

# National Physical Laboratory Underwater Noise

## Learning Lessons from Air Acoustics

23<sup>rd</sup> May 2005

Andrew Bullmore

([andrewbullmore@acoustics.hoarelea.com](mailto:andrewbullmore@acoustics.hoarelea.com))



# Why do we want to hear sound ?

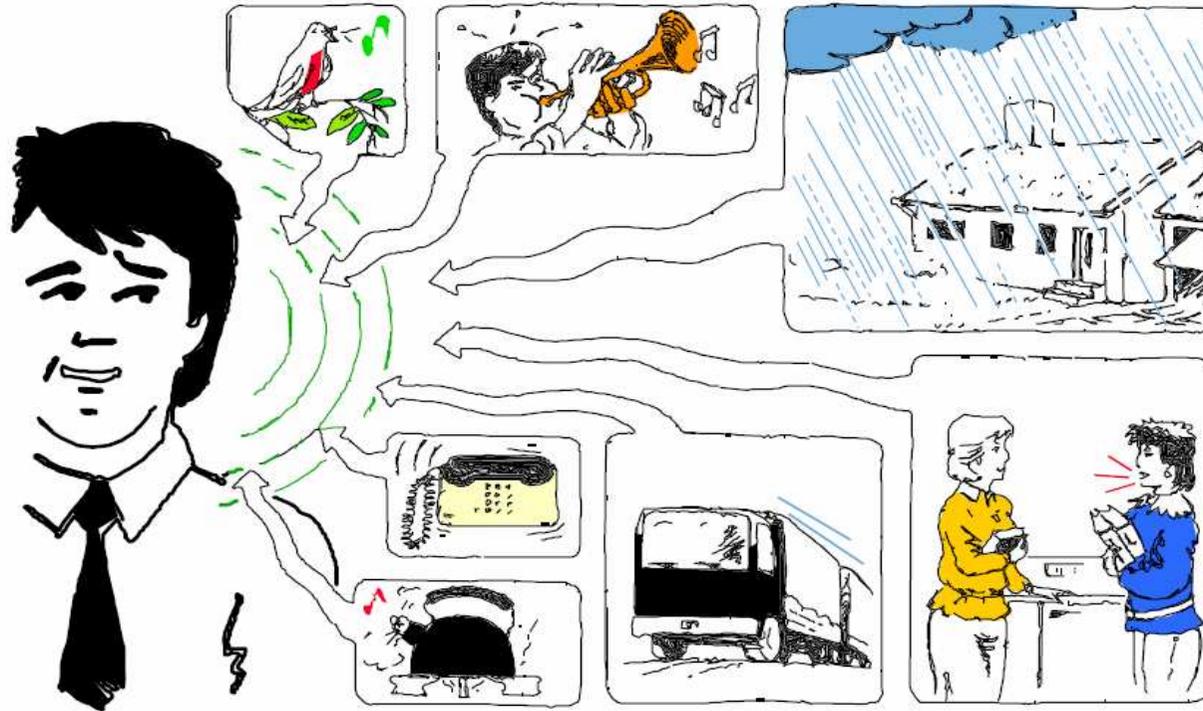


Image courtesy Briel & Kjaer

- warns of danger
- provides information on surroundings
- allows us to communicate and learn
- enjoyment of recreational sound (music)

# Why do we not want to hear noise ?

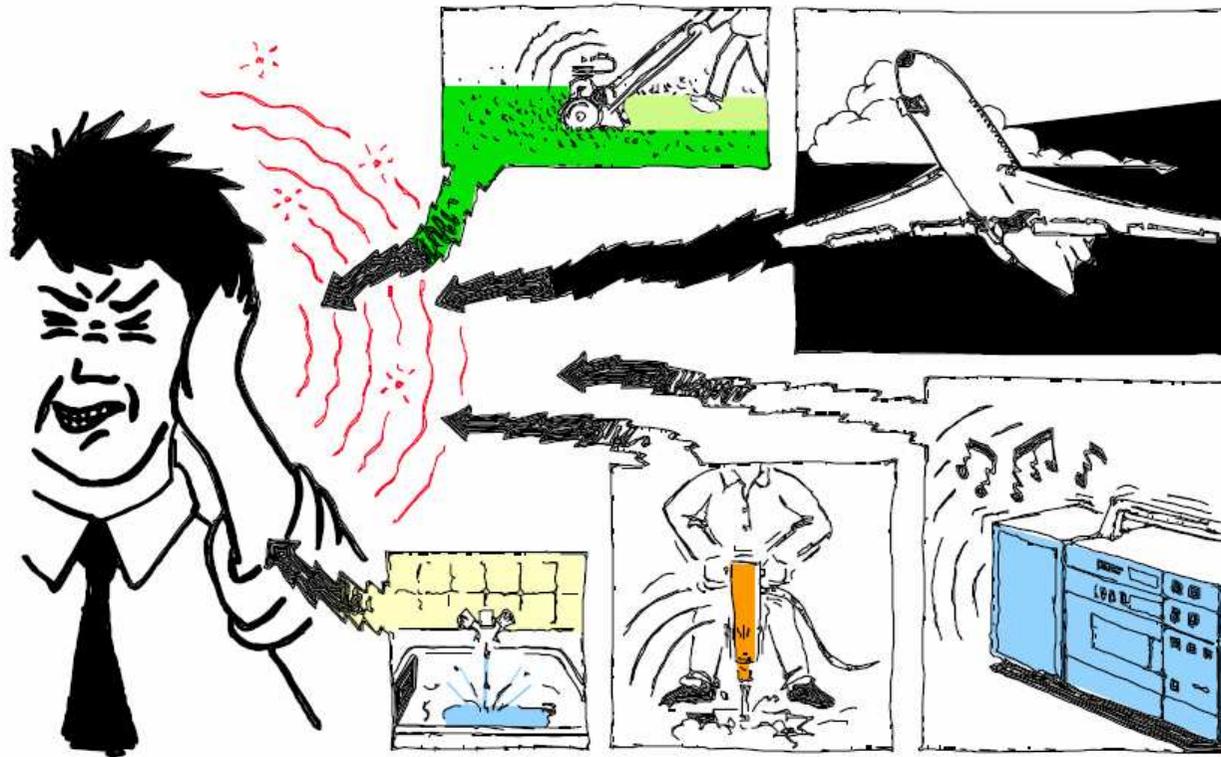


Image courtesy Bruel & Kjaer

- lowers quality of life
- causes annoyance
- interferes with work and ability to learn
- damages health

# When does sound become noise ?



Image courtesy Bruel & Kjaer

- 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

# Potential adverse effects of noise ...

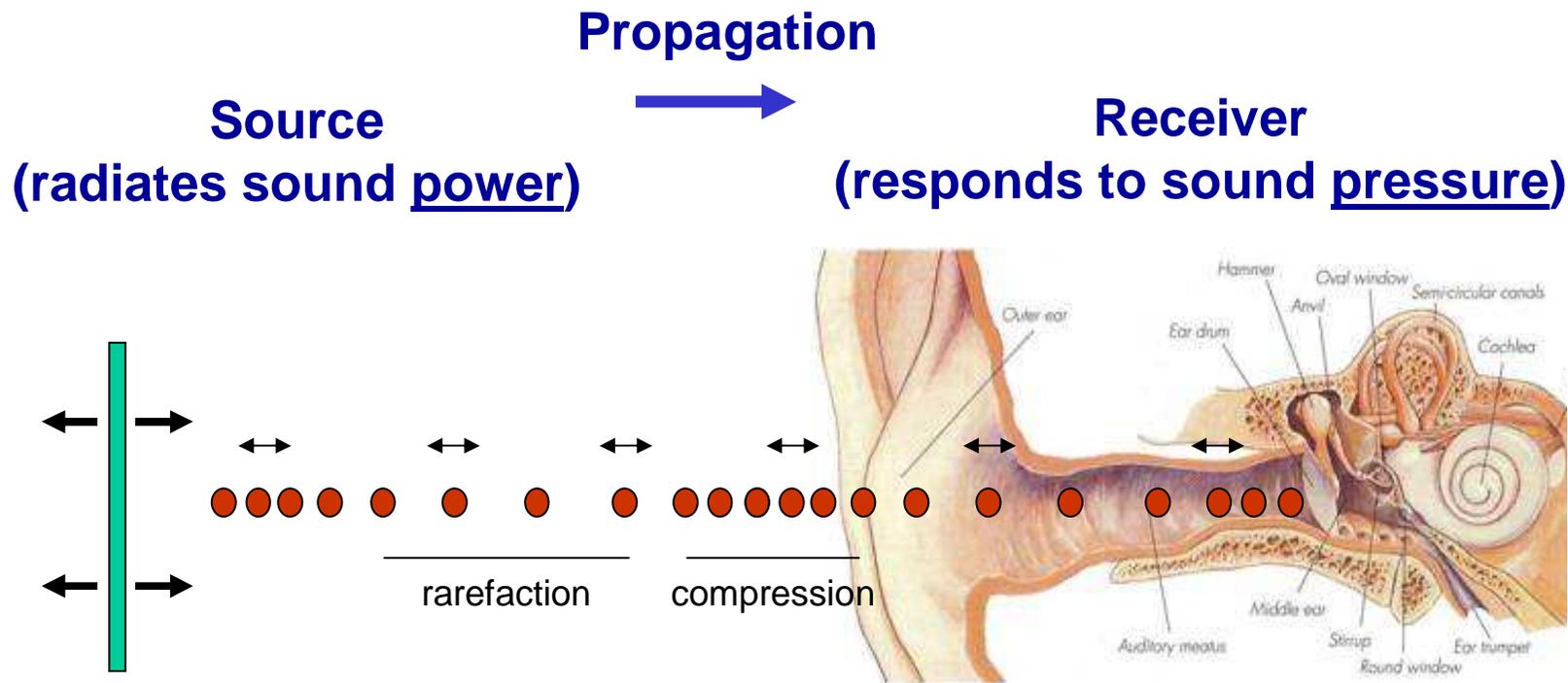
**very high noise level**

- physical damage to structures
- direct physical damage to humans (e.g. irreversible hearing damage)
- secondary adverse health effects (e.g. stress, increased blood pressure, etc.)
- activity interference (e.g. speech, sleep, work, relaxation, etc.)
- annoyance

