An Outdoor Warning System for a Nuclear Generating Station

An Investigation of Modelling and Measurement

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Introduction

In the past…

- Hand calculations (then spreadsheets)
- Published research
- Experts only

In the present…

- Specialized software packages
- Provincial, National, and International Standards
- Anyone can produce "a number"

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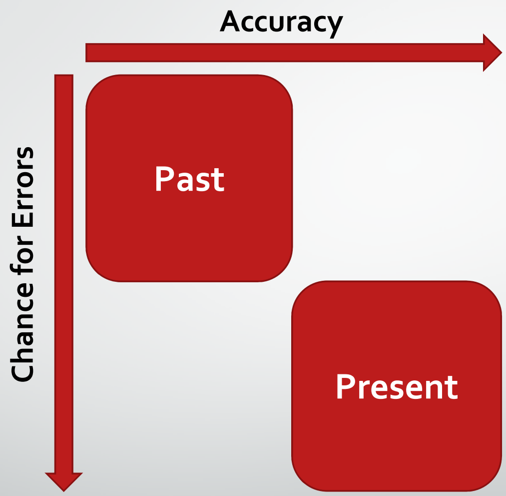

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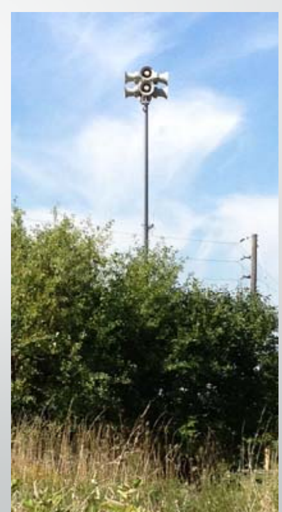
Case Study

- Modelling/Design (#1A – Basic Modelling; 29 Sirens)
- Modelling/Design (#1B – 4 sirens)
- Installation (#1 – 4 sirens)
- Compliance Test (#1 - Failed)
- Modelling/Design (#2 – 9 Sirens)
- Installation (#2 – increase to 9 sirens)
- Compliance Test (#2 - Failed)
- Modelling/Design (#3 – 3D Advanced Acoustic Model; 20 Sirens)
- Installation (#3 – increase to 20 sirens)
- Compliance Test (#3 - Passed)



Guidelines

- Ontario Provincial Nuclear Emergency Response Plan (PNERP)
- Outdoor Warning Systems Guide (CPG 1-17, 1980)
- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants (NUREG-0654/FEMA REP-1, 1980)
- Guide for the Evaluation of Alert and Notification Systems for Nuclear Power Plants (FEMA-Rep-10, 1985)
- Outdoor Warning Systems – Technical Bulletin Version 2.0 (2006)

  - **Siren sound level greater than 70 dBC; and**
  - **Siren sound level at least 10 dBC above the ambient**

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Basic Models

(and their place in history)

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Basic Models

- Simplified relationships
- Approximations
- Conservative assumptions

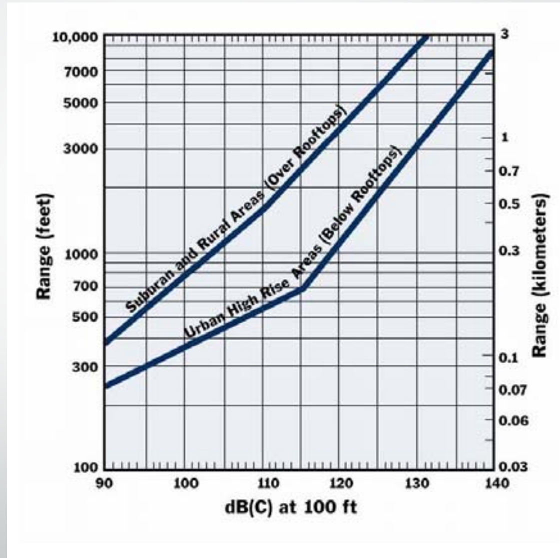

Figure F-1: Rated Output of Warning Device in dB at 100 feet[1]

- CPG 1-17, 1980
- Technical Bulletin Version 2.0 (2006)

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Basic Models

- Simplified relationships
- Approximations
- Conservative assumptions

Table F-1: Correction for Single Tone Sirens

Frequency Range	Correction (dB)
180 Hz – 224 Hz	5
224 Hz – 280 Hz	4
280 Hz – 355 Hz	2
355 Hz – 450 Hz	0
450 Hz – 560 Hz	-2
560 Hz – 710 Hz	-4
710 Hz – 900 Hz	-6
900 Hz – 1120 Hz	-7

