Sound, Noise and Vibration

An explanation

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Outline of Presentation

- What sound is - sources, and ways in which is it transmitted from source to receiver.
- What vibration is - sources, and ways in which is it transmitted from source to receiver.
- Human perception of sound and vibration.
- Measurement scales and indices.
- Assessment approaches - relationship between noise and vibration and human response to them.
- Ways in which noise and vibration and their effects can be reduced.
- Government policy regarding assessment and decision making.
- HS2's application of government policy.

Scope of sound and vibration issues

SURFACE OPERATION - RAILWAY

SURFACE OPERATION - FIXED PLANT

UNDERGROUND OPERATION

SURFACE CONSTRUCTION

TUNNEL CONSTRUCTION

Basics – what sound is

- Sound is air oscillation that is propagated by wave motion at frequencies between 20 cycles/per second (Hertz, abbreviated Hz) and 20,000 cycles/second (20kHz).

- Sound decays with distance – it spreads out, is reduced (attenuated) by soft ground surfaces and by intervening obstacles.

- Sound is measured in frequency – weighted decibels (dBA) approximating the response of the human ear.

- Noise is unwanted sound, which is difficult to measure due to the complexity of the human ear.

Basics – what vibration is

- Vibration is oscillation of solids that can be propagated through wave motion.
- Vibration in soil decays with distance and is also attenuated by energy absorption in the soil and by obstacles and discontinuities.
- Vibration is mainly of interest in the frequency range 0.5Hz to 250Hz and can give rise to audible sound which is then measured in decibels.
- As with sound, human response to vibration is much more complex than can be measured with a meter.

Basics - sound

- Every 10 dB *increase* is about *double* the subjective loudness.
- Every 10 dB *decrease* is about a *halving* of subjective loudness.
- A 1 dB change is only perceptible under controlled conditions.
- A 3 dB change is the minimum perceptible under normal conditions.

INDOOR	Noise Level, dB(A)	OUTDOOR
Rock Band	110	Underneath aircraft landing at 1km from runway
Night club	100	1m from pneumatic road breaker
Food blender at 1m	90	1m from petrol lawnmower
Vacuum cleaner at 1m	80	Pavement of city street
Loud voice at 1m	70	Aircraft at height of 200m
Normal voice at 1m	60	30m from petrol lawnmower
Open plan office	50	Lorry at 100m, heavy rainfall
Refrigerator at 1m	40	Suburban area at night, no local traffic
Concert hall background noise	30	Country area at night, no local traffic
Extremely quiet room	20	Very remote rural area no wind
Nearly Silent	10	Wilderness at night with no wind
Threshold of audibility	0	Threshold of audibility

L_{Amax} sound

- Sounds in the environment normally vary in level, for example due to the passage of vehicles, or trains.

- The sound level therefore varies with time, showing highs and lows. The highs are measured with an index called $L_{Amax.}$

- L_{Amax} levels are presented in the tables in Volume 5 of the Environmental Statement. These are L_{AFmax} levels where F is the “fast” time weighting (0.125 second).

$L_{pAeq,T}$ measurement

- Because many noise events are more annoying than a few noise events, an index is needed to take account of both level and number (and duration) of events.

- Sounds that vary in level are therefore measured in *equivalent continuous sound level*, used internationally.

$L_{eq,T}$ (or $L_{pAeq,T}$)

T = time period

- $L_{pAeq,T}$ levels are presented both in the tables in Volume 5 of the Environmental Statement and also plotted as contours for the time periods (0700-2300) and (2300-0700).

$L_{Aeq,T}$ measurement

- L_{Aeq} is *not* an average of sound levels but an index. A sound which is twice as loud as another contains ten times the amount of energy. So averaging the energy gives a result dominated by the highest sounds in the averaging process.

