is non-residential. For the remaining properties, which have fewer storeys, the effect of the noise barriers will fully offset the maximum potential increase in L_{Aeq} of 8 dB, resulting in no significant change.

14.23 Maximum noise levels from trains are already above 85 dB L_{Amax} in this locality and therefore the maximum noise levels arising from Thameslink 2000 are not significant in the context of the evaluative criteria.

14.24 East of Stoney Street, the south and south-west façades of the Globe public house would be newly exposed to railway noise, and the nearest windows on the top floor would overlook the noise barriers and experience a "moderate increase". For lower floors, the noise barriers would reduce noise levels from the new viaduct, but since these façades currently face away from the existing viaduct and will be as little as 1.2m from the nearest edge, any residential rooms in the public house are likely to be eligible for noise insulation.

14.25 Vibration for Park Street and other properties north of the viaduct will change little. Thameslink trains which already run on that viaduct will increase in number, and their characteristics will be similar to those of other modern electric multiple units. But there will be fewer trains overall on the existing viaduct due to the transfer of the Charing Cross trains to the new viaduct, and the existing slam-door trains will no longer run on the existing viaduct. The new viaduct will carry the Charing Cross service, on new high-quality track, albeit closer to the properties on the south side. Vibration will only be significant in the event of track defects occurring, such as severe rail corrugation or poorly aligned rail expansion joints.

14.26 At No.5 London Bridge Street, the new viaduct would be a minimum of 2m from the façade, with the benefit of a 2.2m noise barrier. The barrier will also provide shielding of noise from the existing viaduct, and the overall change in noise level would only be significant for the upper floor. No 1 London Bridge Street (Three Castles House) is a Vent shaft for the London Underground Northern Line, which also includes some office accommodation. For New London Bridge House, the reduction in structure-radiated noise from the new viaduct will offset its proximity and the effect of the increased number and length of trains. The third floor has line-of-sight (and the second floor partial line-of-sight) over the top of the noise barrier. However, the present day noise climate is dominated by the effect of trains on the existing Borough High Street Bridge, and there will not necessarily be a significant change.

14.27 Levels of airborne wayside noise and vibration can be minimised by the implementation of a high standard of maintenance of both the wheel treads of vehicles and the railhead. Differences of as much as 10 dB(A) exist between different rail systems operating the same rolling stock, simply due to differences in maintenance regimes. Light and frequent rail grinding, and wheel turning to remove wheel flats (flat spots or burns on wheel treads caused by the sliding of locked wheels during braking) as soon as practicable after they occur are measures which can be responsible for such differences in noise level. The occurrence of wheel flats is dependent on the successful operation of wheel slide protection on the rail vehicles and on test regimes. Wheel flats, even when apparently "rolled in" increase wayside noise levels by the order of 10 dB(A). These are matters for the train operating companies rather than Railtrack.

14.28 Some types of track necessitate maintenance regimes which cause greater environmental noise impact than others. Given that most track maintenance takes place in engineering hours at night, the potential for disturbance of neighbouring residents is high. Ballasted track involves tamping which is a noisy activity. The necessity for rail grinding, which can be a noisy activity, is related to the dynamic behaviour of the track and its propensity to develop defects which have to be corrected by grinding. General maintenance work on the railway can also cause noise disturbance especially when undertaken at night.

14.29 Of particular importance is the propensity of the track to give rise to rail corrugation. Although there are many different forms of, and causes of, rail corrugation, some of the potential causes are capable of identification at the design stage, particularly insofar as they relate to the dynamic interaction between the track and the vehicles.

London Bridge Station

14.30 The remodelling works at London Bridge station will not give rise to any significant effects due to operational noise or vibration.

New Cross Station

14.31 There will be no significant effects due to operational noise or vibration.

St John's (Tanners Hill)

14.32 The level of noise would change as a result of changes to train services and length of trains, and to track alignment. The increase in noise would be less than the threshold of significant effect.

Hither Green Station

14.33 There will be no significant effects due to operational noise or vibration.

Power Reinforcement

14.34 Mitigation will be applied as necessary and where practicable to reduce noise from power supply installations to acceptable levels, based on the criterion described in section 4. On that basis there should be no residual impacts from power supply re-inforcement installations.

14.35 Sufficient data exists to enable only transformer noise to be considered at this stage. Table A.14 lists locations at which transformers would be located where there are currently none, and describes the potential likelihood of mitigation being required.

Signalling Installations

14.36 There is the potential for significant effects. However, when sufficient information is known to enable noise predictions to be made, as assessment will be carried out, the need for any noise reduction measures identified, and the appropriate mitigation action taken.

Vent Shafts (Blackfriars Station – North Bank)

14.37 Although designed to accommodate fans, the vent shafts are now likely to rely on natural ventilation in which case there will be no potential impact from fan noise. Train noise emitted from the shaft is not likely to give rise to a significant effect.