**lower noise level**

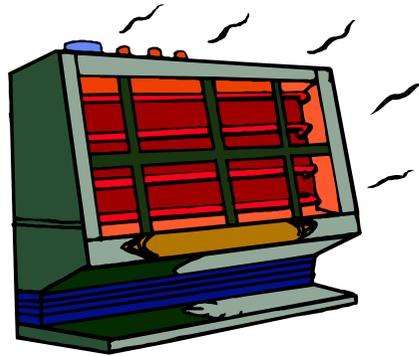


# Physically, what is sound ?

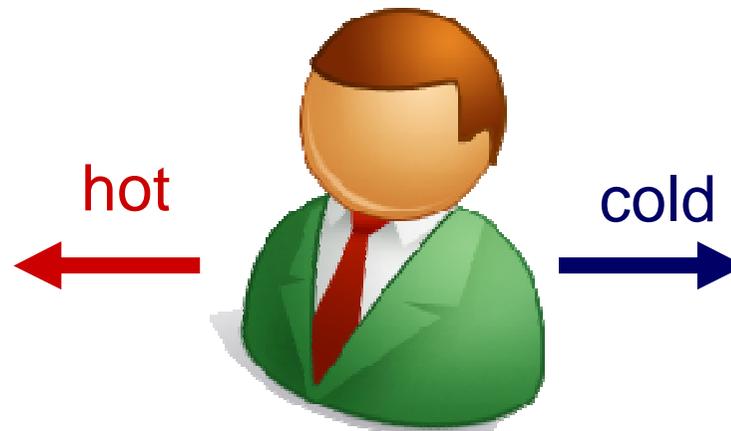


**SOUND** - a regular and ordered oscillation of air molecules about their equilibrium positions

# Sound Power vs Sound Pressure



source radiates power  
(function of source)



receptor feels heat  
(function of surroundings)

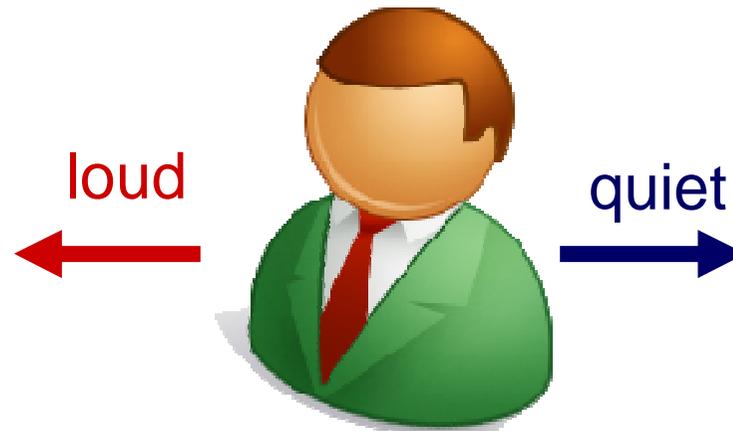
# Sound Power vs Sound Pressure



source radiates sound power  
(function of source)



standards for quantifying  
source strengths typically  
based on sound power

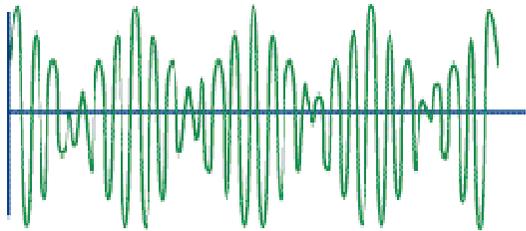


receptor responds to sound pressure  
(function of surroundings)

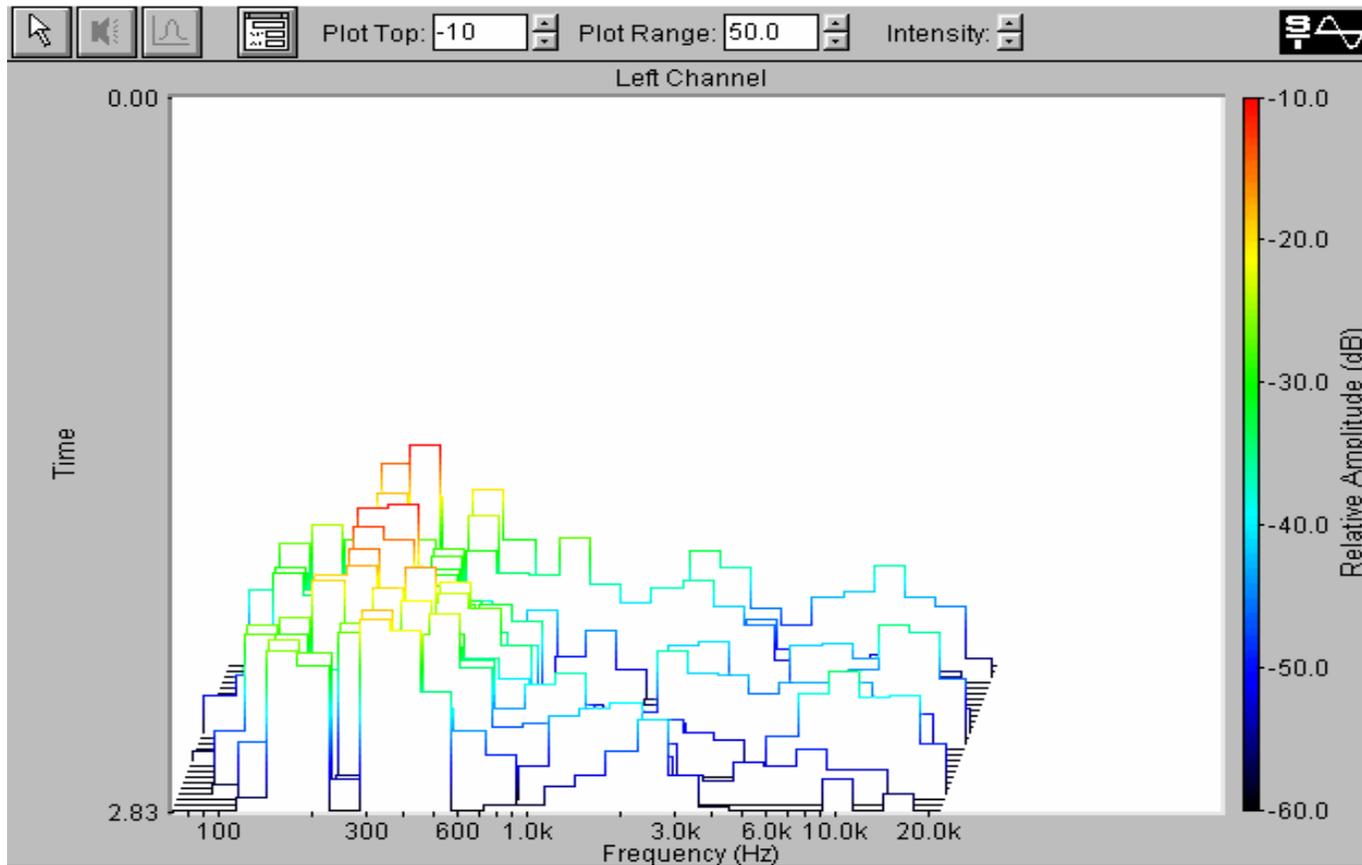


standards for assessing  
impact typically based on  
sound pressure

# How do we interpret sound ?



- loudness (amplitude)
- pitch (frequency)
- character (temporal variation)



# Amplitude – Sound Pressure (in Pascal, Pa)

- ear detects amplitude of vibration of air molecules
- threshold of hearing  $\sim 0.00002\text{Pa}$
- onset of pain  $\sim 200\text{Pa}$
- if absolute units of Pa were used for measurements:
  - range of number would be very large (i.e. 10,000,000 to 1)
  - also, human hearing actually responds more to fractional change in sound pressure

# Typical range of sound pressure, Pa

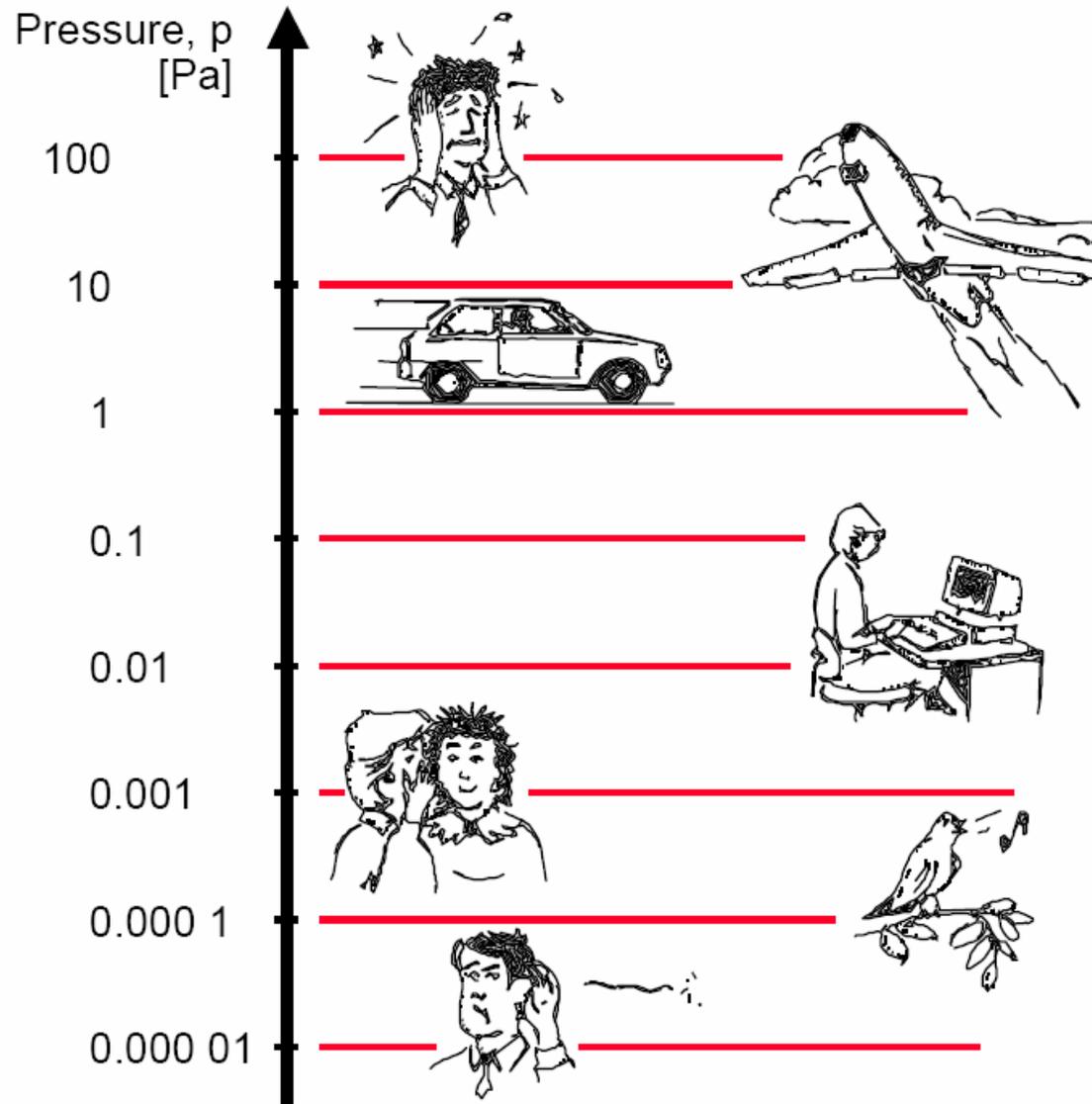


Image courtesy Bruel & Kjaer

# Sound Pressure Level (in decibels, dB)

The logarithmic 'decibel' scale corresponds more closely with the way we hear sounds .....