- With L_{Aeq} :
  - **Doubling:** the energy in the sound, the number of sources, the duration of sound event, the number of similar events

    each give +3dB

- With L_{Aeq} :
  - **Ten times:** the energy in the sound, the number of sources, the duration of a sound event, the number of similar events

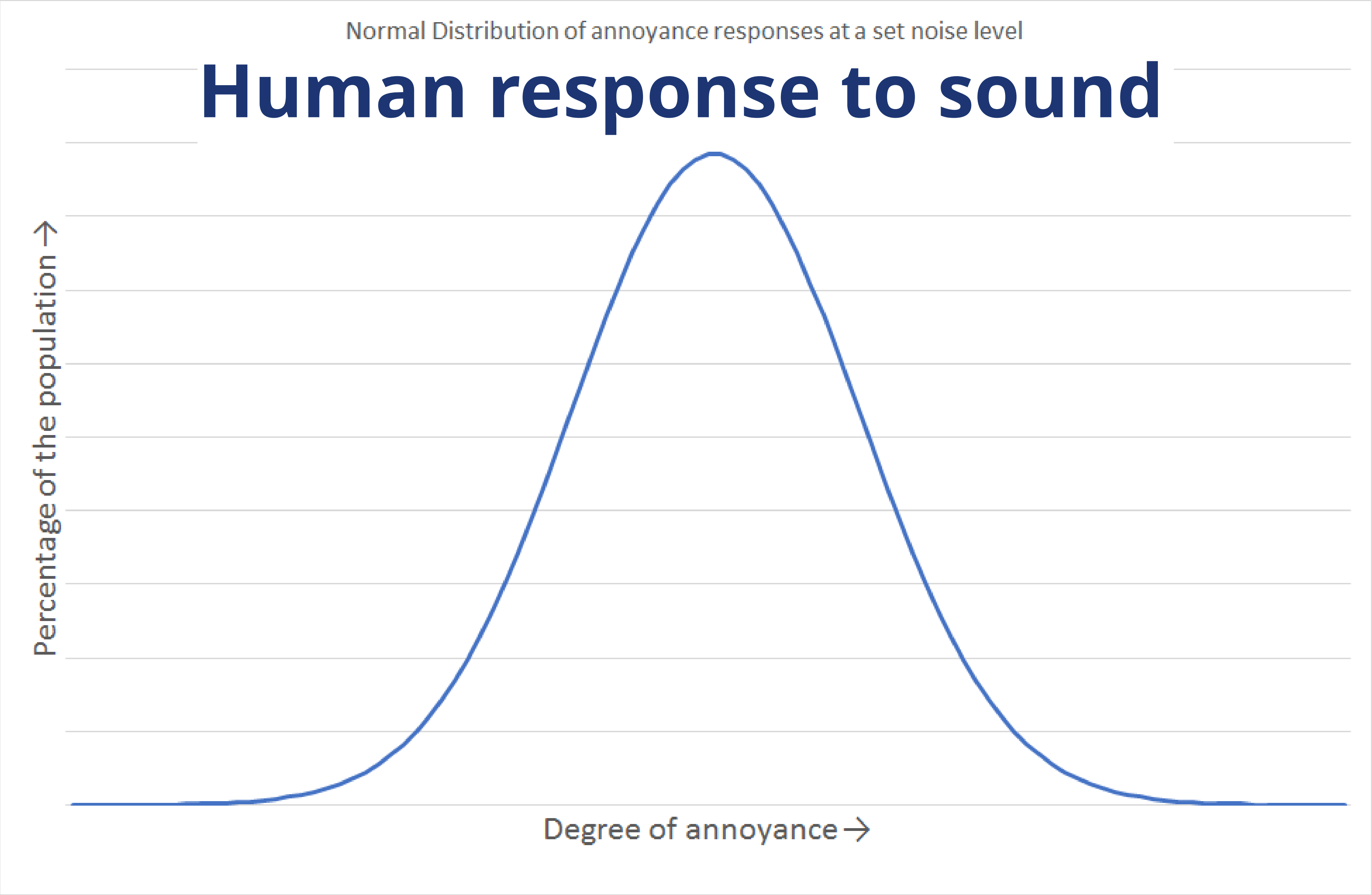
    each give +10dB

Human response to sound and vibration

- In terms of human response at environmental sound levels:
  - Sound levels on their own mean nothing.
  - Social surveys link sound levels with human response.
  - There is always a wide distribution of responses.
  - There is never a clear distinction between “acceptable” and “unacceptable” or “significant” and “not significant”.

- The same is true of vibration.