- Technical Bulletin Version 2.0 (2006)

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Basic Models

- Simplified relationships
- Approximations
- Conservative assumptions

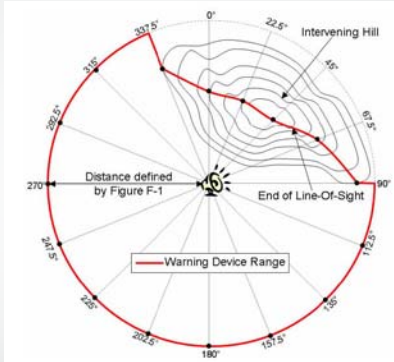

Figure F-2: Example of terrain blocking the LOS of a warning device with a device height of 50 feet and elevation isopleths of 30 feet.

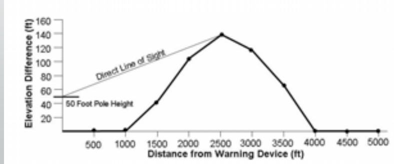

Figure F-3: Plot of the elevation changes along the 67.5 degree radial in Figure F-2

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So what are some shortcomings of the "Basic Models"?

- Some models provide no accommodation for topography. Other models address it in only a rudimentary way
- Basic models provide only a simple prediction of screening from buildings
- Simpler models don't account for variation in atmospheric absorption as a function of frequency
- Most models assume ambient sound level is a function of population density only

Advanced Models

(the "state of the art")

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How can we improve the Acoustic Model?

- Accurately account for topography
- Include specific screening for all buildings
- Accurately predict ground absorption (hard and soft) and air absorption

Advanced Computing Systems

- Provide a parallel prediction of ambient sound levels in order to determine the excess siren sound level over the ambient (not just the siren sound level)
- Use accurate and verifiable source sound power data

Expertise

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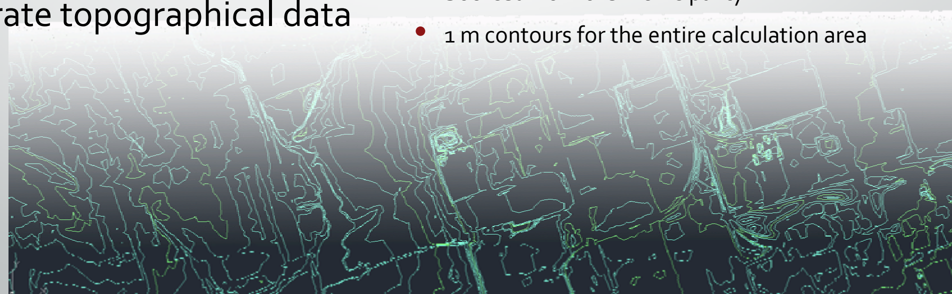
Characteristics of the Acoustic Model

1. Accurate topographical data

- Sourced from the Municipality
- 1 m contours for the entire calculation area



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Characteristics of the Acoustic Model

2. Included over 4000 buildings

- Building envelopes were approximated based on hi-res ortho-photography
- Heights were input for each building – grouped by area (subdivisions were typically of a similar building height – either one or two storey)
- Building heights for hi-rises were input individually

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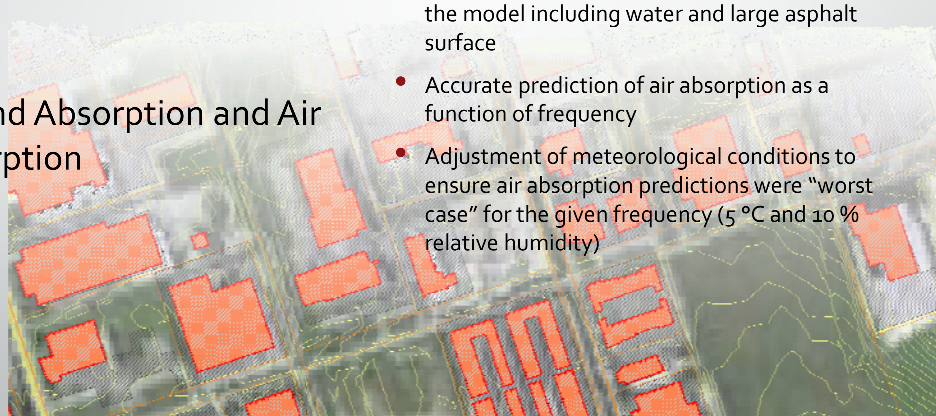
Characteristics of the Acoustic Model

