National Physical Laboratory Underwater Noise

Techniques and Terminologies of Airborne Acoustics

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Andrew Bullmore

(andrewbullmore@acoustics.hoarelea.com)

Why should we be interested in airborne environmental sound?

Depending on its level and character, sound may ….

- cause physical damage to structures
- cause direct physical damage in humans and/or animals (e.g. irreversible hearing damage)
- invoke secondary adverse health effects in humans and or animals (e.g. stress, increased blood pressure, etc.)
- cause activity interference (speech, sleep, etc.)
- cause annoyance

- ……. but it may also convey useful information

Why undertake an environmental noise assessment?

To inform the outcome of some decision making process …

- research
- strategic planning
- complaint resolution
- specification of noise control measures
- compliance testing
- etc. ……

Can noise data help?

- the decision making process to be informed must have some 'target' outcome

- would a knowledge of noise assist in the outcome of the decision making process?

- noise may be one of many factors affecting the potential outcome

- compared with the other controlling factors, is noise a significant factor?

How should noise be described?

- objectively: sound is a regular and ordered oscillation of air molecules about their equilibrium positions

rarefaction   compression
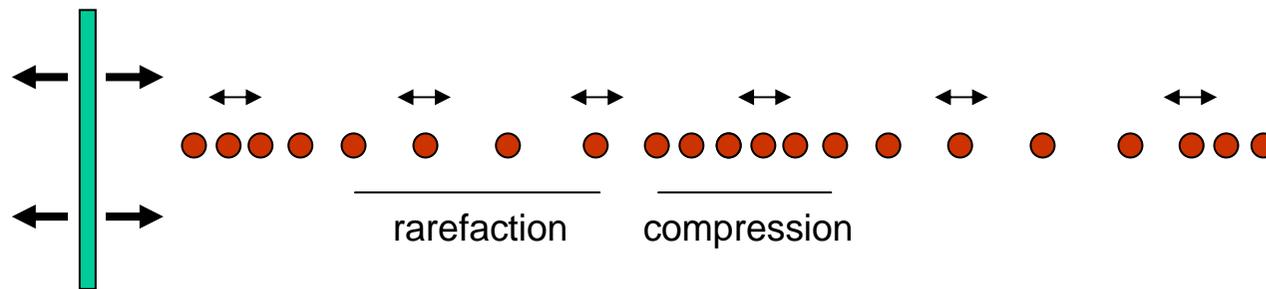
- subjectively: sound is the sensation of hearing excited by the oscillations of air molecules

- noise is sound that is <u>unwanted</u> in a particular situation

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When does sound become noise ?

- depends on individual

- depends on activity of individual

- depends on attitude of individual

- depends on hearing acuity of individual

- depends on level of noise

- depends on character of noise
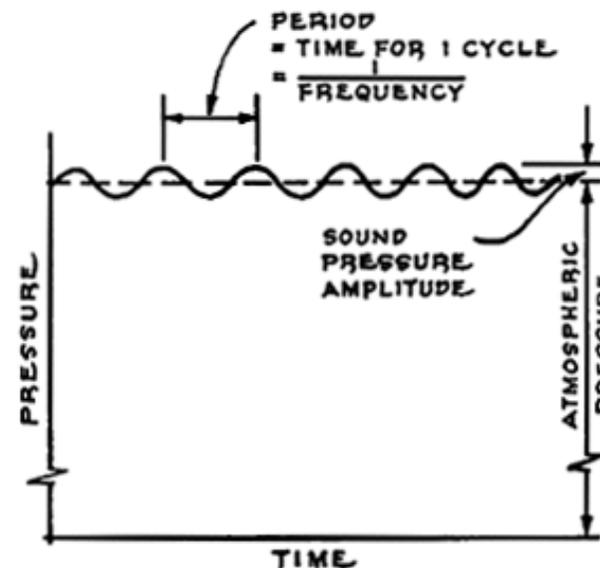
Fundamentals of hearing
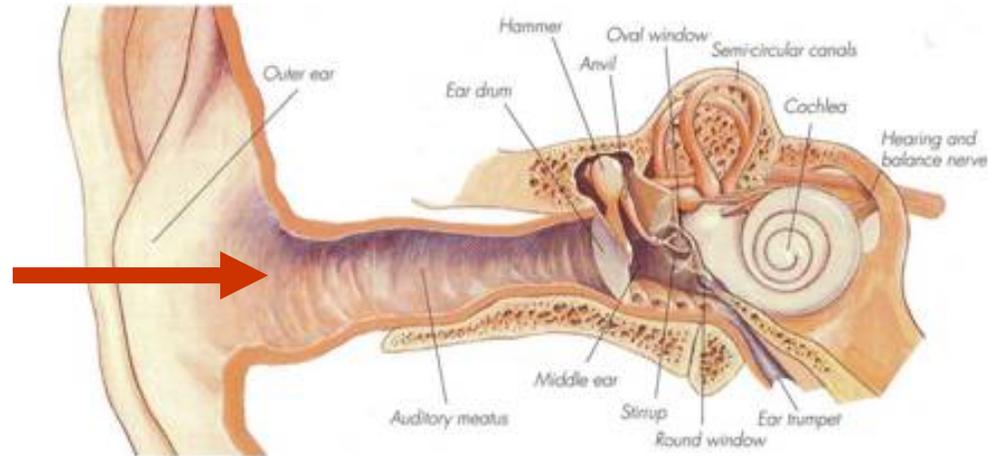
The ear detects:

- amplitude, Nm^{-2} or Pa

- frequency, Hz

The brain analyses for:

- temporal characteristics

- information content

- loudness (subjective)

Amplitude – Sound Pressure

- the ear detects amplitude and frequency of vibration of air molecules

- threshold of hearing 0.00002Pa

- onset of pain ~20Pa

- dynamic range of ear 1,000,000 to 1
  - c.f. scales weighing 1 gramme or 1 tonne
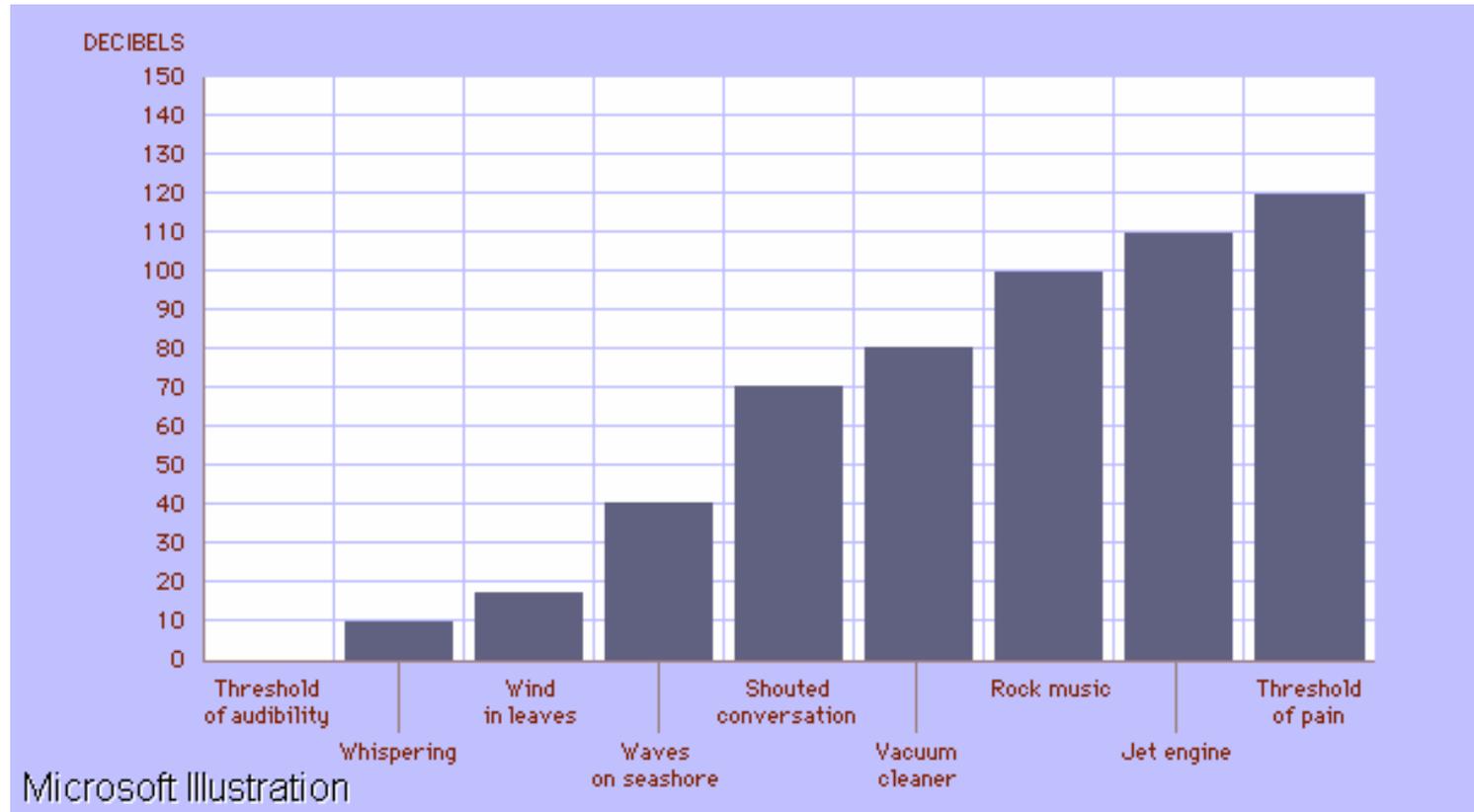
Amplitude – Sound Pressure Level (decibels)