Human response to sound



Measurement of vibration & ground-borne noise

- Vibration felt by touch is assessed using Vibration Dose Value (VDV).
- Vibration affecting buildings is assessed using peak vibration velocity called "Peak Particle Velocity" or PPV.
- Ground-borne noise is assessed using maximum sound level, $L_{Amax,S}$ where S is the "slow" time weighting (1 second).

Government Policy

- Noise Policy Statement for England aims to:
  - avoid significant adverse impacts on health and quality of life.
  - mitigate and minimise adverse impacts on health and quality of life.
  - where possible, contribute to the improvement of health and quality of life.

- In light of the Explanatory Note the approach is to:
  - avoid effects above Significant Observed Adverse Effect Level (SOAEL).
  - mitigate and minimise effects between Lowest Observed Adverse Effect Level (LOAEL) and SOAEL.
  - proactively manage noise taking account the guiding principles of sustainable development.

- Not focusing solely on the noise impact without taking into account other related factors.

- Not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations. SOAEL is likely to be different for different noise sources, for different receptors and at different times.

HS2 implementation of government policy

To set Lowest Observed Adverse Effect Level (LOAEL) and Significant Observed Adverse Effect Level (SOAEL) values having due regard to:

- Established practice.
- Research results.
- Guidance in national and international standards.
- Guidance from national and international agencies including World Health Organization 2018 Environmental Noise Guidelines for the European Region and surviving parts of Guidelines for Community Noise 1999.
- Independent review by academic, industry and government employees on Acoustics Review Group.
- Use DfT Transport Analysis Guidance: WebTAG to assess impact on health of populations and at a local level to calculate the monetised value of noise control measures.

Operational airborne noise effect levels

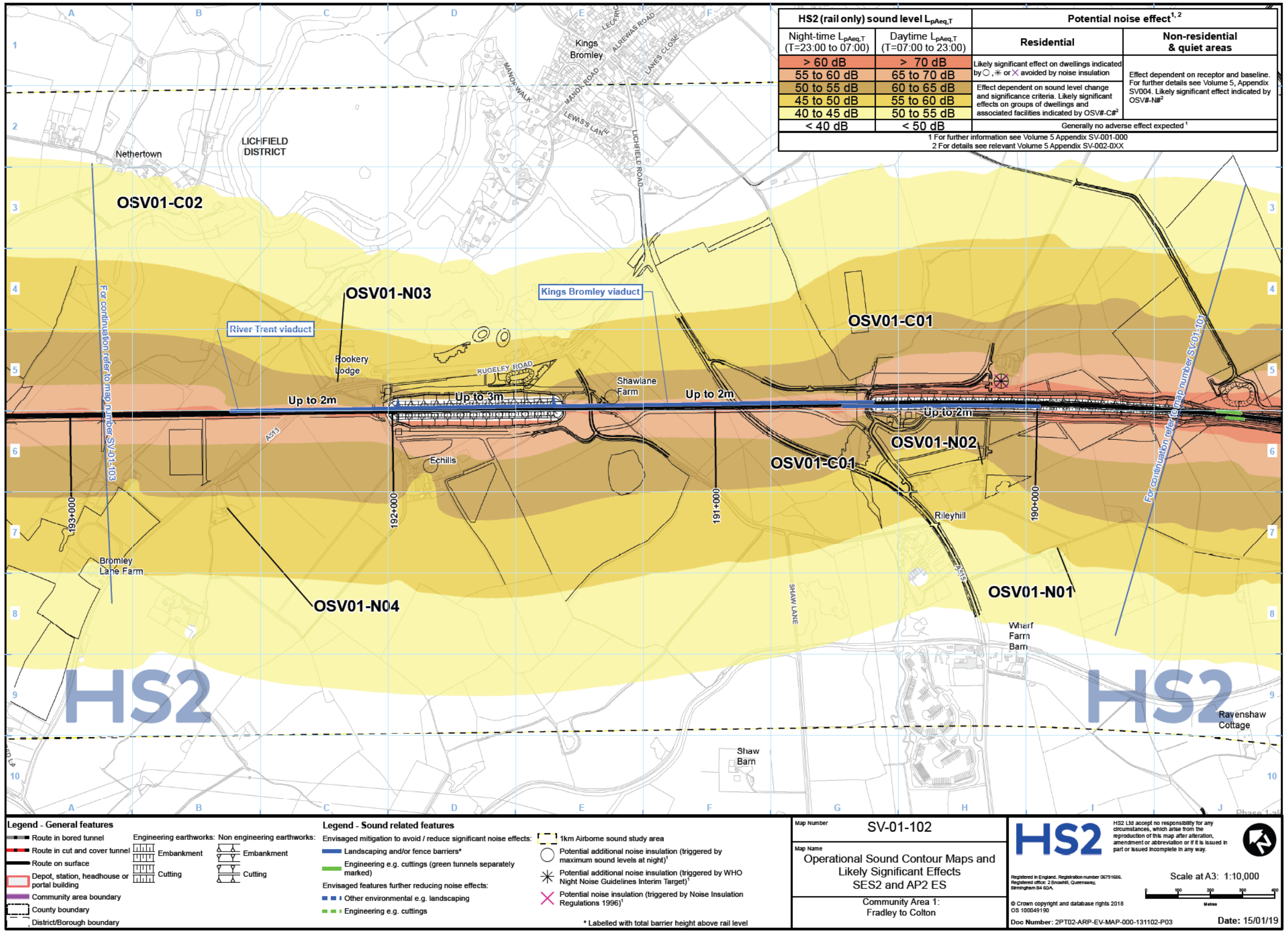
Time of day	Lowest Observed Adverse Effect Level (dB)	Significant Observed Adverse Effect Level (dB)
Day (0700 – 2300)	50 $L_{pAeq,\ 16hr}$	65 $L_{pAeq,\ 16hr}$
Night (2300 – 0700)	40 $L_{pAeq,\ 8hr}$	55 $L_{pAeq,\ 8hr}$
Night (2300 – 0700)	60 L_{pAFMax} (at the façade, from any nightly noise event)	80 L_{pAFMax} (at the façade, from more than 20 nightly train passbys), or 85 L_{pAFMax} (at the façade, from 20 or fewer nightly train passbys)