3. Ground Absorption and Air Absorption



- Ground absorption data for specific regions in the model including water and large asphalt surface
- Accurate prediction of air absorption as a function of frequency
- Adjustment of meteorological conditions to ensure air absorption predictions were "worst case" for the given frequency (5 °C and 10 % relative humidity)

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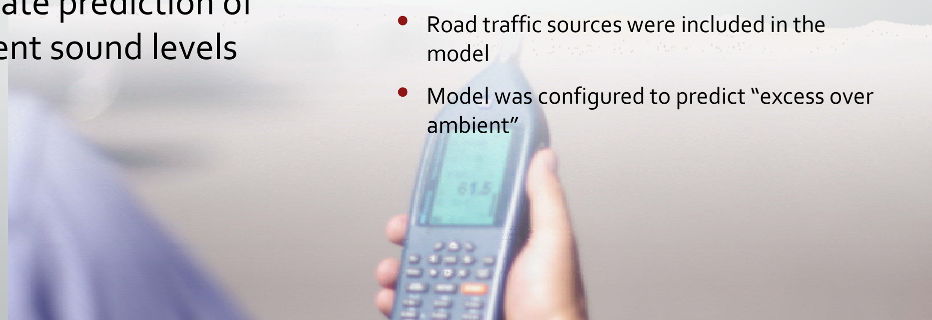
Characteristics of the Acoustic Model

4. Accurate prediction of ambient sound levels

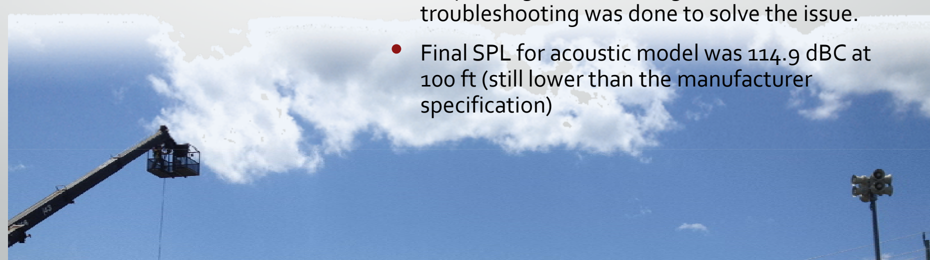


- Short term (20 minute) and long term (3 or 4 days) measurements of ambient sound levels due to road traffic were conducted.
- Road traffic sources were included in the model
- Model was configured to predict "excess over ambient"

Characteristics of the Acoustic Model

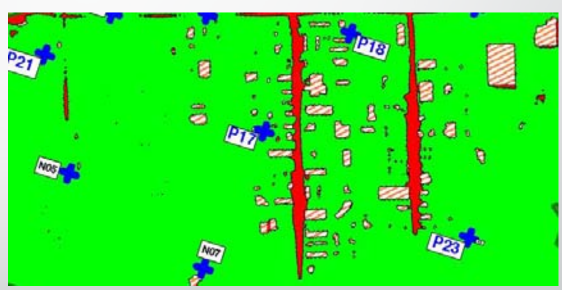
5. Appropriate source sound power level

- In a previous model, the source sound level was assumed to be 125 dBC at 100 ft. This would result in a ground level SPL in excess of 123 dBC
- Various tests conducted by VCL indicated that the sirens were not producing the stated sound output. Significant testing and troubleshooting was done to solve the issue.
- Final SPL for acoustic model was 114.9 dBC at 100 ft (still lower than the manufacturer specification)



Model Results

- Increased required number of sirens from 9 to 20
- Predicted compliance against both criteria for over 90% of the coverage area
  - Siren sound level greater than 70 dBC; and
  - Siren sound level at least 10 dBC above the ambient.



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Final Verification Testing

- Excellent agreement with the model data
- Sound level criteria met at ALL measurement locations

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Pitfalls and Key learnings

- Manufacturer's Data must be validated (not necessarily taken at face value)
- Good Output requires Good Inputs (screening, topography, etc)
- Understand the ambient sound field

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Conclusions

- Older models may lack accuracy (computational constraints)
- Newer models always produce "a number", but require expertise to implement correctly