- SPL, dB = 20 x log (p/p_o)

  p = rms acoustic pressure in Pa
  p_o = threshold of hearing 0.00002Pa

- threshold of hearing = 0dB

- onset of pain = ~120dB

- dB arithmetic is NOT linear (e.g. 60dB + 60dB = 63dB)
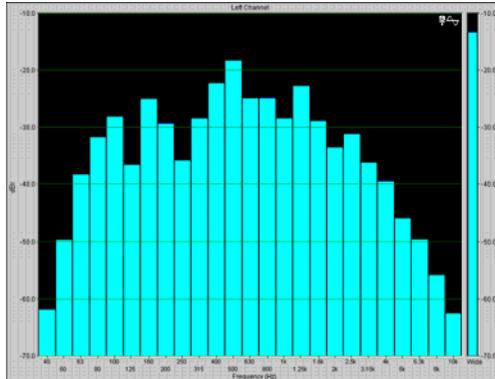
What difference does a dB make?

Microsoft Illustration
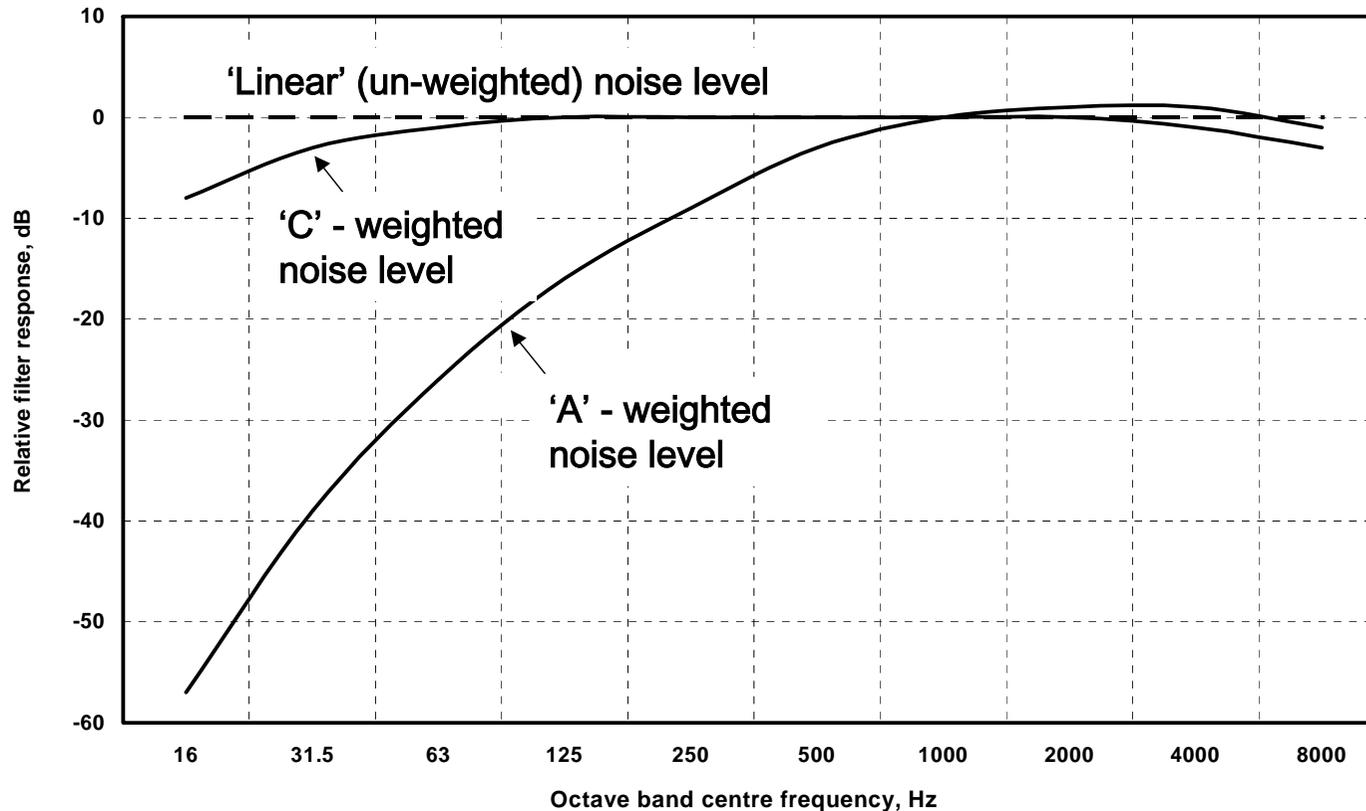
0 dB ➔ −1dB

0 dB ➔ −3dB

0 dB ➔ −10dB

0 dB ➔ −20dB

Frequency – sample noise spectra

Orchestra

Dance music

Road traffic

Hammering

Frequency sensitivity of the ear, dB(A)

- actual frequency sensitivity of human hearing is level dependent

- subjective response heightened by particular character of noise

- low frequency noise (<200Hz) currently attracting much attention

Some typical ambient noise levels

Remote rural area on a still ($<2ms^{-1}$) night	15 to 20dB(A)
Remote rural area on a still ($<2ms^{-1}$) day	20 to 25dB(A)
Rural area approximately 2km from motorway	35 to 40dB(A)
Any area on a windy ($>10ms^{-1}$) day or night	>40dB(A)
Town centre environment by night	45 to 60dB(A)
Town centre environment by day	55 to 75dB(A)
Edge of housing estate 50m from motorway	60 to 70dB(A)
Kerbside of busy 'A'-road	70 to 75dB(A)
Approximately 10m from busy motorway	75 to 80dB(A)
Noise at Work Regulations 'action levels'	85 to 90dB(A)

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What are the major sources of environmental noise?

| Noise Sources	Estimated proportion in 1990	Estimated proportion in year 2000
General Road Traffic	91±3%	87±4%
Motorway	2±1%	2±1%
Aircraft	61±6%	41±10%
Railway	15±4%	12±4%
Industry	4±2%	5±2%
Construction	5±2%	8±2%
Farm Equipment	8±3%	6±4%
Birds/Animals	55±6%	68±6%
School Children	18±4%	21±4%
Trees/rustling	18±6%	29±7%