Operational airborne noise effect levels

Table 14: Explanatory notes for assessment results

Symbol	Explanation
	Where the significant effect column is marked, then a significant effect is identified at the referenced group of dwellings, or individual residential or non-residential receptor
	Yellow denotes a minor impact at a residential building – a change is of 3-5 dB
	Orange denotes a moderate impact at a residential building – a change is of 5-10 dB
	Red denotes a major impact at a residential building – a change is of >10 dB
*	Day - $L_{pAeq,07:00-23:00}$
**	Night - $L_{pAeq,23:00 – 07:00}$

Operational airborne noise effect levels



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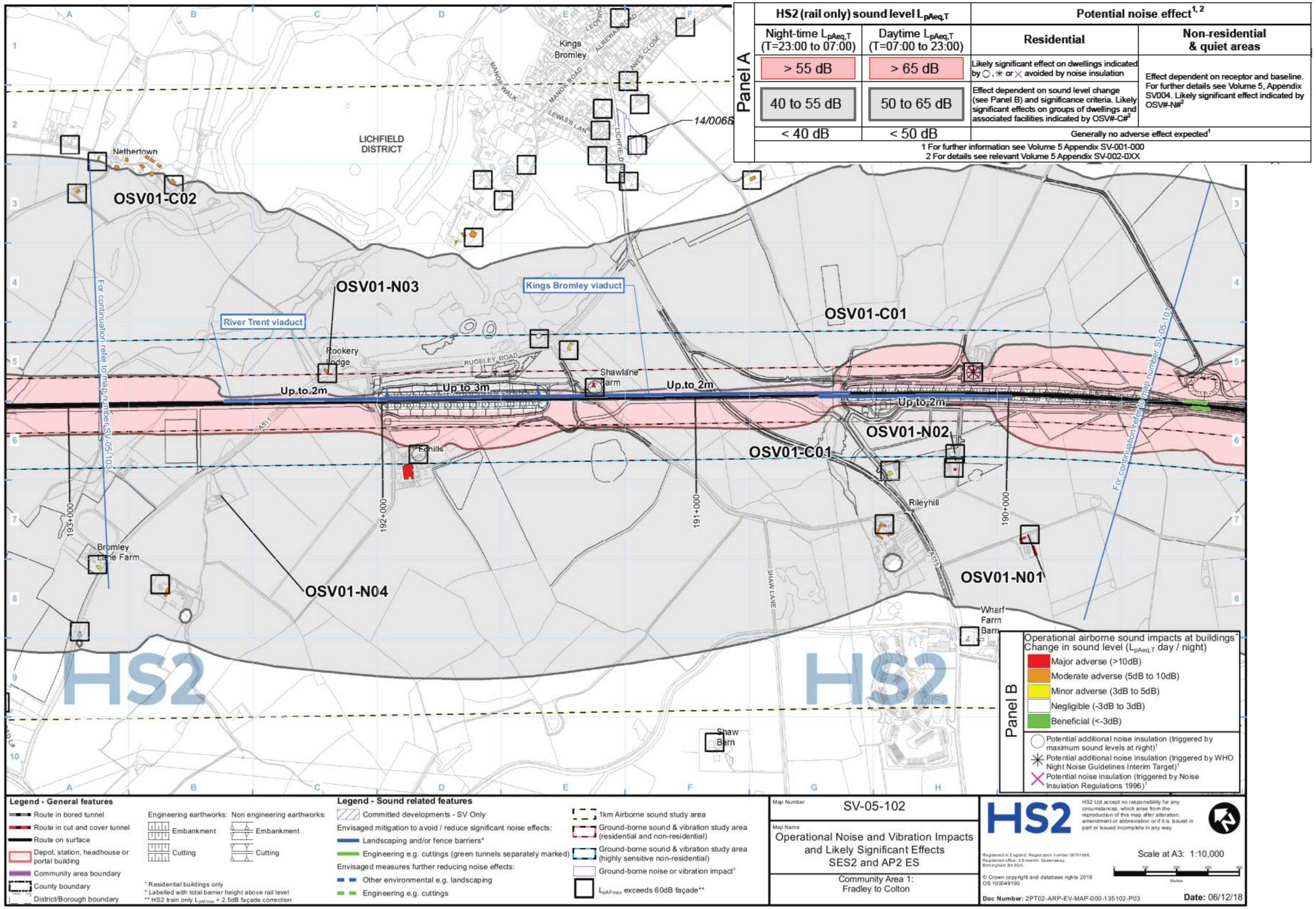
Operational airborne noise effect levels



Operational airborne noise effect levels

Assessment location		Impact criteria										Significance criteria								
Ref	Area represented	SES2 scheme only (year 15 traffic)			Do nothing (opening year baseline)			Do something (opening year baseline + year 15 traffic) ****		Change		Type of effect	Number of impacts represented	Type of receptor	Receptor design	Existing environment	Unique feature	Combined impact	Mitigation effect	Significant effect