$$\text{SPL(dB)} = 20 \log \left( \frac{p}{p_0} \right)$$

$p$  = rms acoustic pressure in Pa

$p_0$  = rms sound pressure of a 1kHz pure tone at the threshold of hearing which is  $2 \times 10^{-5}$  Pa

# Sound pressure level (dB)

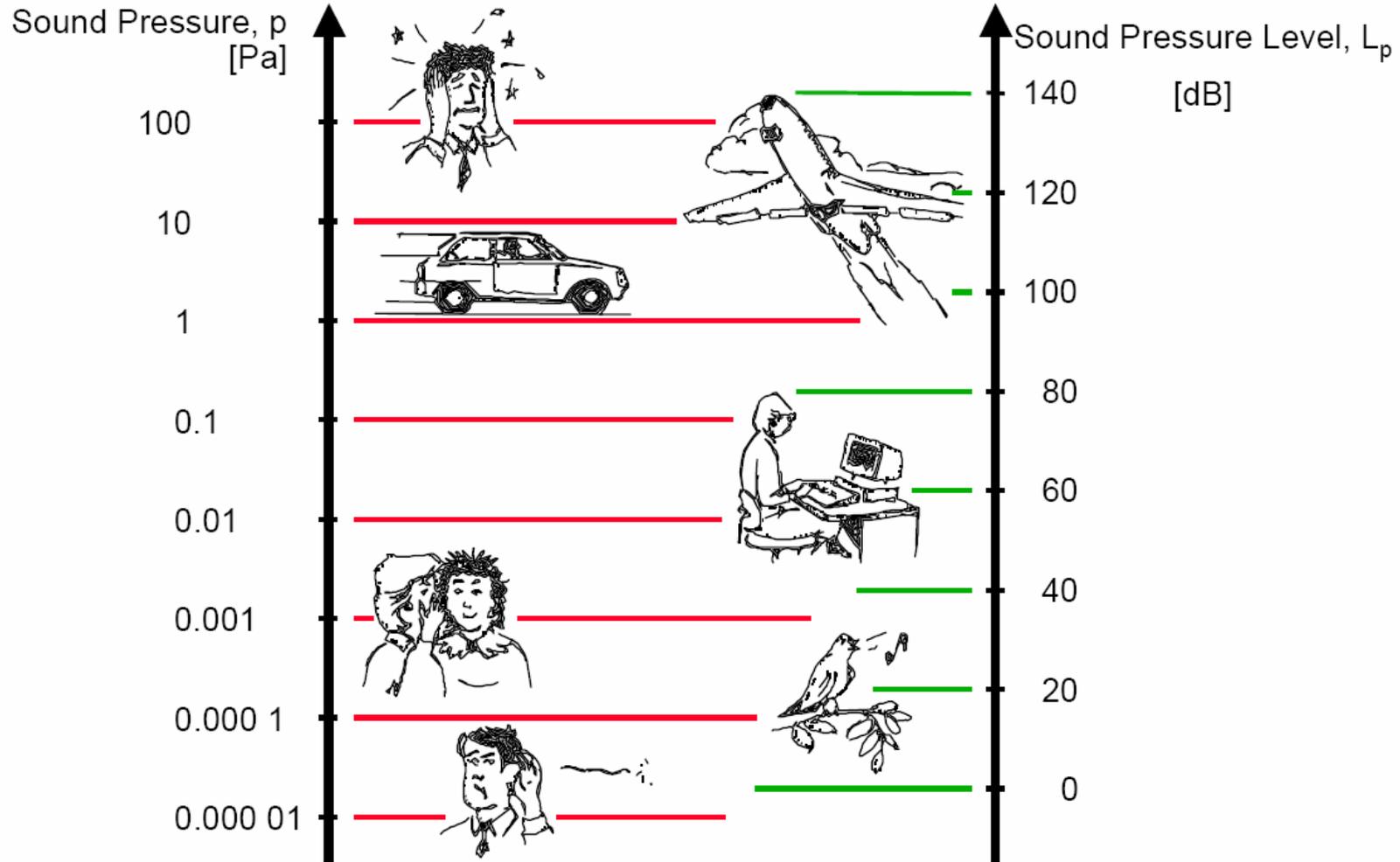
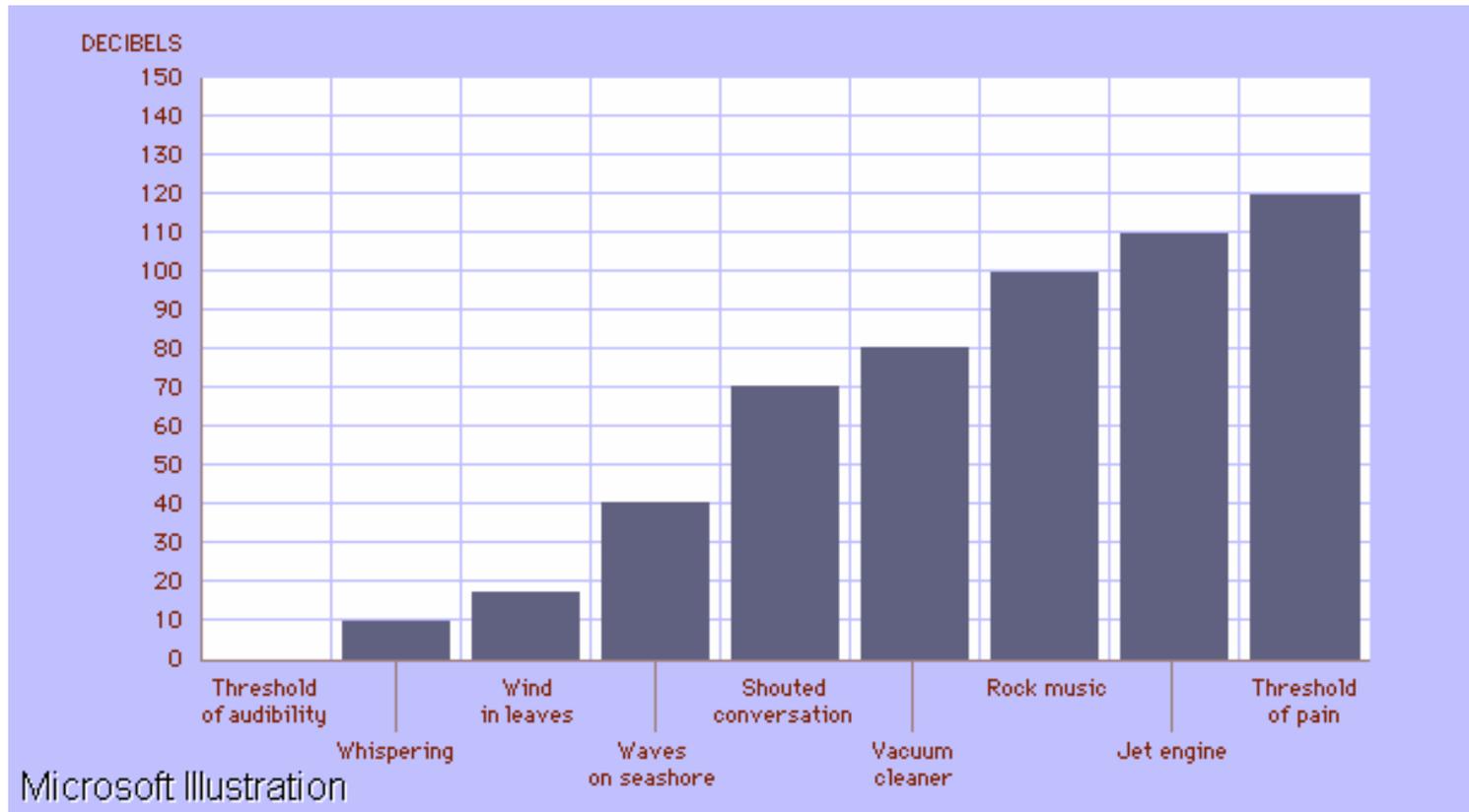