Source: All information extracted from the BRE National Noise Incidence Surveys 1990 and 2000

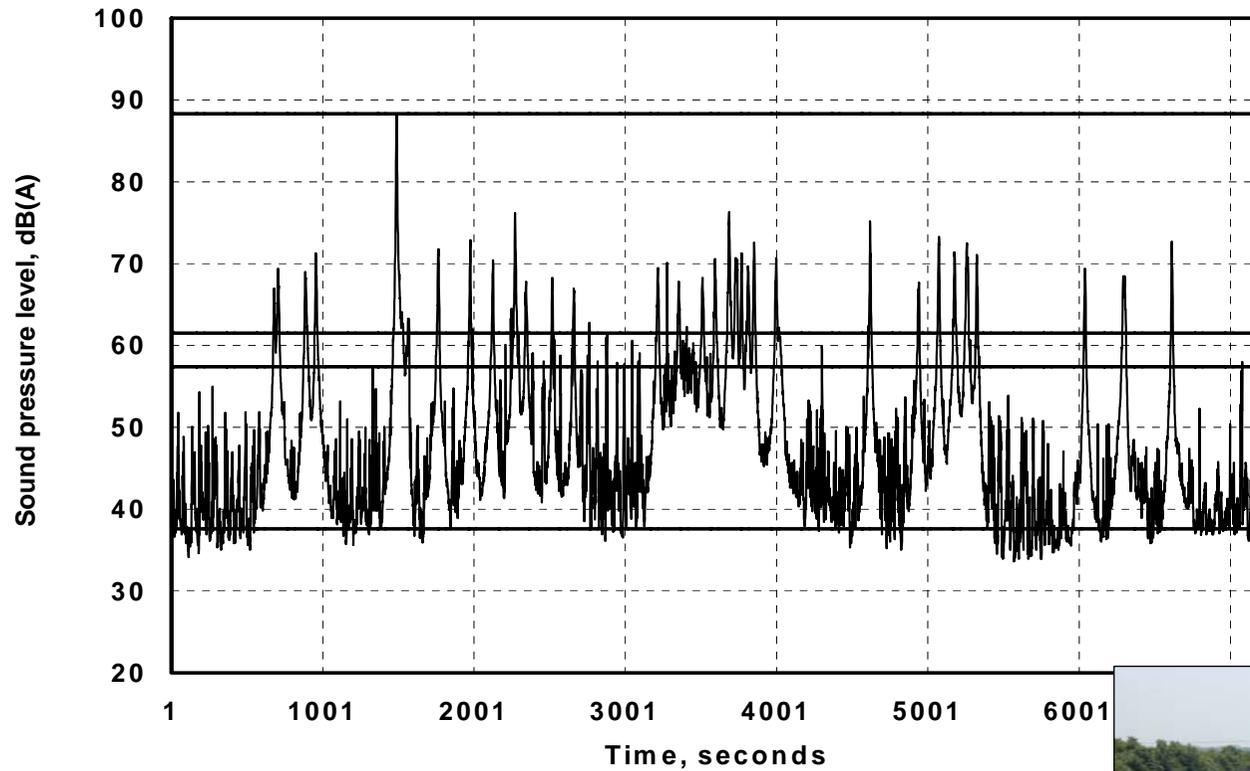# NNIS Distribution of Daytime Noise Levels
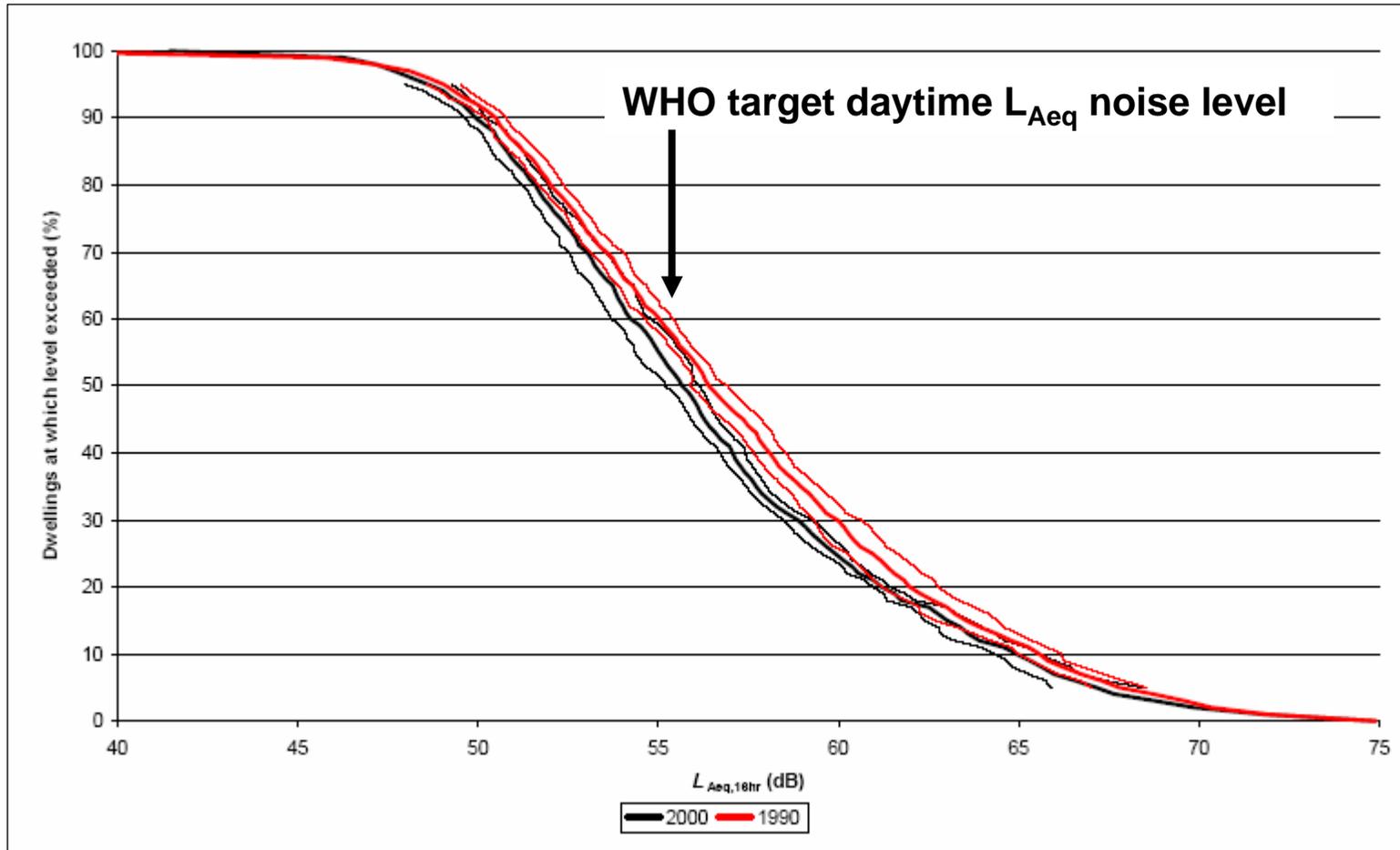
Source: All information extracted from the BRE National Noise Incidence Surveys 1990 and 2000