		Day *	Night **	Max ***	Day *	Night **	Max ***	Day *	Night **	Day *	Night **									
11043	Holly Cottage, Rileyhill[9]	59	49	76/77	46	43	50	59	50	13	7	A	1	R	T	-	-	-	-	OSV01-C01
11048	Manor Walk, Kings Bromley[9]	42	32	55/57	36	34	58	43	36	7	2	NA	4	R	T	-	-	-	-	
11059	Manor Park, Kings Bromley[9]	49	40	63/64	40	35	48	50	41	10	6	A	3	R	T	-	-	-	-	#
11064	Shawlane Farm, Shaw Lane, Kings Bromley[9]	63	53	82/83	49	39	50	63	54	14	15	S	1	R	T	-	-	-	NI	OSV01-C01/ OSV01-D02
11068	Echills Farm, Rugeley Road, Kings Bromley[9]	64	55	80/81	50	38	49	65	55	15	17	S	1	R	T	-	-	-	NI	OSV01-D03
11071	Nethertown, Rugeley[9]	49	40	62/63	47	38	51	51	42	4	4	A	4	R	T	-	-	-	-	~
11083	Kings Bromley Lane, Rugeley[9]	54	44	66/67	48	41	61	55	46	7	5	A	1	R	T	-	-	-	-	~
11093	Goldhayfields Farm, Blithbury[9]	50	40	65/67	43	28	47	51	40	8	12	A	3	R	T	-	-	-	-	~

[9] Change as a result of SES2 change: lowering of Kings Bromley viaduct, Bourne embankment and River Trent viaduct (SES2-001-003).