Public Address Systems

14.38 As explained in paragraph 4.7 above, where new Public Address Systems are installed, they will be designed to minimise noise impact for neighbouring receptors.

SITE-SPECIFIC EFFECTS: THE OUTER AREAS

Train Operations

14.39 The Thameslink 2000 project in the outer areas involves the provision of no significant new railway alignments and the only changes to the baseline conditions are the introduction of through Thameslink trains to replace or supplement existing services terminating in London.

14.40 Thameslink trains would be up to 12 cars in length, and this necessitates works to increase platform length in many cases. The effect of these works on operational noise is limited to the fact that they would allow trains to operate which are up to 50% longer than 8-car trains currently in operation.

14.41 Thameslink 2000 has operational information showing changes in peak services on routes passing through Kings Cross and/or London Bridge. This information indicates that service levels outside the core area would not be increased except on St Johns - Dartford, Preston Park - Littlehampton, Wivelsfield - Eastbourne and Wivelsfield - Brighton routes. On these services there is proposed a net increase on London Bridge trains of one train per hour in the peak, in each direction (two per hour in the case of Dartford). Wivelsfield to Brighton, on the worst case short section south of Preston Park, has some 5 trains per hour. The Guildford service is planned for trains of no more that 8 cars. Thus for trains of the same length, the increase from three trains per hour to four trains per hour is an increase of 1.25 dB which is not significant. On the Brighton, Eastbourne and Littlehampton lines, 12 car trains are planned, but taking into account the existing Victoria service the increase will be no more than 1.4 dB which is not significant. St John's - Dartford has no change off-peak, so that the increase of 2 trains per hour in the two peak hours, even with an increase in length to 12 cars, will not cause a significant effect.

14.42 On no route, including those where there is a net increase in train services, does the proposed Thameslink 2000 train length represent an increase sufficient to cause a significant noise effect.

Power Re-inforcement

14.43 Mitigation will be applied as necessary and where practicable to reduce noise from power supply installations to acceptable levels, based on the criterion described in Section 4, namely BS 4142 "Method of assessing industrial noise affecting mixed residential and industrial areas". This is a method of rating the noise from the installation on the L_{Aeq} index, adding a 5dB "penalty" for acoustic feature characteristics such as the pure tone sometimes associated with transformers, and comparing the result with the background noise level exceeded for 90% of the time. If the rating level minus the background level is around 10 dB this indicates that complaints are likely. If the rating level minus the background level is around 5 dB this is of marginal significance in assessing the likelihood of complaints. If the rating level is more than 10 dB below the measured background noise level then this is a positive indication that complaints are unlikely.

14.44 Only transformer noise has been considered at this stage. Table A.15 lists locations at which transformers would be located where there are currently none, and describes the potential likelihood of mitigation being required.

Public Address Systems

14.45 As explained in paragraph 4.7 above, where new Public Address Systems are installed, they will be designed to minimise noise impact for neighbouring receptors.

15 NEW INFORMATION

15.1 Since the completion of the Environmental Statement (CD/34), further technical studies have been carried out. These have related to

a) Vibration in premises above the Clerkenwell Tunnels between King's Cross and Farringdon

b) Noise and vibration from the viaducts, existing and proposed, in the Borough Market Area.

c) Construction noise impacts at Blackfriars Station and their effects on premises at 1 Puddle Dock.

d) Operational noise surveys and predictions at Quadrant House and Edward Edwards House.

e) Noise and vibration from the proposed works at Tanner's Hill.

Vibration in premises near the Clerkenwell Tunnels

15.2 A baseline vibration survey carried out in 1997 indicated high levels of existing vibration above the Clerkenwell Tunnels, particularly in the Wharton Street, Acton Street and Swinton Street areas. The levels produce the conclusion "adverse comments probable" according to BS

6472, and in some cases were above that range, which is the strongest semantic description available in the Standard.

15.3 Since that date, maintenance work has been carried out on the track which has resulted in a marked improvement in the condition of the rail running surfaces. A repeat vibration survey was carried out in December 1999 which indicated that levels were much reduced, to the extent that the BS 6472 conclusion is "Low probability of adverse comment".

15.4 A feature of the index used to assess vibration is that it is not (by contrast to the decibel scale) logarithmic. Thus changes appear larger than they are, and it takes a factor of 2 to move from one category to another in BS 6472. In decibel terms, the vibration levels fell between 1997 and 1999 by the order of 25dB. Because of differences in access facilities it was not possible to use identical measurements locations, and some of the difference between 1997 and 2000 is due to differences in measurement position. Nevertheless, the difference represents approximately the difference between the worst rail roughness profiles generally encountered, and the best.

15.5 The effect of the increased number and length of trains operating after completion of the project is limited to the effect of the increased duration and occurrence of train vibration events. The VDV index rises in proportion to the fourth root of the total duration, so that to move from one BS 6472 category to the next requires $2^4 = 16$ times the number of railway vehicles. Despite the increase in length from a minimum of 4-cars to a maximum of 12-cars, and the three-fold increase in train numbers, there is still no possibility of a sixteenfold increase in rail vehicle passages. In other words, the level of vibration is much more important than the duration. The level of vibration has been shown to be sensitive to rail maintenance rather than any other factor.