Image courtesy Bruel & Kjaer

# Subjective response to changes in SPL



0 dB → -1dB

0 dB → -5dB

0 dB → -10dB

0 dB → -20dB

# Pitch – audible frequency range (hz)

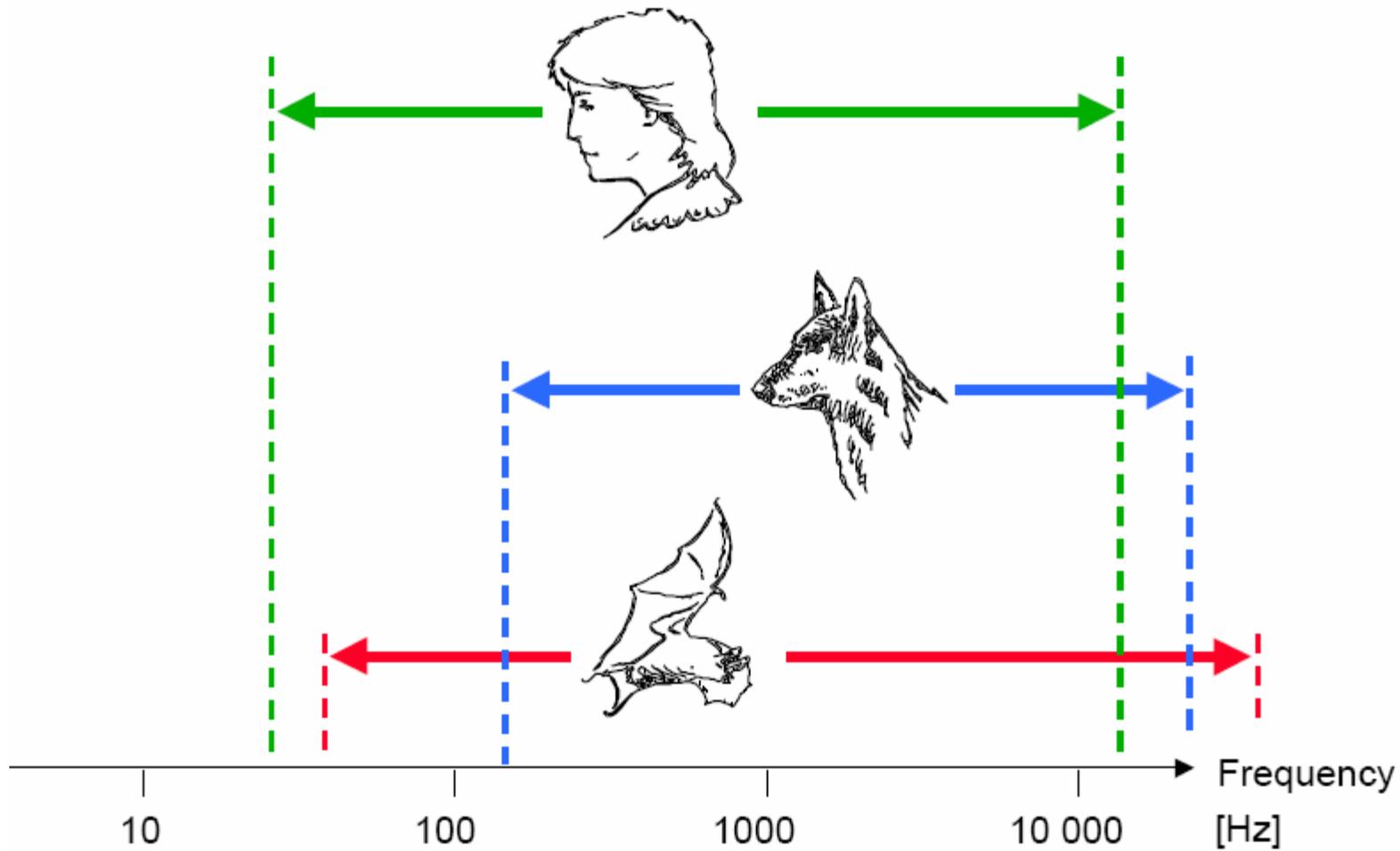
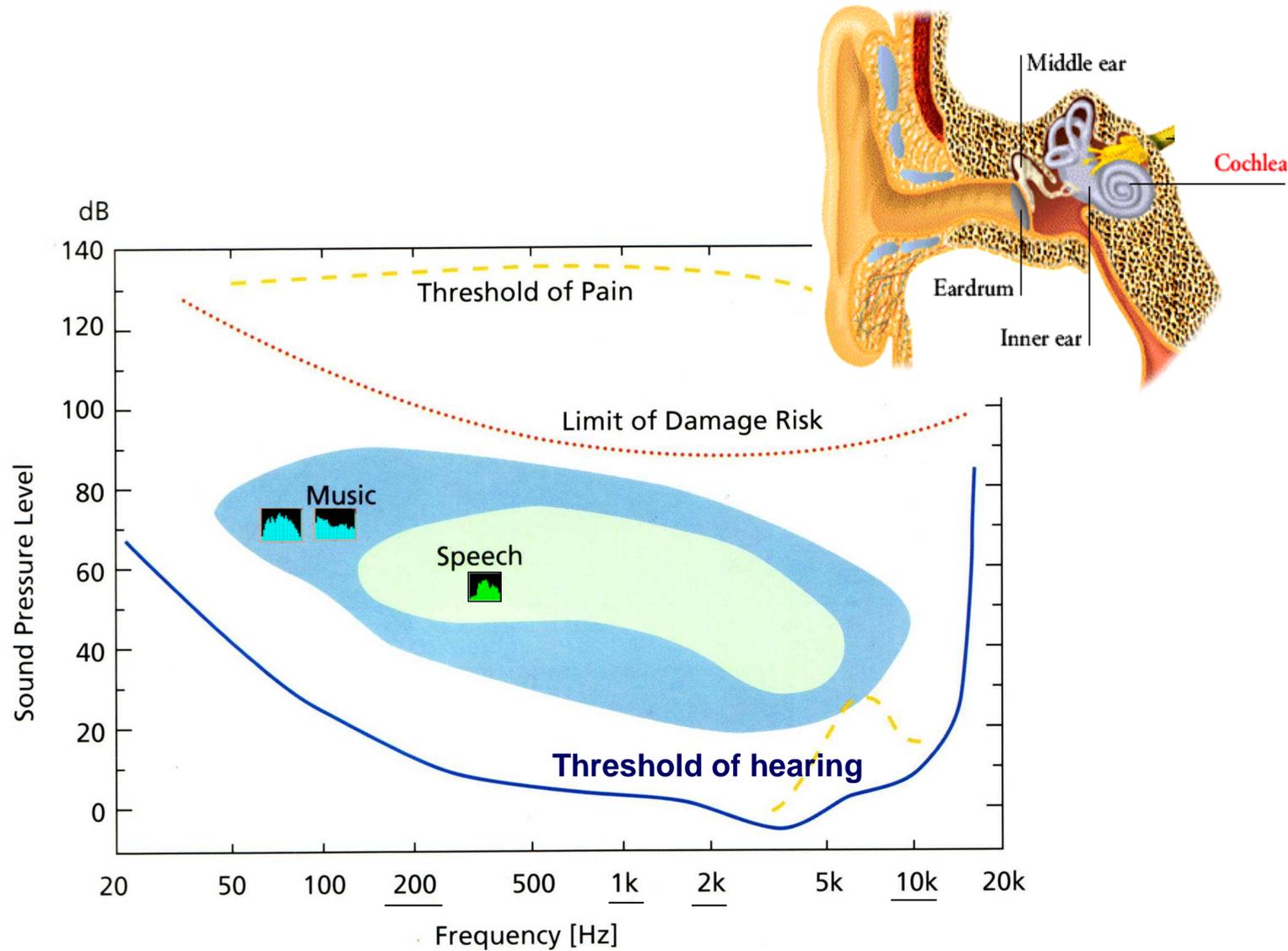
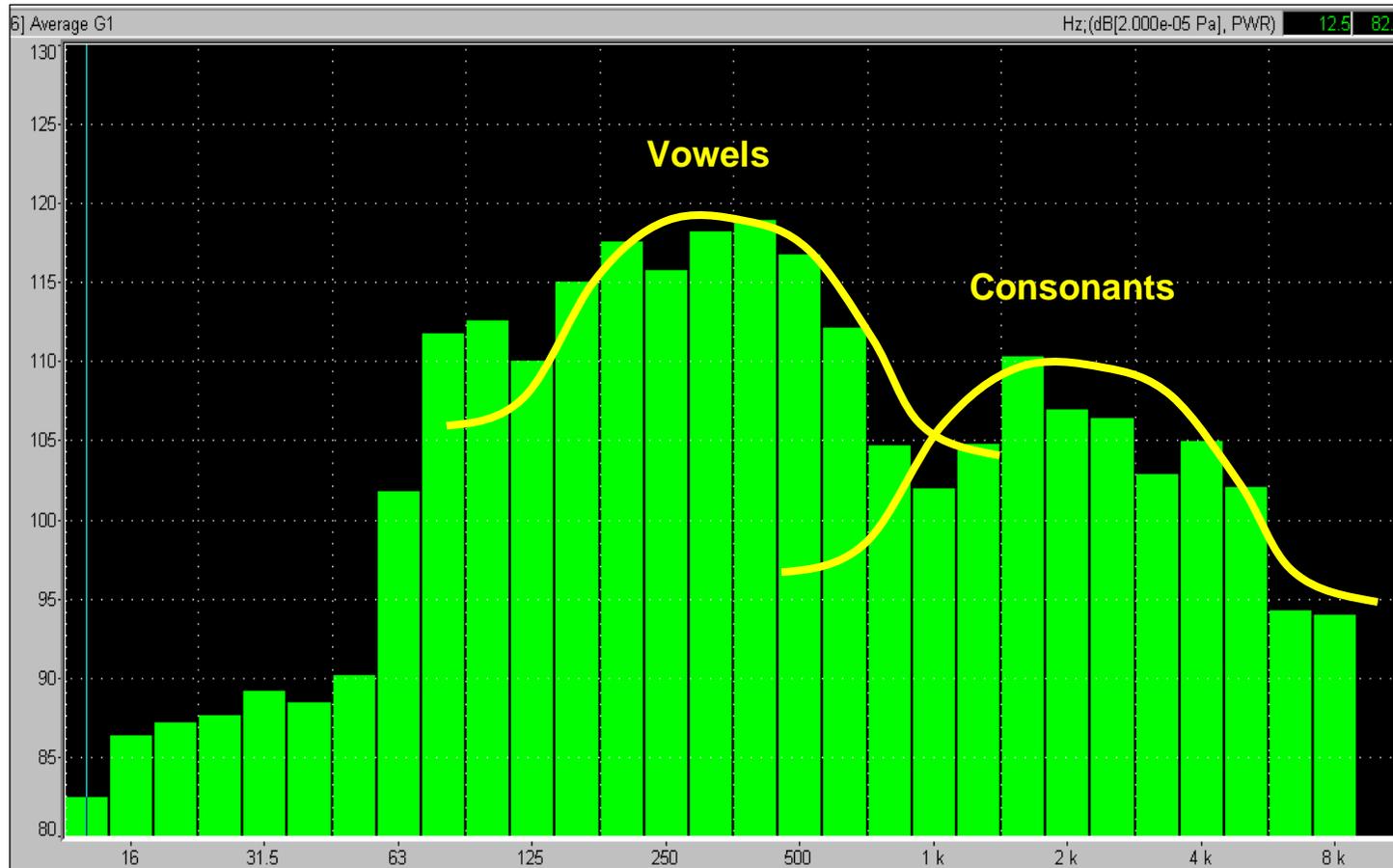