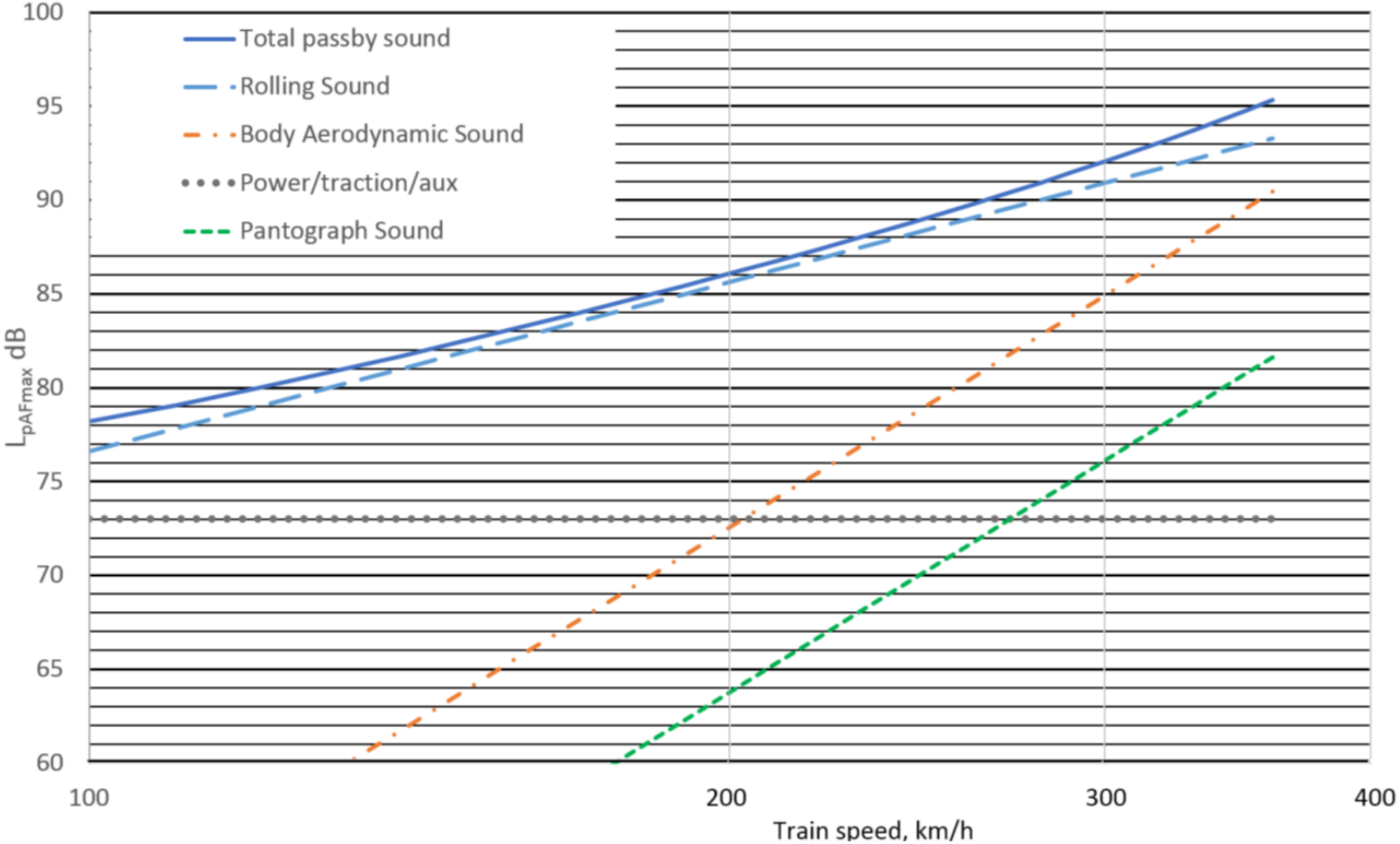
Operational ground-borne noise and vibration effect levels

(including temporary railways)

Ground-borne noise	Lowest Observed Adverse Effect Level	L_{pASMax} [dB]	35
	Significant Observed Adverse Effect Level	L_{pASMax} [dB]	45
Vibration	Lowest Observed Adverse Effect Level	VDVday[$m/s^{1.75}$]	0.2
		VDVnight[$m/s^{1.75}$]	0.1
	Significant Observed Adverse Effect Level	VDVday[$m/s^{1.75}$]	0.8
		VDVnight[$m/s^{1.75}$]	0.4