Noise and vibration from the viaducts, existing and proposed, in the Borough Market Area.

15.6 Detailed numerical studies have been carried out by my practice into the vibration and noise characteristics of train operations on the existing and proposed viaducts in the Borough Market area. Studies have also been carried out into the noise and vibration environment within Southwark Cathedral.

15.7 These have shown that airborne noise from existing train movements is sufficiently high, and occurs sufficiently frequently, to interfere with some of the activities carried on in the cathedral, for example, services and teaching of parties on school visits. External existing train noise reaches a maximum of approximately 70 dB(A). The noise radiated by the existing viaduct has been computer-modelled with a good degree of accuracy, and using the same technique the noise which will be radiated by the proposed new viaduct has also been modelled. This shows that noise levels from the new viaduct will be below 60 dB(A), and the low frequency rumble apparent in the cathedral will be largely absent.

16 CONCLUSIONS

16.1 The noise and vibration studies which have been carried out show that in no case is the operational effect of Thameslink 2000 great enough to outweigh the benefits described in other evidence. As with all major infrastructure works there are likely to be significant construction noise and vibration effects, for which appropriate mitigation measures will be adopted.

GLOSSARY

dB Decibel. The decibel scale measures levels relative to a reference, either a fixed reference when measuring absolute levels, or another level when expressing changes. If the quantity is power-like (i.e. could be expressed in watts) the level in decibels is 10 times the common logarithm of the ratio of the measured quantity to the reference quantity. If the quantity is a physical amplitude such as pressure or voltage, and the power of the quantity is related to the its square, then the decibel level is 20 times the common logarithm of the ratio of the measured quantity to the reference quantity. Thus doubling of power gives a 3 dB increase, while a doubling of pressure gives a 6 dB increase.

L_A A-weighted sound pressure level. The units are decibels, abbreviated dB (or dB(A) if the subscript A is omitted). A-weighting is a frequency weighting which discriminates against low frequency and very high frequency sound in order to approximate the frequency response of the human ear. The subscript *s* or *f* signifies that the time constant of the measurement is either 'slow' (1 second) or 'fast' (125 milliseconds)

L_{Amax} The maximum value of L_A reached during one or more noise events. (See reference to 's' and '*f*' subscripts above).

$L_{Aeq,T}$ Equivalent continuous sound level. The root mean square sound pressure level determined over time interval T expressed in decibels. May be regarded as the level of a notional steady sound which has the same energy in period T as an actual time-varying sound which occurs in the same period. Sound level, duration and number of events are treated such that doubling the number of events, or doubling the duration of an event, has the same effect as doubling the number of sources (i.e. doubling the energy), which in the decibel scale is an increase of 3 dB (see above).

L_{A10} The A-weighted sound level in dB which is exceeded for 10% of the time period stated.

ppv Peak particle velocity, the highest instantaneous velocity reached by a vibrating surface.

VDV Vibration Dose Value, the fourth root of the time integral of the fourth power of the frequency-weighted vibration velocity. The frequency weightings are specified in BS 6841:1987 and BS 6472:1992. The units are ms-1.75.

SEL_v Sound Exposure Level (or Single Event Level), the time integral of the squared sound pressure expressed in decibels. May be regarded as $L_{Aeq,T}$ normalised so that T is one second regardless of the actual duration of the event. Is used to construct $L_{Aeq,T}$ for a period containing many noise events, from knowledge of the SEL_v for each individual event.

i Rice, C.G. and Morgan, P.A. A Synthesis of studies of noise-induce sleep disturbance, ISVR Memorandum No 623

ii Guidelines for Community Noise, Edited by Birgitta Berglund, Thomas Lindvall and Dietrich H Schwela, World Health Organization Geneva, 2000

iii British Standard 5228:Part 1:1997. Noise and vibration control on construction and open sites. BSI.

iv Based on case studies presented in Table 4 and Table 8, BS 5228 Pt 4 (Appendix C) Only London sites used and highest levels in each case

v TRL data supplied 12th July 1997 (D Hiller), and TRL Supplementary Report 544, Ground Vibrations from impact pile driving during road construction, DJ Martin (1980)

vi Calculation of Railway Noise, Department of Transport, H.M.S.O., London, 1995

vii Building and Buildings, The Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996, SI 1996 No. 428, H.M.S.O. London

viii Calculation of Road Traffic Noise. Department of Transport and the Welsh Office. HMSO. 1988.

ix Railtrack Line Specification RT/E/S/21019. Transformer/Rectifier Equipments for DC Traction Substations. Issue 1 August 1996.

x Information from Project Team, July 1999.

xi British Standard 4142:1997 Method for Rating industrial noise affecting mixed residential and industrial areas.