Image courtesy Bruel & Kjaer

# The human auditory field

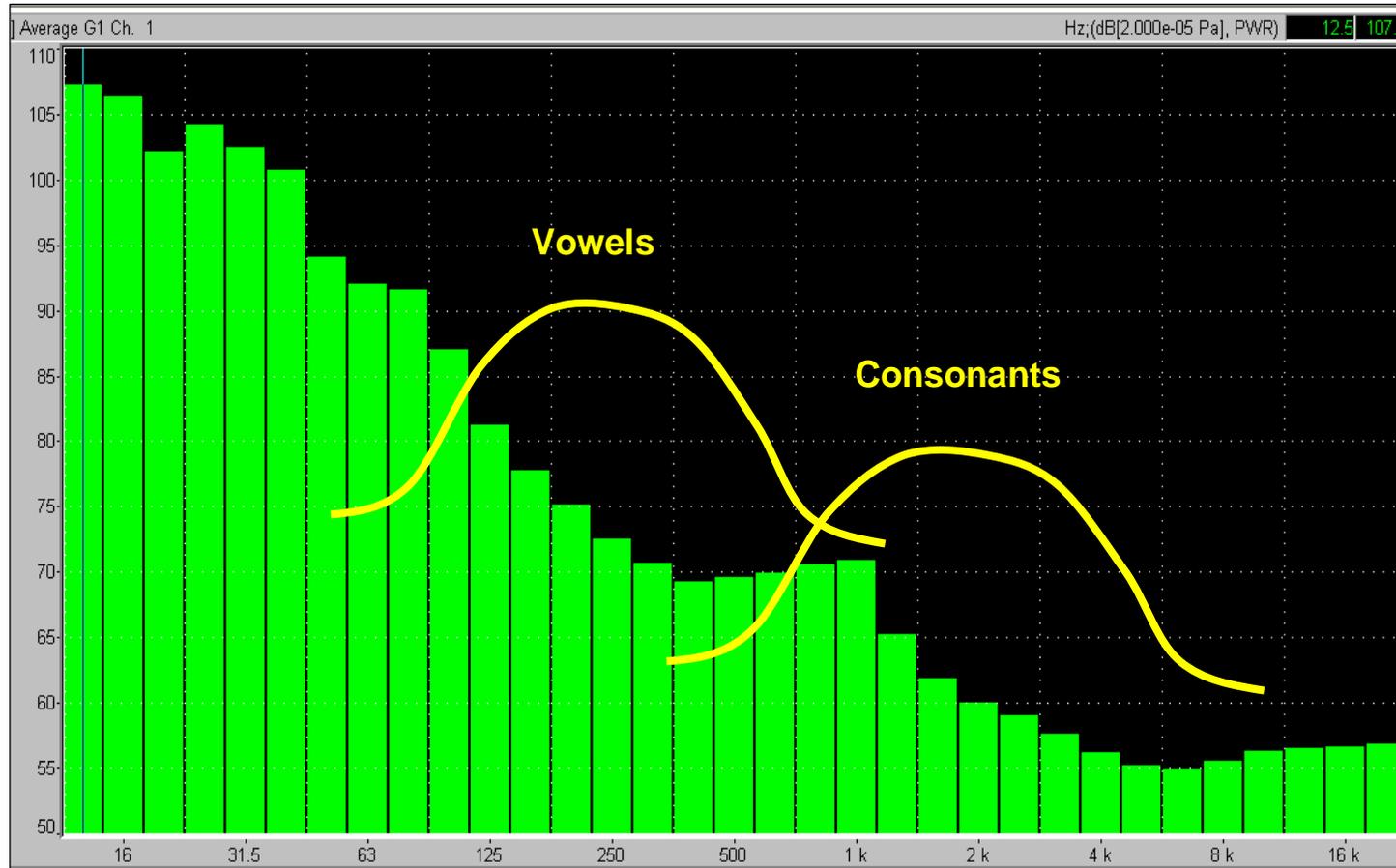


# Frequency sensitivity of the human ear



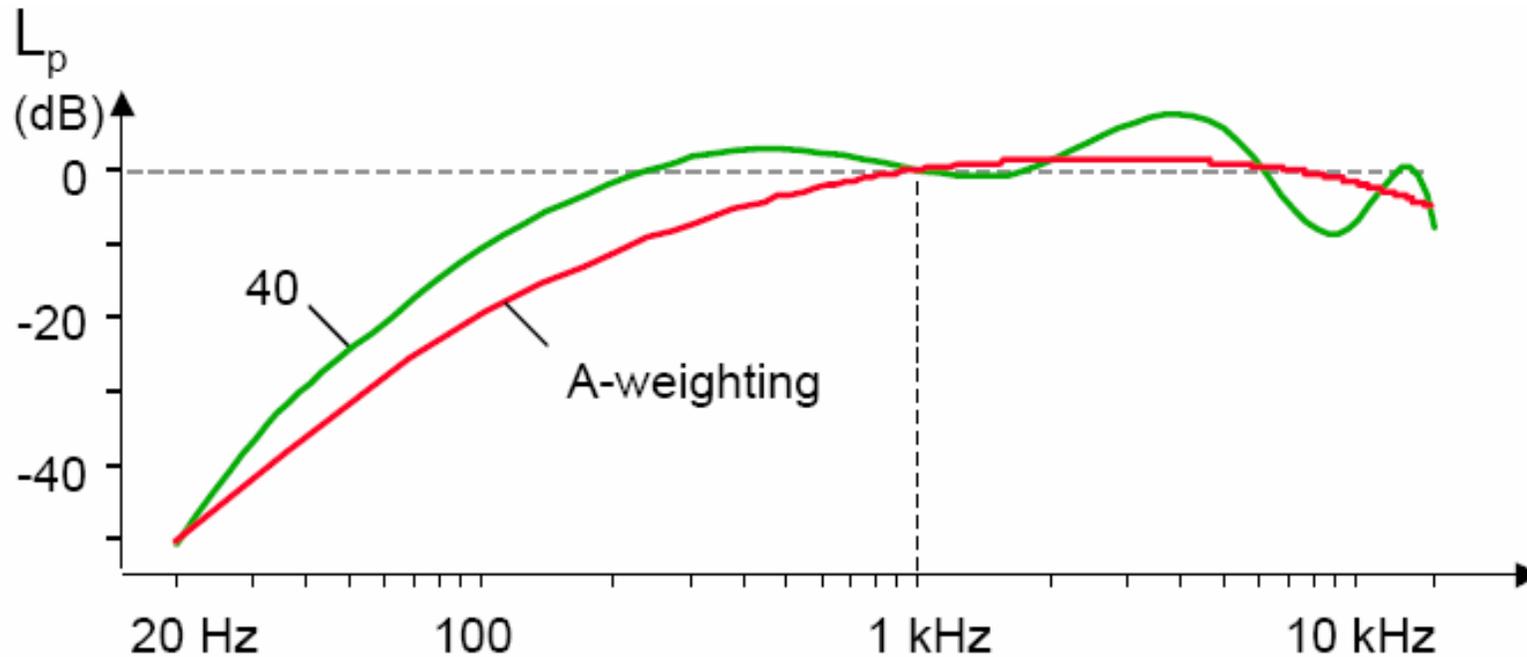
Speech frequencies

# Frequency sensitivity of the human ear

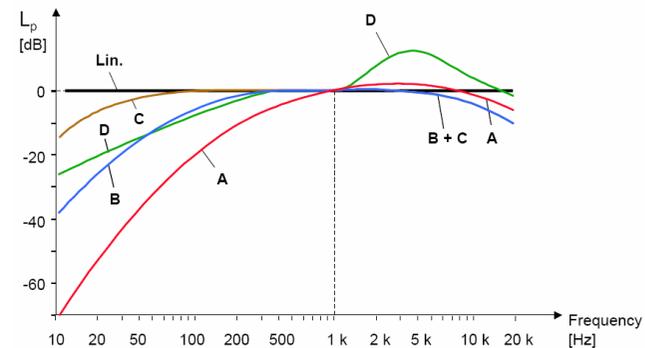
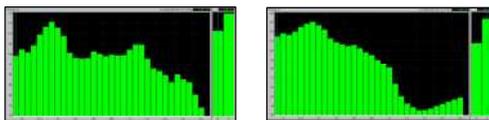