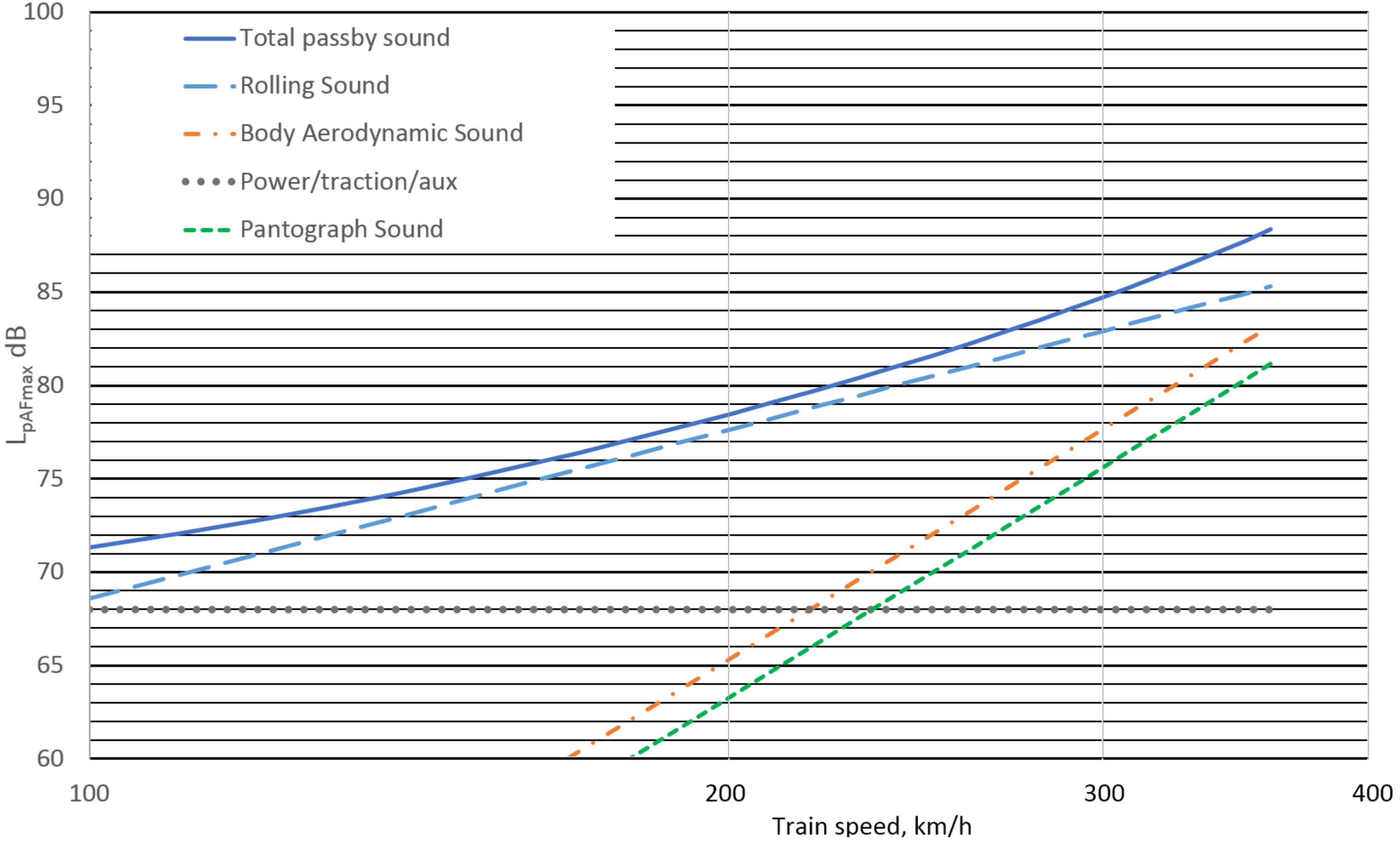
Operational Noise – contribution of sources

25m from track - no noise barrier



Operational Noise – contribution of sources

25m from track - 2m noise barrier



Effect of track support system

- The HS2 track design has been changed from sleeper-and-ballast to non-ballasted slab track.
- The Phase 2a Environmental Statement makes the precautionary assumption that one of the sources (rolling noise) on non-ballasted track will be 3dB noisier than on ballasted track.
- When rolling noise is combined with the other sources, the increase is 1.5 dB at 330 km/h.
- More detailed studies taking into account the HS2 track design indicate that rolling noise from trains on ballasted and non-ballasted track will actually be similar and the overall increase will be negligible.