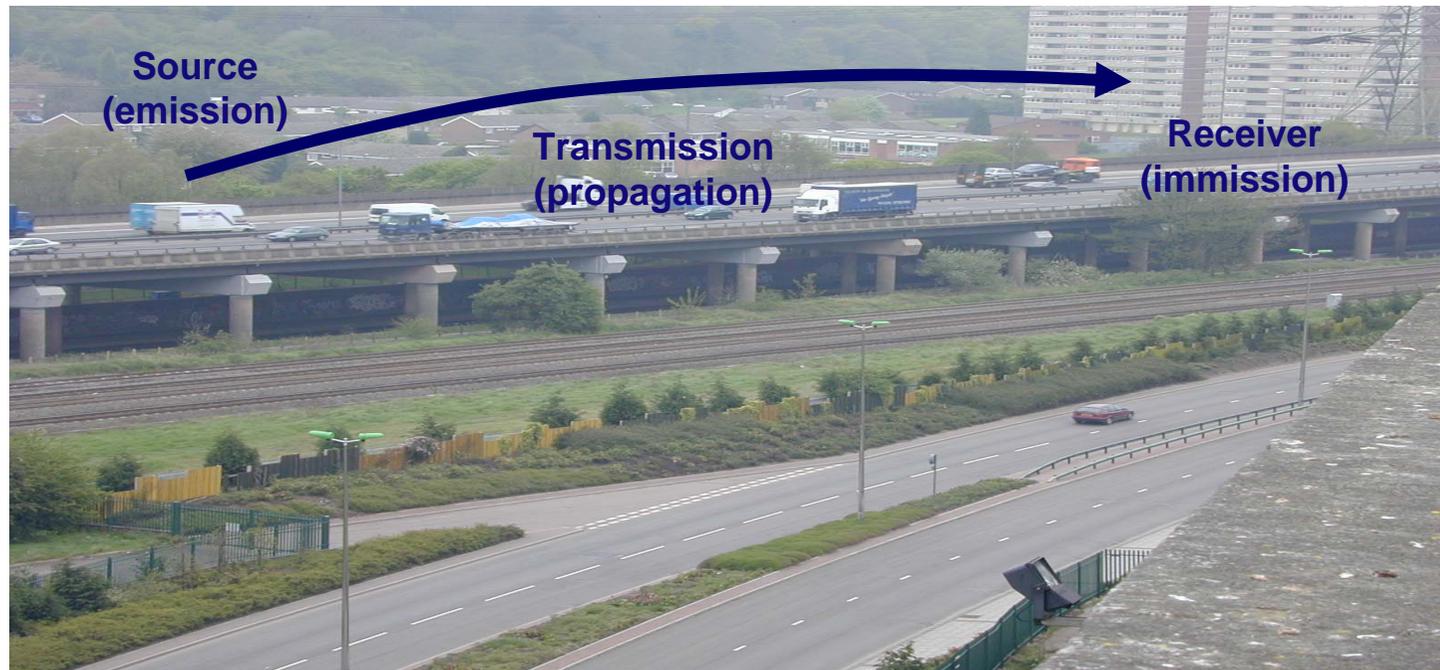
NNIS Distribution of Night-time Noise Levels
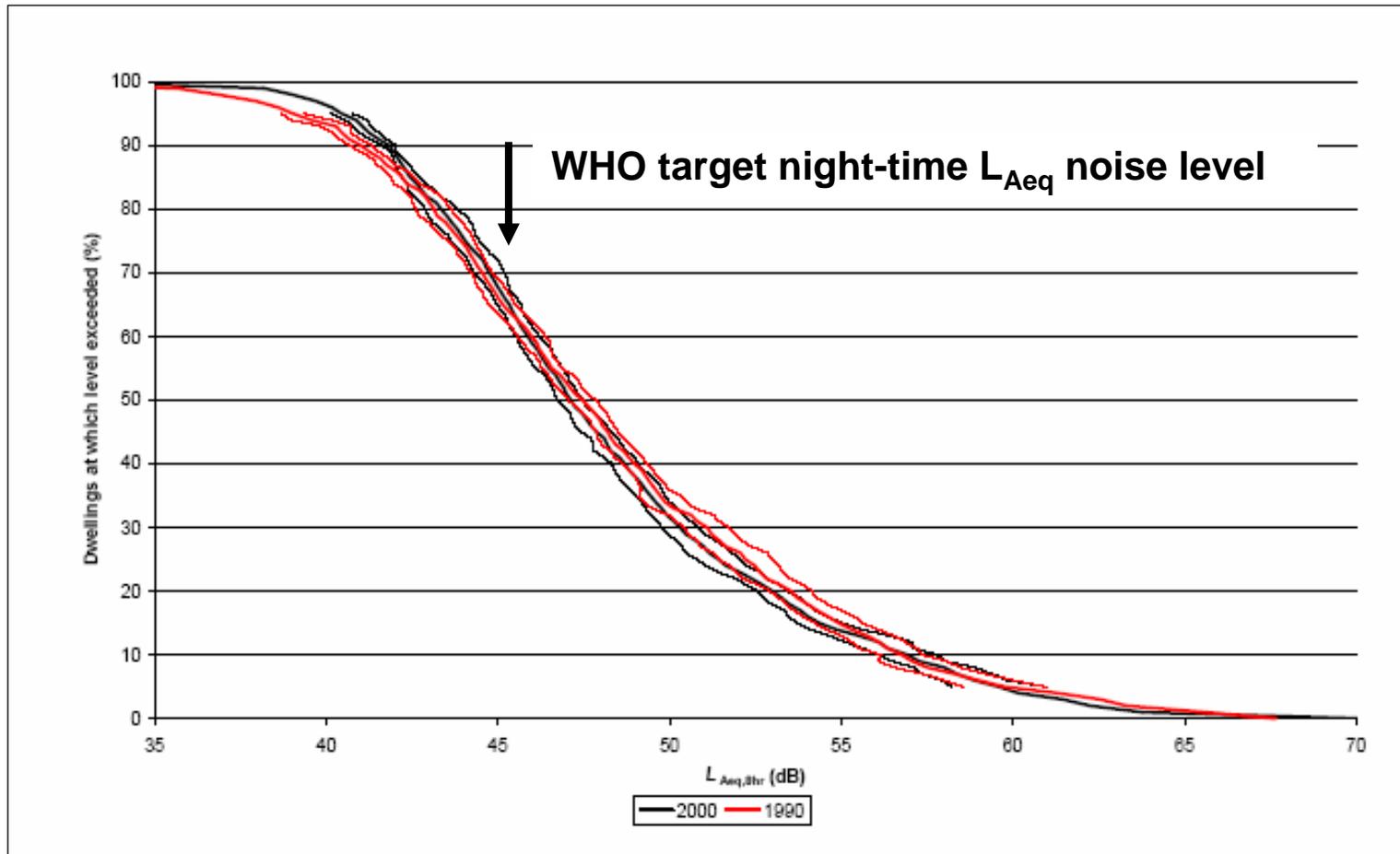
Source: All information extracted from the BRE National Noise Incidence Surveys 1990 and 2000
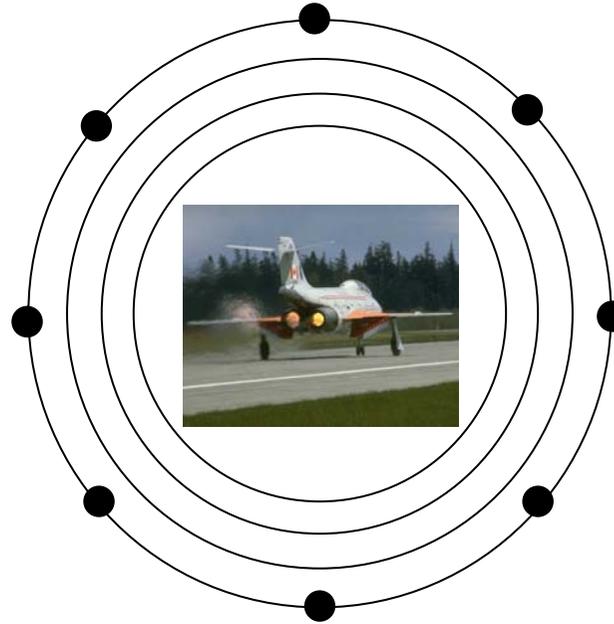
but noise is not usually constant .....