**Natural Sounds**  
(wind, waves, thunder)

# The A-weighted sound level, dB(A)



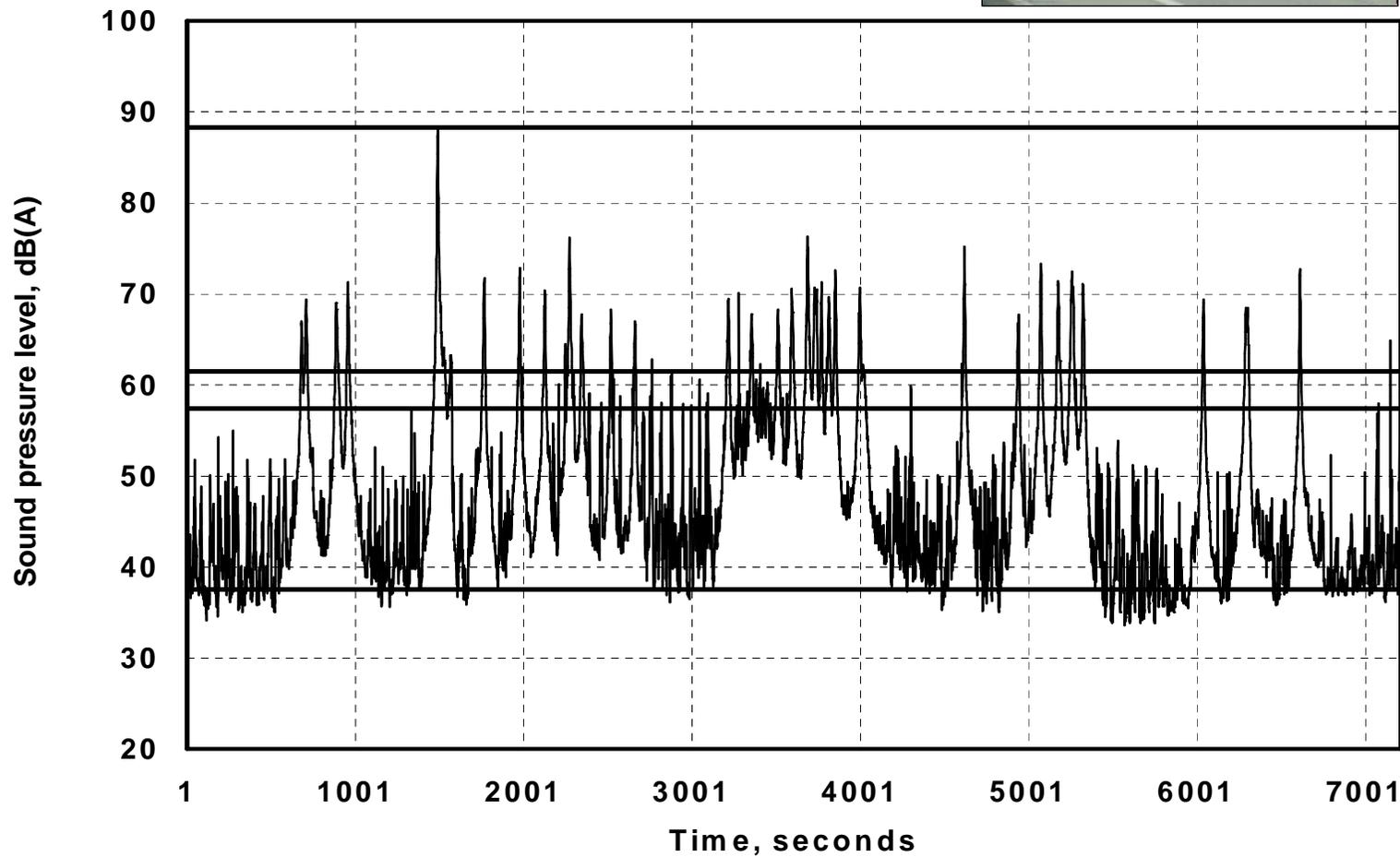
Just be aware that other frequency weightings also exist (B, C, D, LIN)



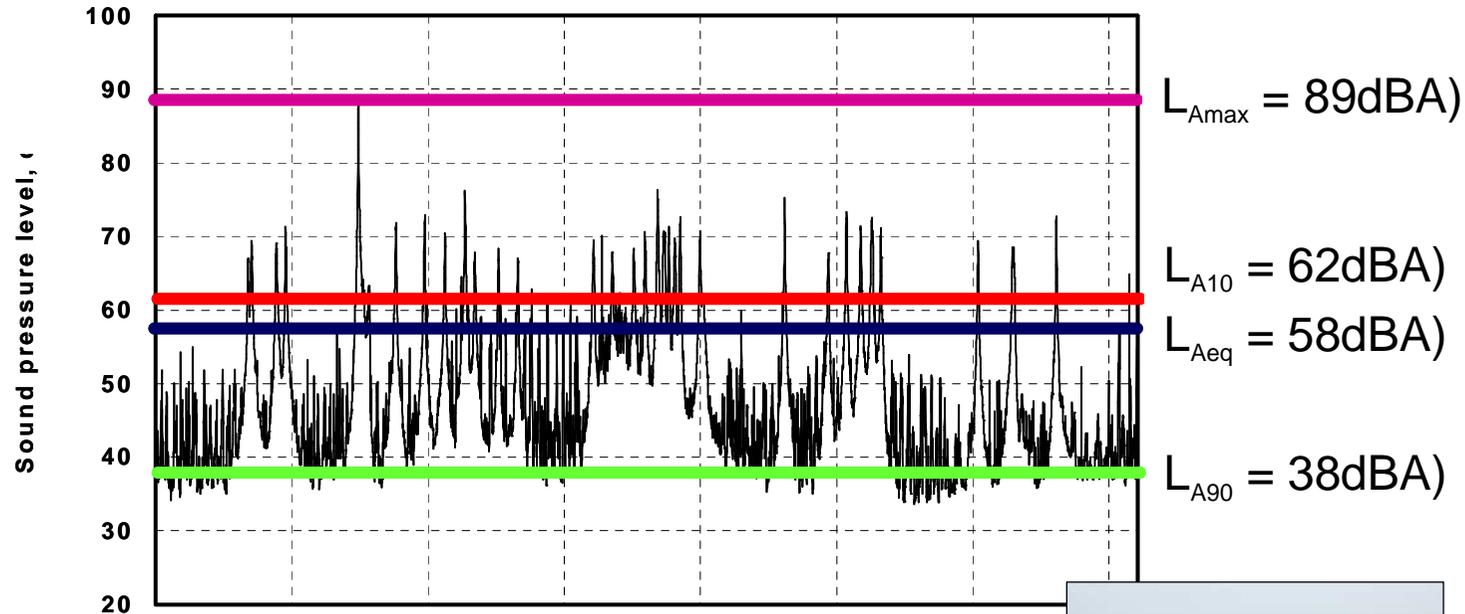
# Some typical ambient noise levels

- Remote rural area on a still ( $<2\text{ms}^{-1}$ ) night 15 to 20dB(A)
- Remote rural area on a still ( $<2\text{ms}^{-1}$ ) day 20 to 25dB(A)
- Rural area ~2km from motorway 35 to 40dB(A)
- Any area on a windy ( $>10\text{ms}^{-1}$ ) day or night  $>40\text{dB(A)}$
- 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)

**But noise in general is not constant .....**



# Objective measures of noise .....



- aim generally is to replicate the subjective response of human hearing
- measuring instruments mimic the frequency selectivity and reaction time of the ear ...



# 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?

# BEWARE - environmental noise levels are inherently variable!



- 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)

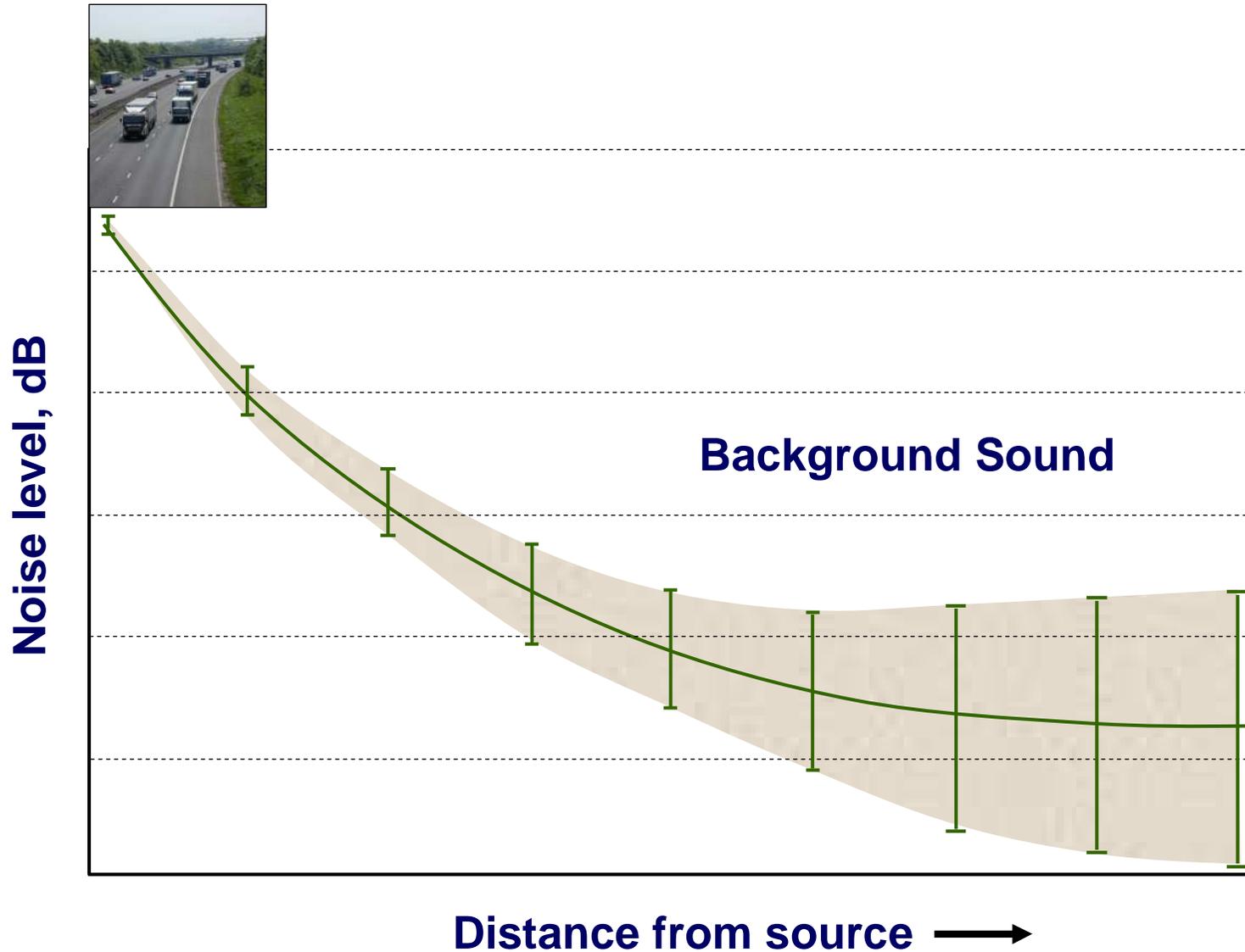
# What is the risk?