Ballasted track


Non-ballasted slab track

Mitigation – Operational Vibration & Ground-borne Noise

- Operational vibration & ground-borne noise will be mitigated by:
  - Train design and maintenance.
  - Track design and maintenance.
  - Continuous welded rail.
  - Resilient rail support.

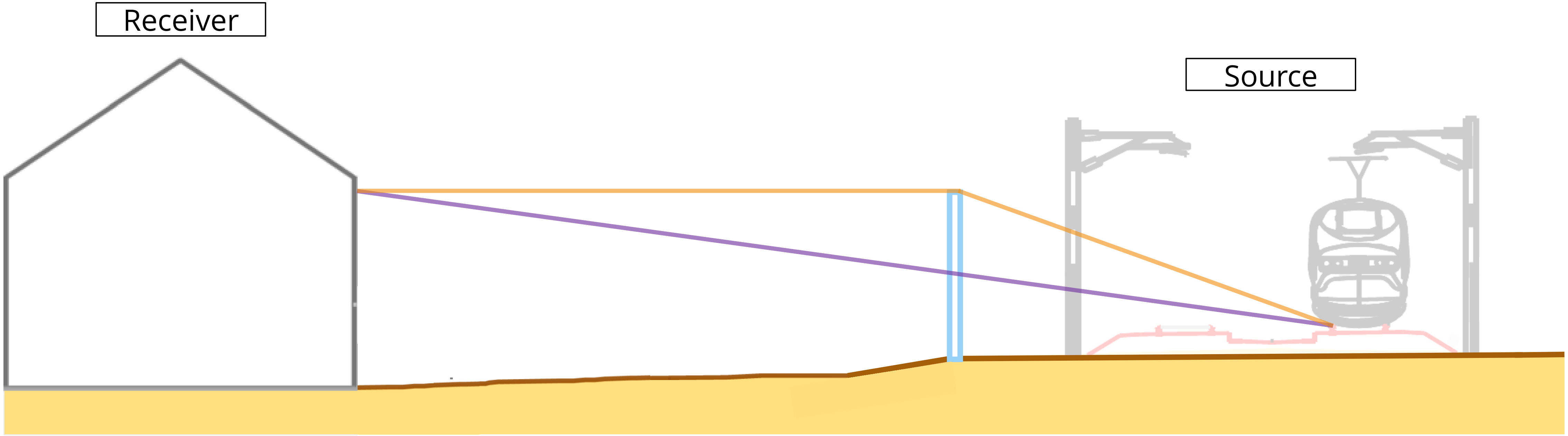
Mitigation – Train design

Current European TSI compliant trains do not have pantographs / wells designed to minimise aerodynamic noise
(TGV / Eurostar)

Current Asian HS trains do have pantographs / wells designed to minimise aerodynamic noise
(Shinkansen N700)

Mitigation – Noise barriers

Mitigation – Noise barriers



- The effectiveness of a noise barrier depends on how much longer the **orange** lines are than the **purple** line (the path difference).

- The path difference is longer the closer the barrier is to the source, therefore greater barrier height brings diminishing returns.

Mitigation – Construction Noise & Vibration

- Construction noise & vibration will be mitigated by:
  - Up-to-date methods of working.
  - Modern plant.
  - Noise barriers.
  - Noise enclosures.
  - Monitoring and management.

All subject to Section 61 of the Control of Pollution Act 1974 consent.

  - Noise insulation/temporary rehousing/compensation where applicable.

HS2 Information Papers

E9 Control of Environmental Effects

E10 Control of ground-borne noise and vibration from the operation of temporary and permanent railways

E11 Control of noise from the operation of stationary systems

E12 Operational Noise and Vibration Monitoring Framework

E13 Control of construction noise and vibration