Factors affecting received noise levels

Source (emission)

Transmission (propagation)

Receiver (immission)

- variations in the source (e.g. traffic flows, wet roads)

- variations in the propagation path (mainly distance and wind effects)

- local effects at the receiver (including cumulative effects of all sources)

Source descriptors

- standardised techniques exist for the determination of source levels

- techniques vary between laboratory (precision) and field (engineering) measurements

- source levels almost always quoted in terms of the sound power output level, L_w, of the source

- source directivity is also often important

- measurements made under 'standardised' operating conditions for the source under test

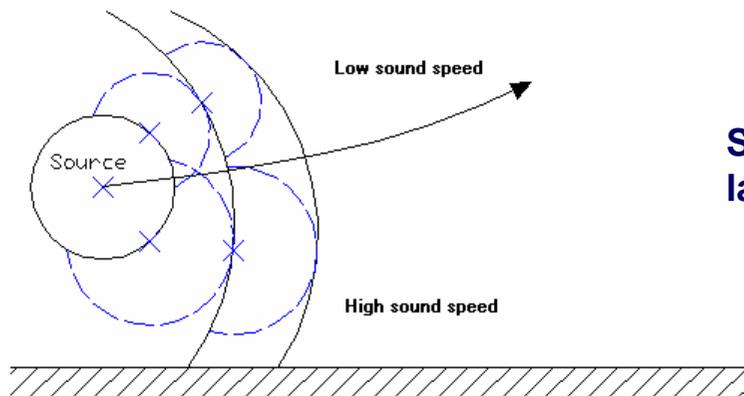- **not always realised in real world situations**

Transmission effects

Variability dominated by meteorological effects

- wind and temperature effects cause sound speed gradients

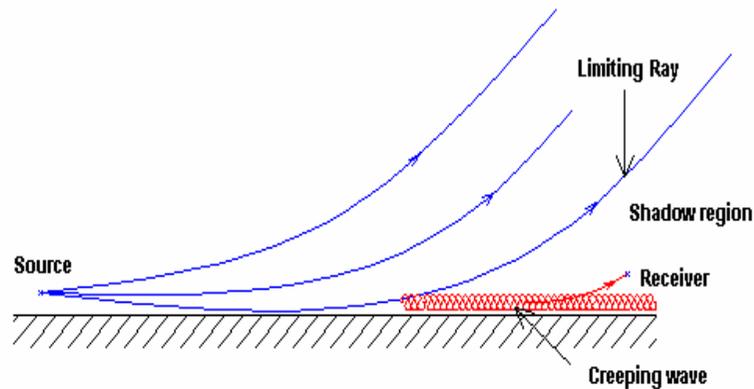- significant effects can occur within seconds, not just diurnally
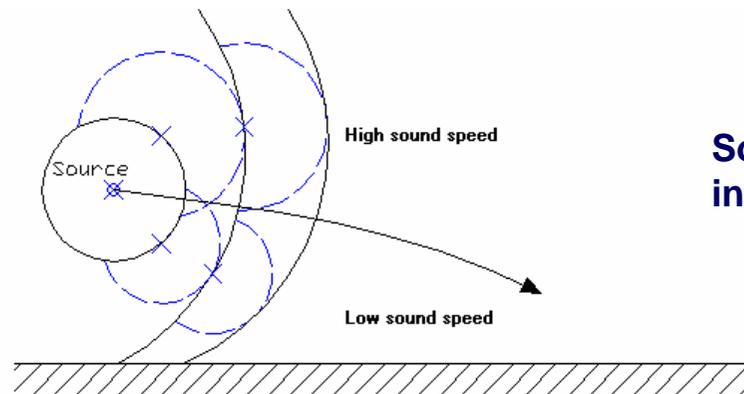
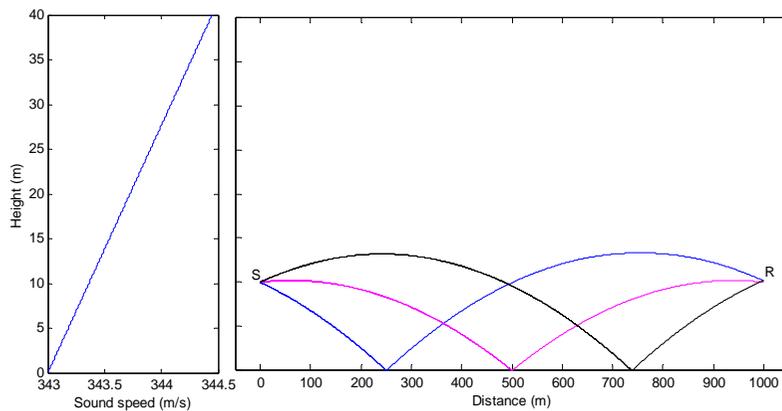**Sound curvature under temperature inversion and/or downwind conditions**

Sound curvature under temperature lapse and/or upwind conditions

Transmission effects

Sound 'shadow' results under temperature lapse and/or upwind conditions

Result is large decreases over neutral
[typically -10dB(A) to -15dB(A)]
and noise levels highly variable

Sound enhancement results due to multiple paths under temperature inversion and/or downwind conditions

Result is small increases over neutral [typically +1dB(A) to +3dB(A)] and noise levels much more stabl

Measurement versus Calculation

Calculated – constant level **Measured – variable levels**

Legend:
- LA10,18hr
- LA10, 1hr

Y-axis: Traffic noise level (dBA), scale 40 to 58

X-axis: fourteen days
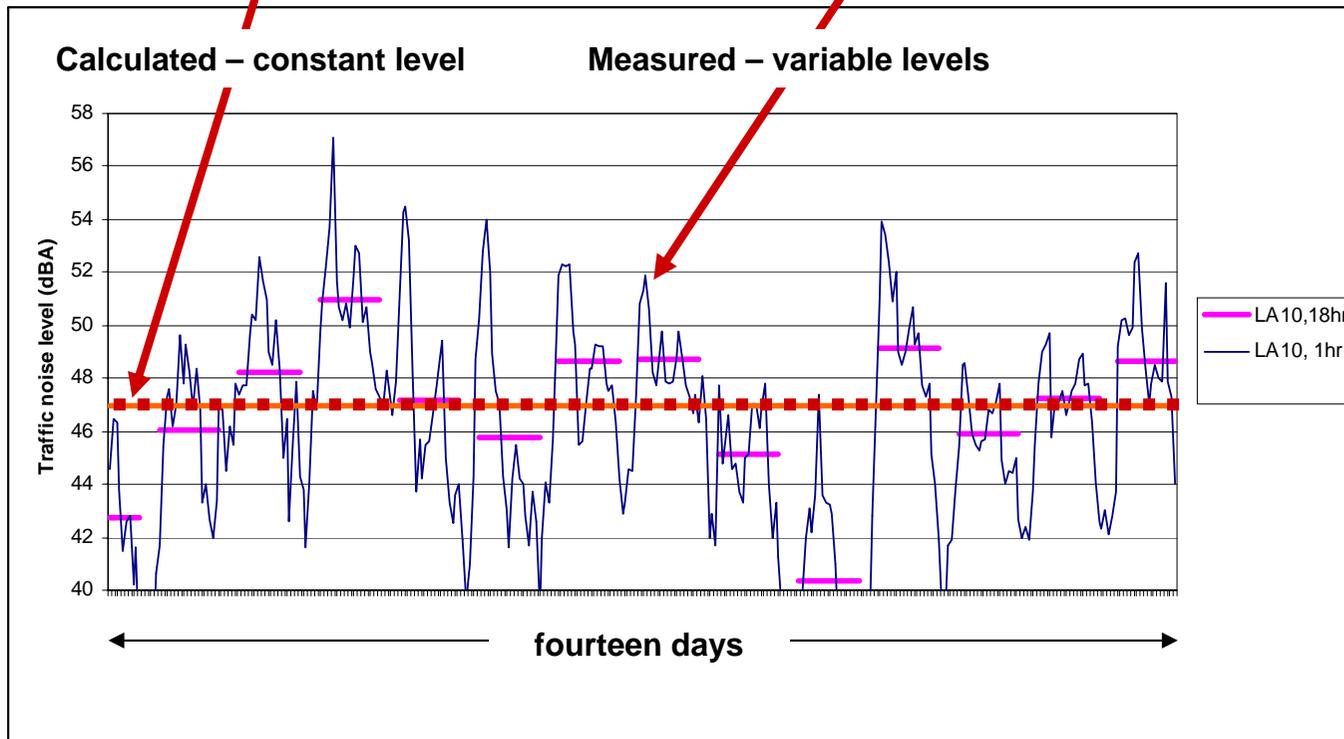
Need to differentiate between …

- variability

- uncertainty

- risk

What is the risk?