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

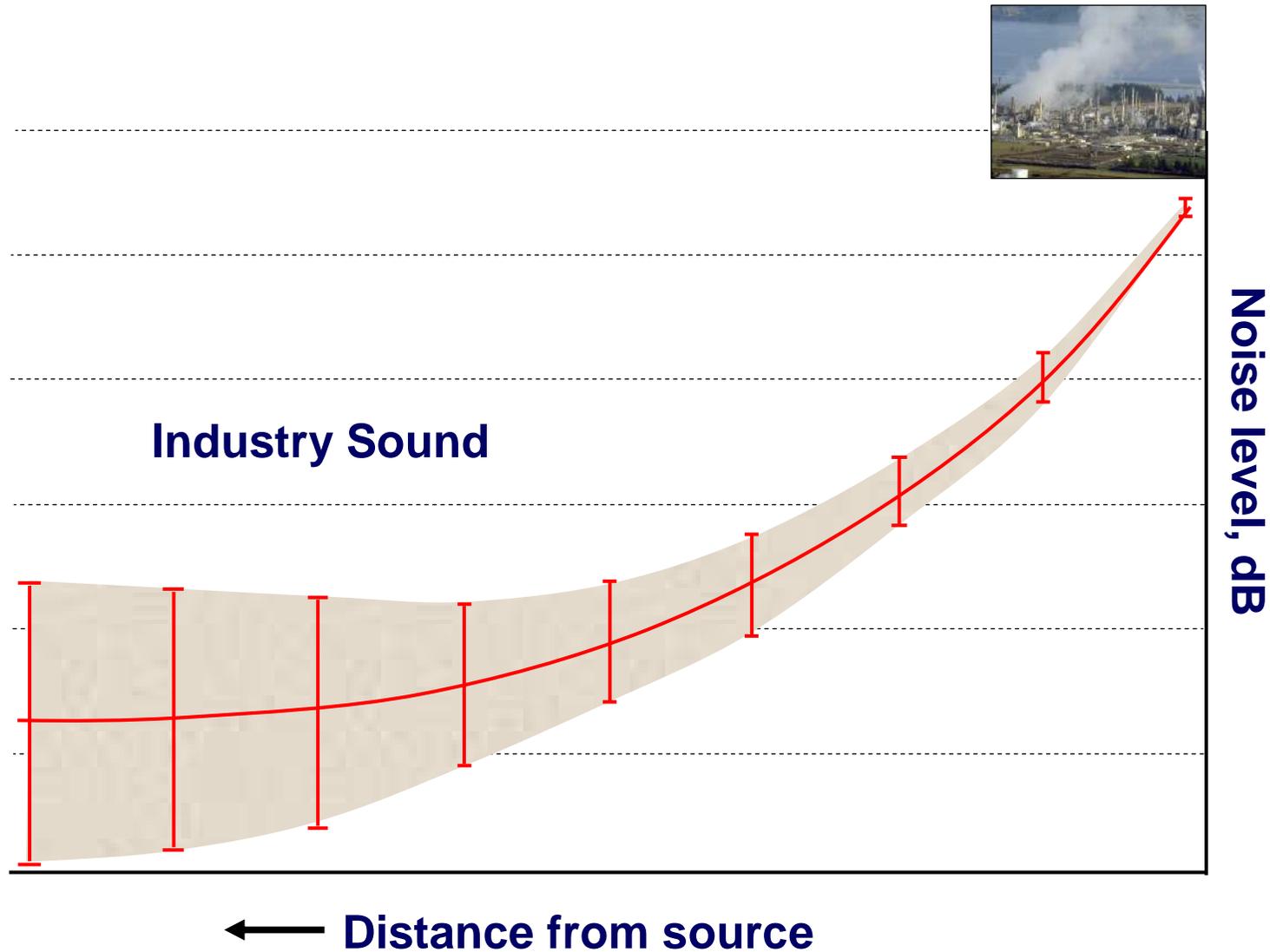
- health implications to the exposed population
- refusal of planning consent
- money directed towards ineffective strategic noise mitigation measures
- enforcement action against noise producer