What if the 'wrong' decision were to be made due to 'incorrect' or 'inadequate' noise data?

- health implications to the exposed population
- refusal of planning consent
- money directed towards ineffective strategic noise mitigation measures
- enforcement action against noise producer

The design and 'accuracy' requirements of any noise assessment should focus on the **RISK** associated with the outcome

What defines 'accuracy' in the context of environmental noise?
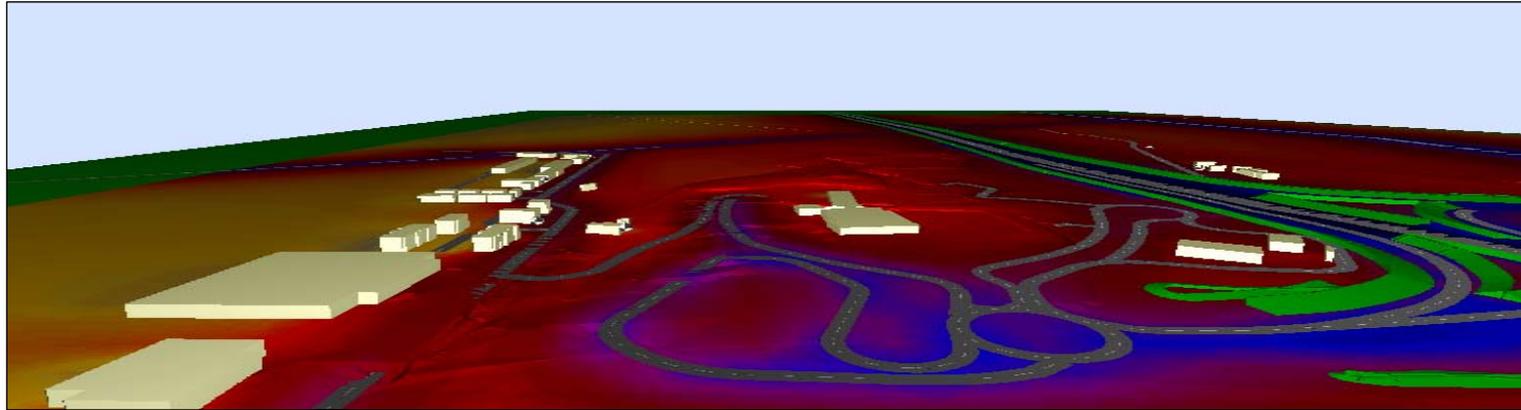

- 'accuracy' should be driven by the need to manage 'risk' to the <u>appropriate</u> degree

- 'accuracy' should <u>not</u> be driven by the desire to minimise 'uncertainty' at all costs

- 'accuracy' requirements can therefore only be defined within the context of a particular assessment

Noise level measurements

- selected to be as representative as possible of the situation under study

- practical constraints limit the number of measurements that can be undertaken

- within the accuracy limitations of the measurement system and the competency of the user, measurements provide a 'true' measure of the noise level that existed under the specific measurement conditions

- uncertainty is introduced the moment noise data measured under one set of conditions is used to infer the noise environment at some other location or time

- the final intended use and 'quality' requirements of noise data is a key factor in driving the design of the measurement survey
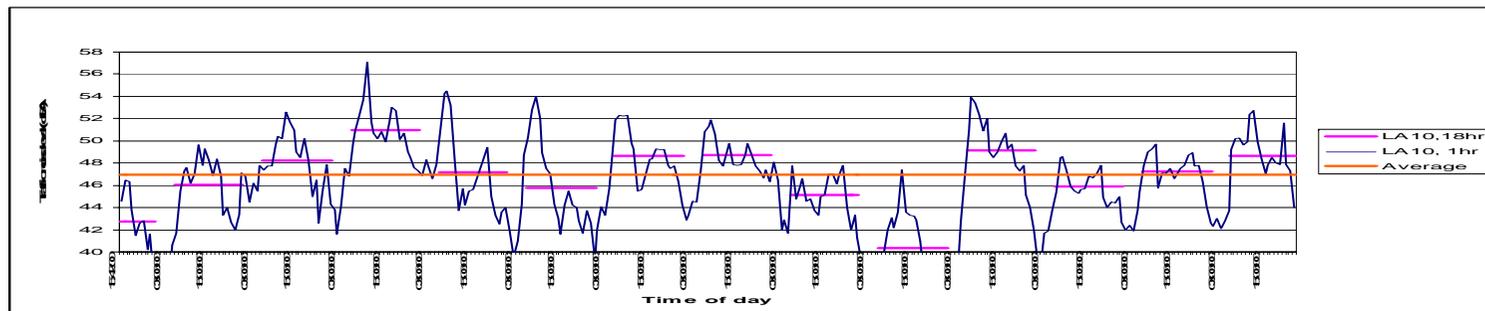
Objective indices for measured sound levels …
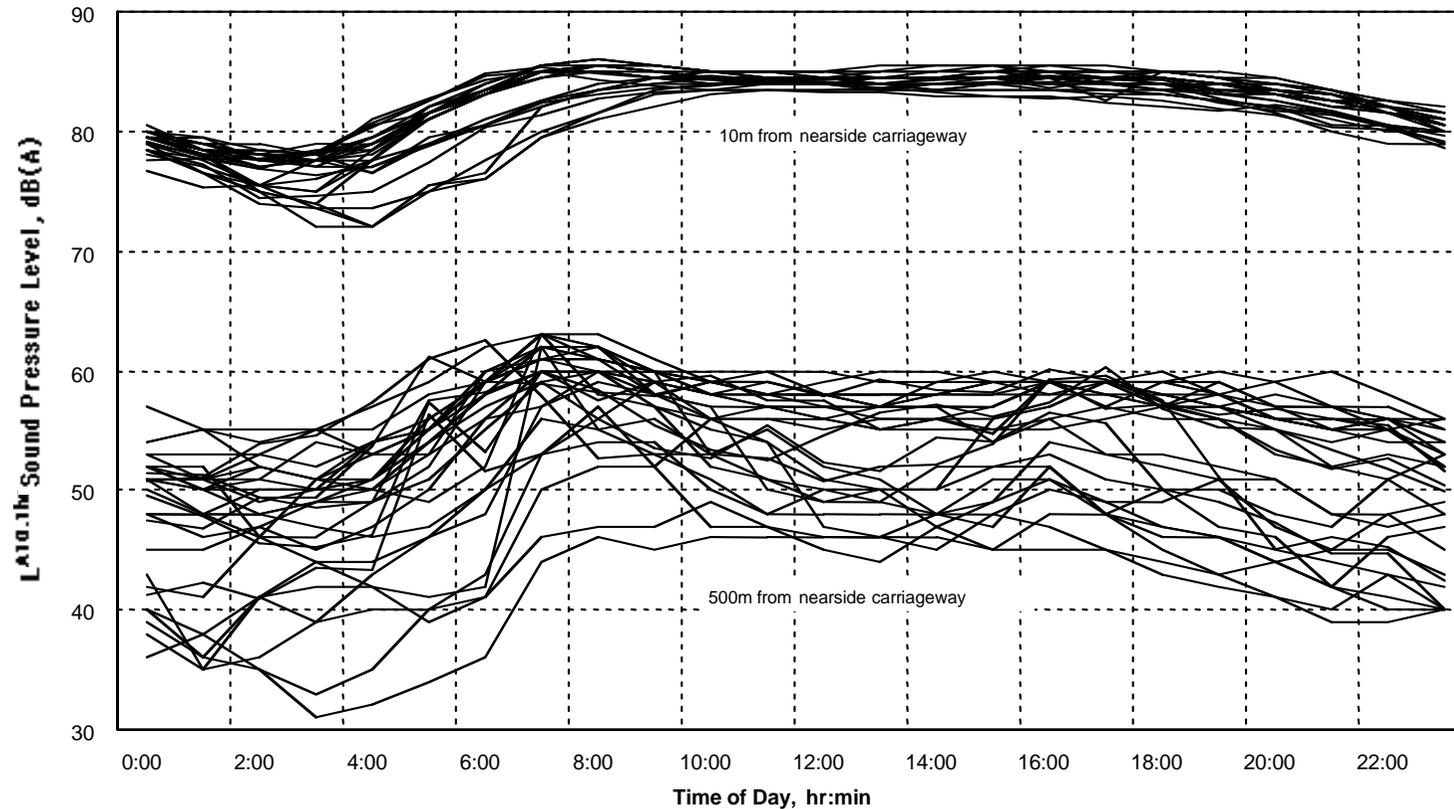
- traffic noise is usually assessed using the $L_{A10,T}$ noise index