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

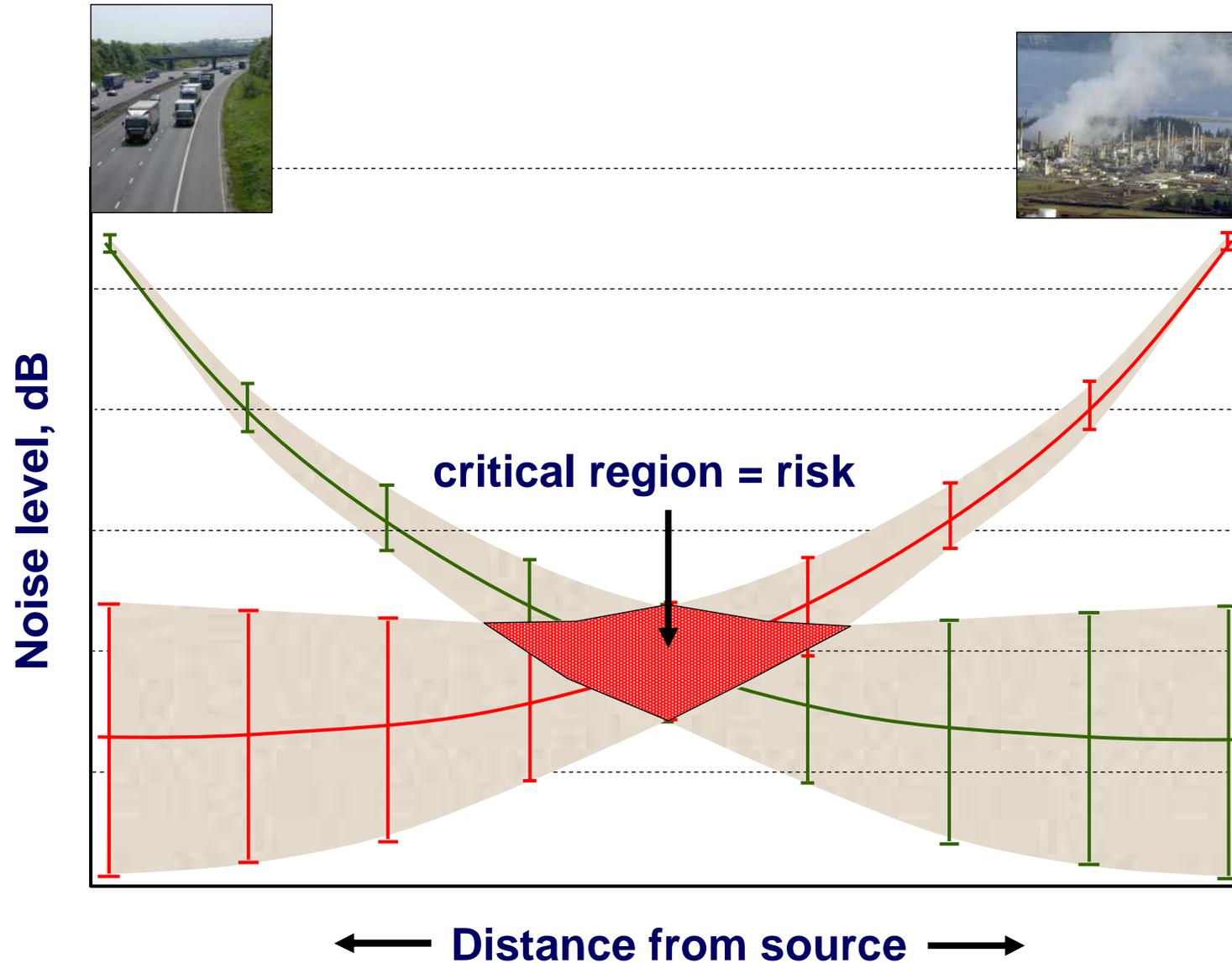
# variability – uncertainty - risk



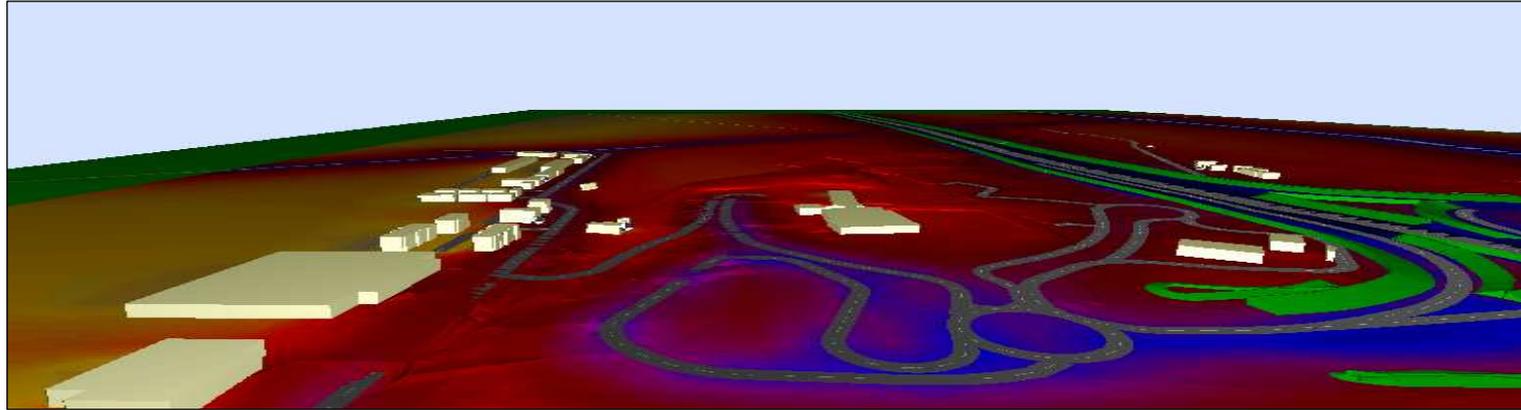
# variability – uncertainty - risk



# variability – uncertainty - risk

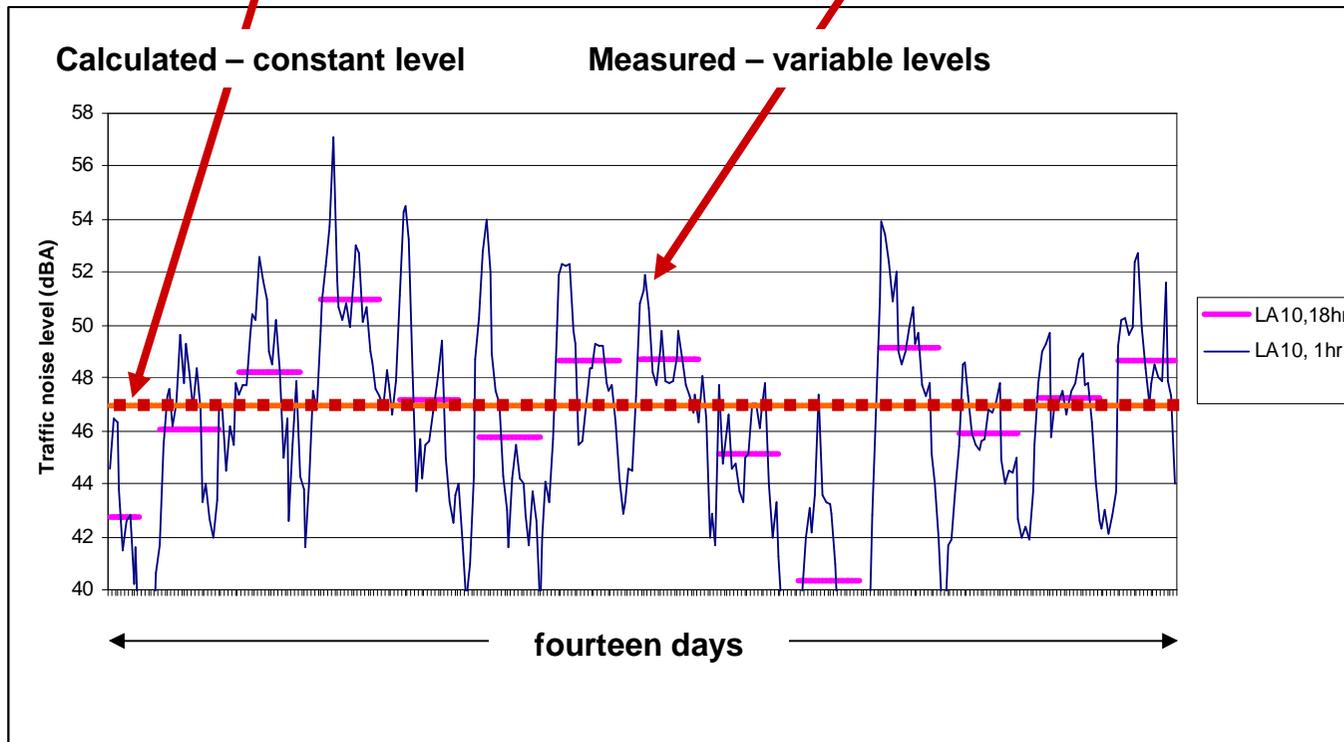
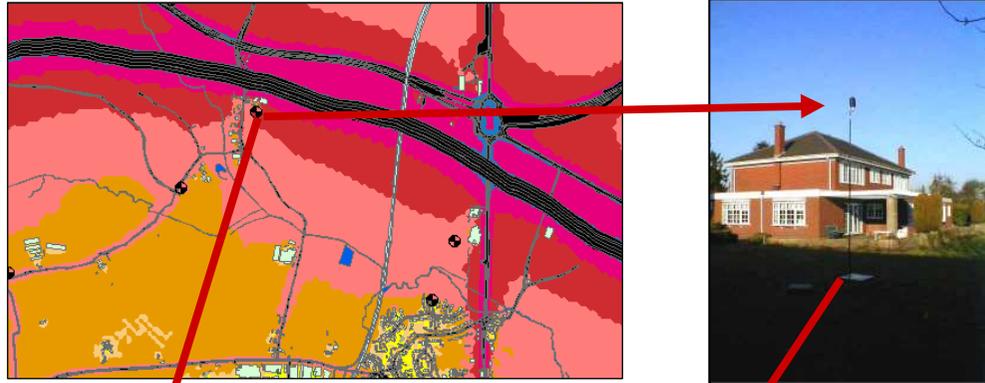


# What defines 'accuracy' in the context of environmental noise?



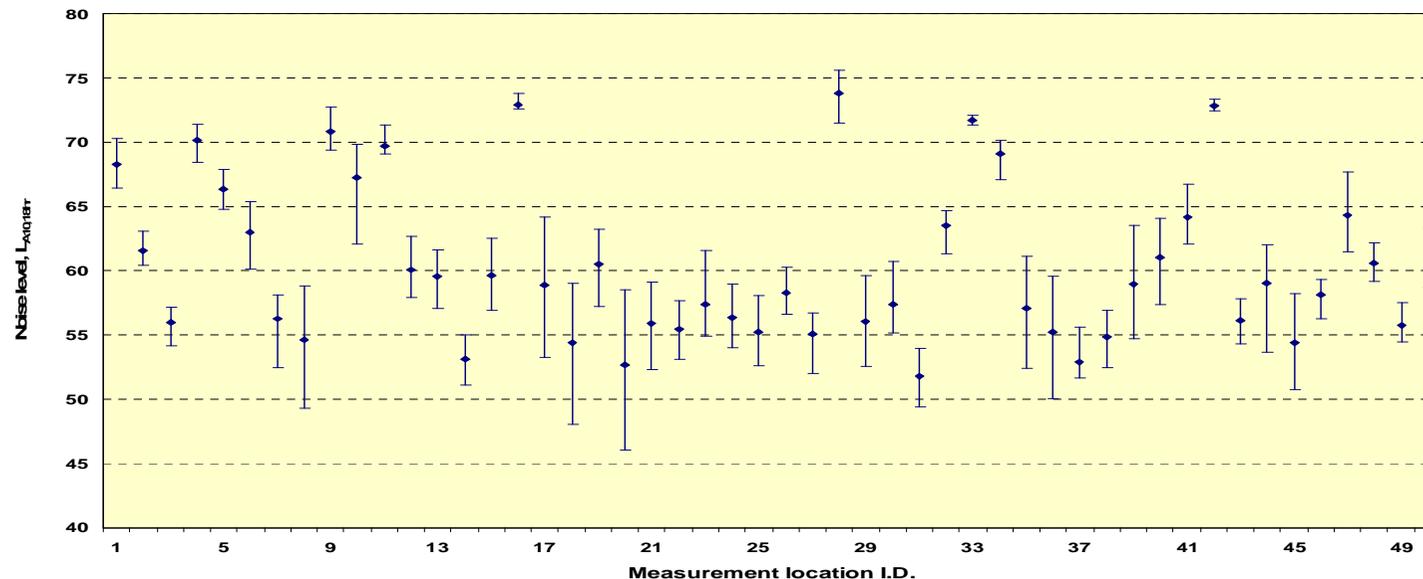
- 'accuracy' should be driven by the need to manage 'risk' to the appropriate degree
- 'accuracy' should not be driven by the desire to minimise 'uncertainty' at all costs
- 'accuracy' requirements can therefore only be defined within the context of a particular assessment

# Measurement versus Calculation



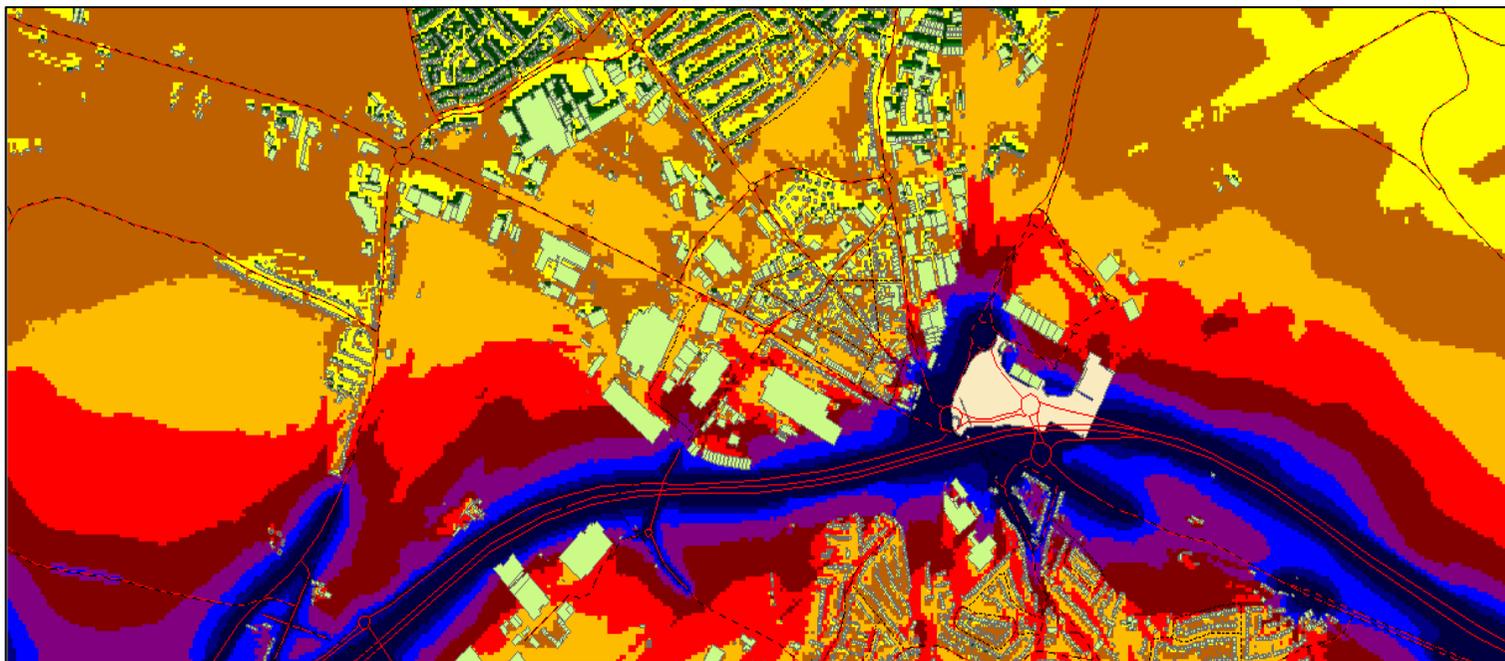
# Assessment methodology – measurement

- provides an absolute indication of the noise level existing at the precise time and location of the measurement
- provides a measure of the temporal variability of the sound field over the duration of the measurement period
- does not isolate noise from the specific source under study from other extraneous sources
- significance of trend changes can be less than natural variability



# Assessment methodology – prediction

- allows isolation of specific noise from other sources
- allows trends due to specific source to be positively identified without problems of measurement variability
- allows generation of results over wide areas
- output results only as good as the input data



## Assessment of 'true' impact

- overall level - dB(A)
- additional noise characteristics - tones etc.
- time of exposure – day/evening/night
- actual duration of exposure to noise
- activity during exposure – work/home/sleep
- expectations of sound environment
- variability of noise – level/character
- masking effects of other sounds
- variability of masking sounds
- attitude towards the source of noise
- non-acoustic influences

WHO <30% of noise problems are due to noise level