- background noise is usually assessed using the $L_{A90,T}$ noise index

- the 'universal' index is the $L_{Aeq,T}$, sometimes in modified form, e.g. L_{den}

- all are 'A'-weighted to account for the frequency sensitivity of human hearing

L_{A10} = 62dBA)

L_{Aeq} = 58dBA)

L_{A90} = 38dBA)
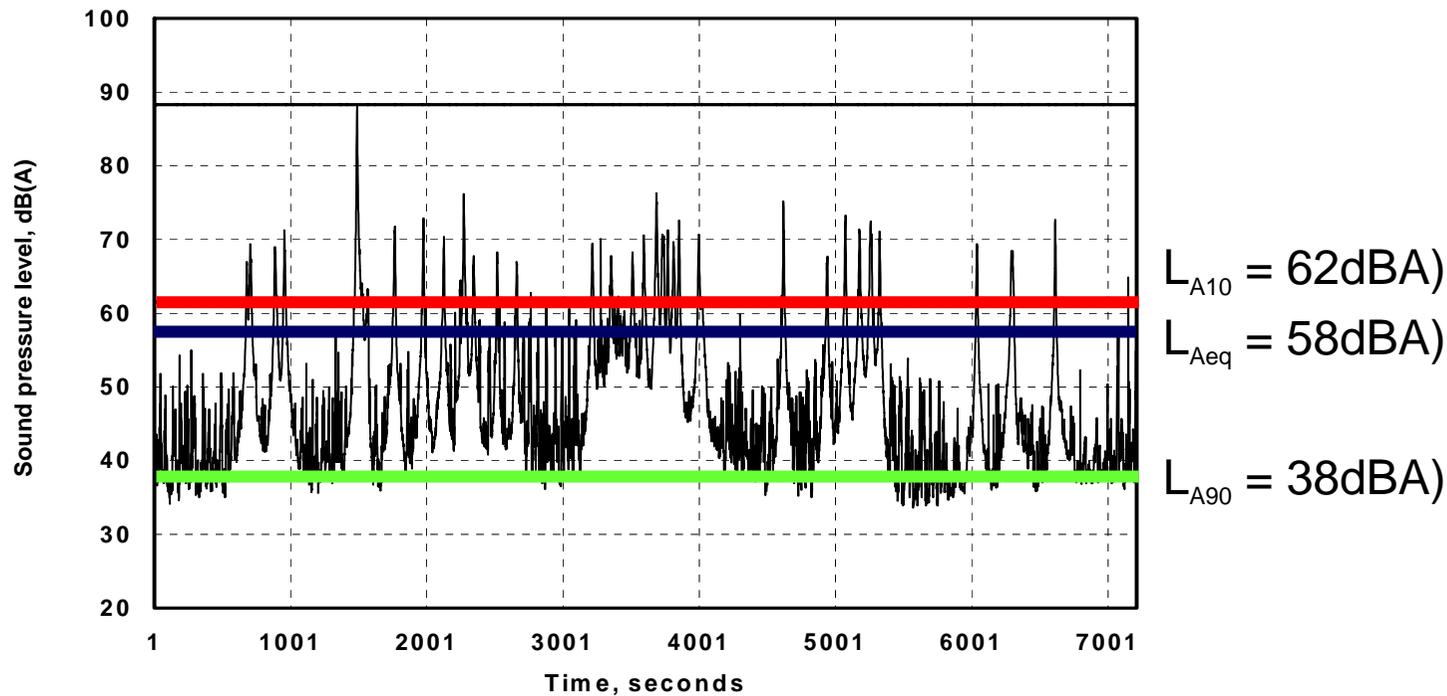
Hour to hour variability of noise levels

e,g. hourly traffic noise levels are averaged over the 18 individual $L_{A10,1hr}$ levels obtained over the period 06:00 to 24:00

Day to day variability of noise levels
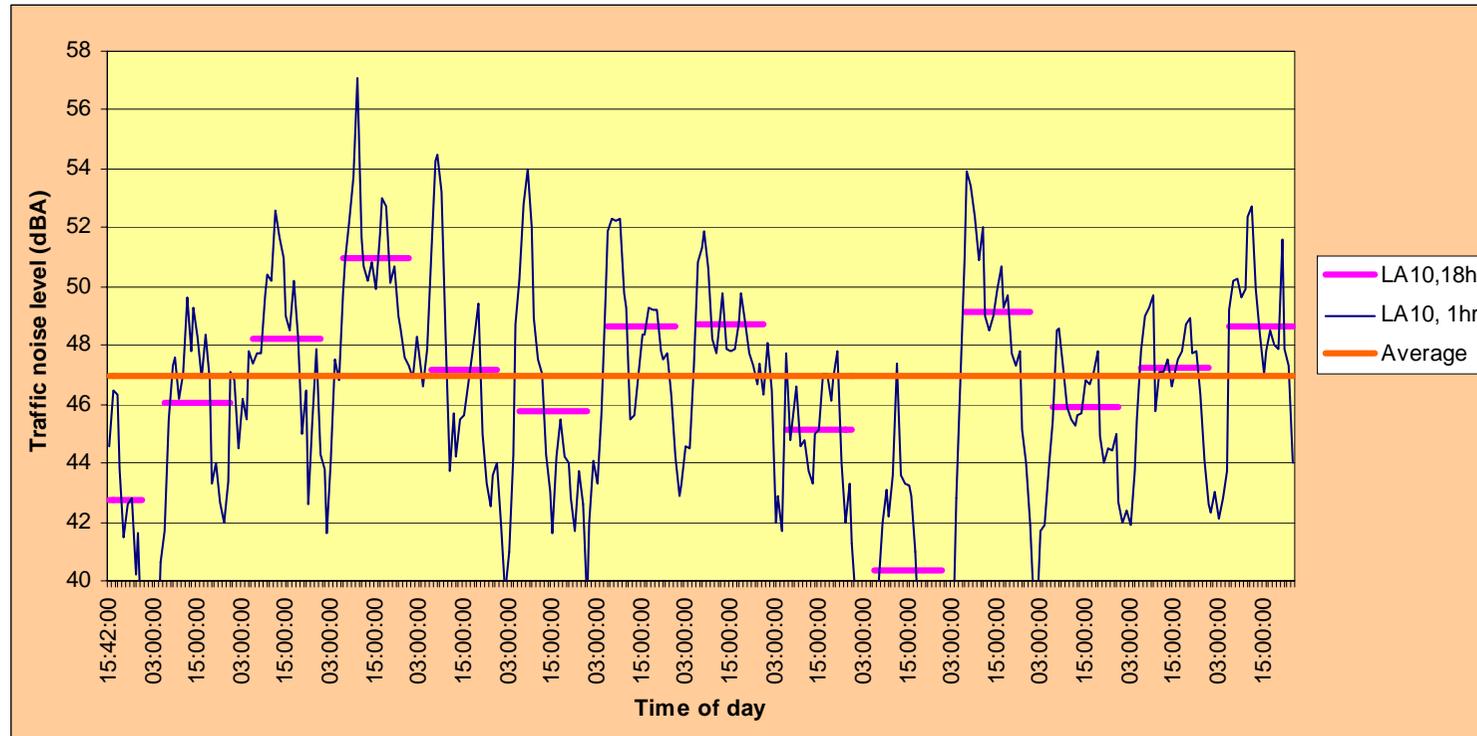
- despite extensive averaging, variability in environmental noise levels still exists from day to day

- results in problems if using measurements for e.g. compliance testing

- EU proposed solution is to take annual averaged levels to establish population exposure

Noise level calculations
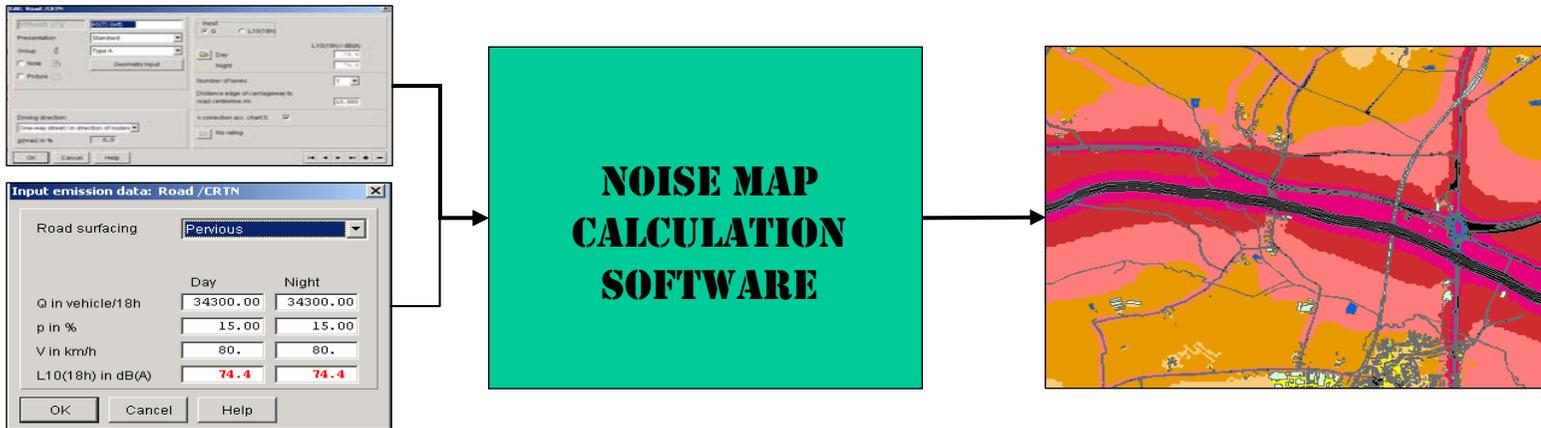
Input data

- represents a specific set of conditions

- general aim is to be representative of the 'real world' scenario

- may or may not account for all potential sources of noise in an area

Noise mapping software

- implements user selectable noise calculation algorithms

- may be differences between same algorithms implemented in different software packages

- also may be differences due to calculation simplifications and/or speed enhancements

- outputs also reliant on user competence

Output results

- predictions can be produced to cover extensive areas

- each result based on one specific set of input conditions

- spatial resolution can limit 'accuracy'

- final intended use of noise output data is a key factor in driving the input requirements (e.g. absolute levels or difference levels for strategic assessment)

Calculating transmission effects

Broad range of prediction algorithms of varying complexity

a) Engineering methods – algorithms widely employed for practical noise assessments - include ISO 9613, CONCAWE and the recently developed HARMONOISE integrated method

b) Scientific methods - mostly employed for specialist/research applications – range from simple ray tracing through to complex numerical methods based on direct solutions of the wave equation

Engineering methods of calculation

- engineering methods tend to be empirically based and approximate average conditions.

- offer the benefit of rapid calculation times and reliable prediction of overall noise levels for relatively simple noise sources in environments of limited complexity

- generally only relate to total A-weighted noise levels over an average range of meteorological conditions

- potentially significant inaccuracies for frequency analysis, short term meteorological conditions, and more complex topographies

Scientific methods of calculation

- generally based on solutions of the wave equation – ranging from simplified analytical solutions (simple ray tracing) through to direct solutions such as the Parabolic Equation

- possess ability to provide highly accurate representation of propagation effects for individual frequencies in certain conditions

- provided the basis for the 'reference models' used to validate engineering methods

- output results only as good as the 'accuracy' of the input parameters (e.g. time and distance dependent meteorological conditions along whole of transmission path)

Narrow angle parabolic equation calculations for upward refraction
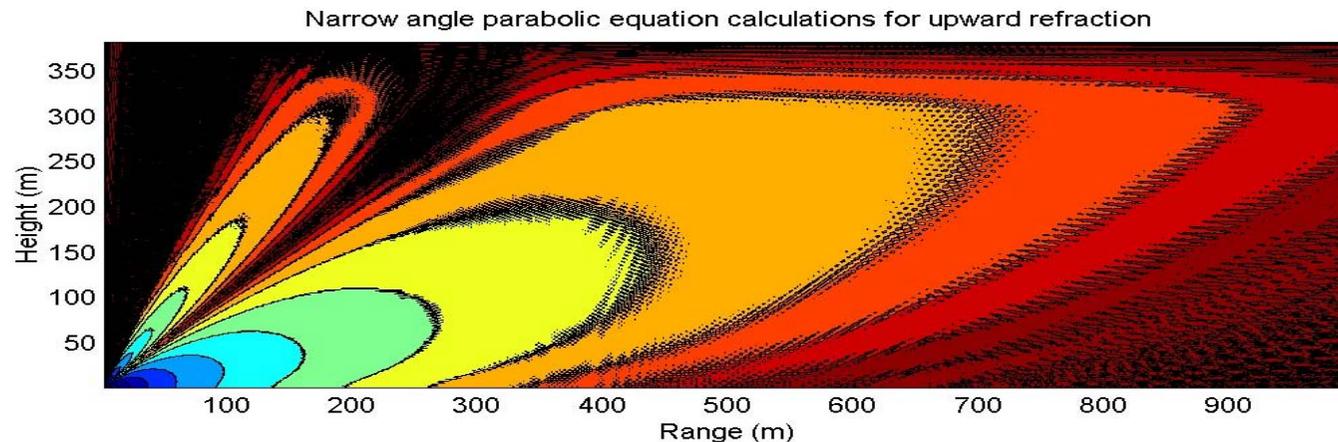
Conclusions - why undertake an environmental noise assessment?

To inform the outcome of some decision making process …

- research
- strategic planning
- complaint resolution
- specification of noise control measures
- compliance testing
- etc. ……

Conclusions - can noise data help?

- the decision making process to be informed must have some 'target' outcome

- would a knowledge of noise assist in the outcome of the decision making process

- noise may be one of many factors affecting the potential outcome, compared with the other controlling factors is noise a significant factor?

- could spatial and/or temporal variability of the sound field under study introduce significant risk in the assessment?

- the risk associated with an 'incorrect' outcome decision must drive the design of any noise assessment strategy from the outset

- causes of variability must be understood and quantified to the <u>appropriate</u> <u>degree</u> to control uncertainty <u>within</u> <u>the</u> <u>context</u> of the risk associated with the particular decision being informed

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