Blast Fume Monitoring and Modelling

- Andrew Martin
- Principal HSE Scientist, Simtars
- 3810 6313
- andrew.martin@deedi.qld.gov.au

Topics

- PPE
- Scientific perspective
- Purposes and types of monitoring
- Monitoring protocols
- Maintaining and calibrating equipment
- Meteorology: influence and monitoring
- Computer modelling of dispersion

PPE

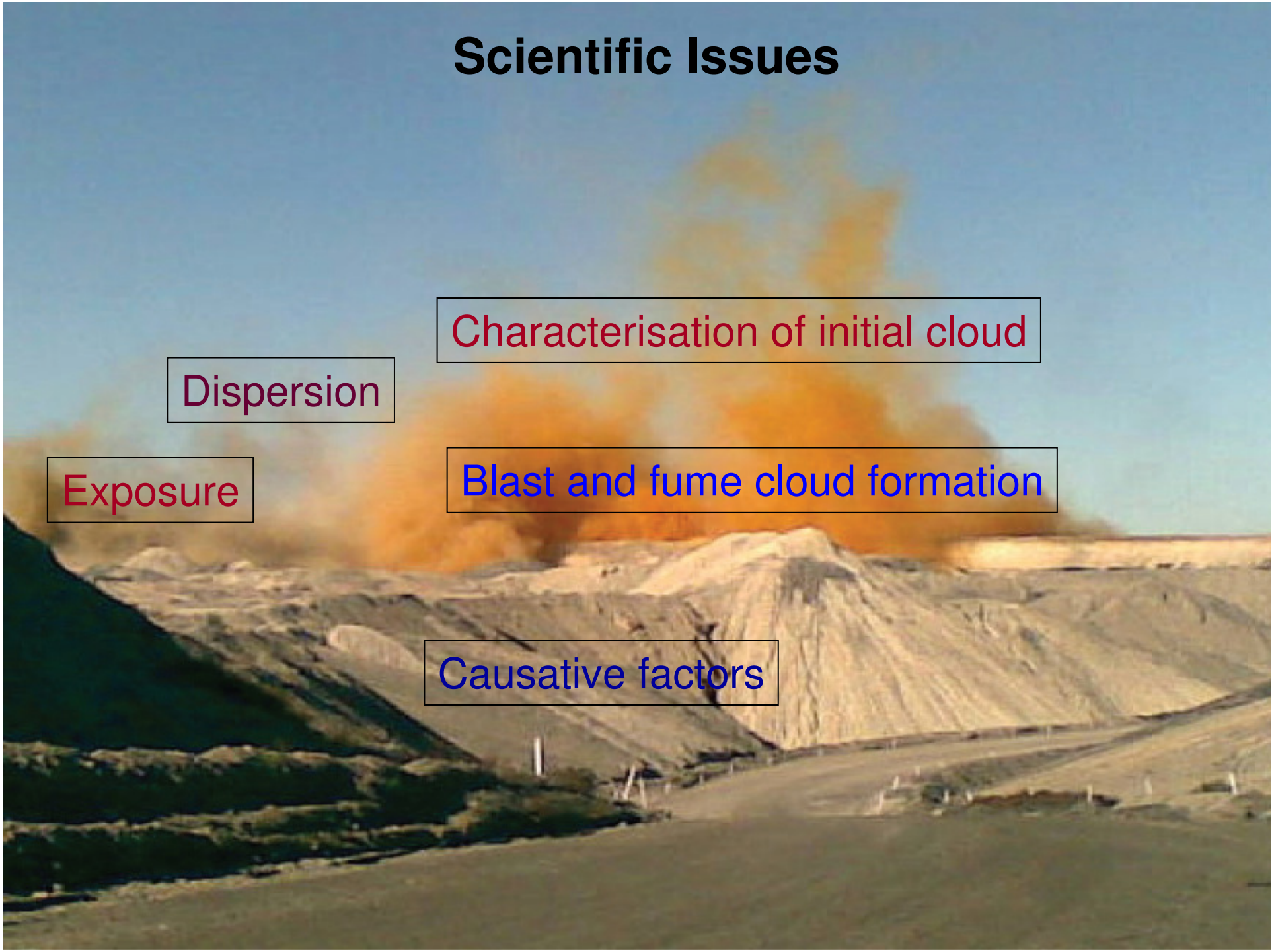
- Last resort in risk management.
- If likelihood of exposure is moderate then evacuate beforehand.
- If likelihood of exposure is low, then standby for evacuation.
- If standby not practical then use monitoring and:
  - have PPE available; and/or
  - recirculating sealed building / vehicle.

PPE examples

- Half/full face respirators
- North NO_2 canister (40NBC)
- Quantum NO_2 cartridge at www.aearo.con/industrial/cartridges.cfm

- 3M and Sundstrom recommend supplied air

Scientific Issues



Scientific Perspective

- What is the concentration of fumes?
- The uncertainties are large and include:

1. Quantity of CO, NO_2 & NO produced initially
2. Conversion between NO & NO_2
3. Size of cloud (& hence concentration)
4. Dispersion of these gases downwind

➢ Need to monitor.

Purposes of Monitoring

1. Record exposure of personnel
2. Record concentrations at ground level for validation of assumptions and models
3. Measure concentrations in the elevated cloud
4. Record environmental concentrations outside lease

Types of monitoring (1. personal)

Personnel exposure monitors

- Measure exposure of workers
  - medical treatment
  - legal claims
  - proactive management
- Simtars uses Odalog 6000 as it is IS
- 0.1 ppm sensitivity
- alarm on STEL
- logging capability
- up to $5000 + gas for calibration

Personal exposure monitors examples

- Odalog from Thermo
- Gas Alert from Aegis
- MX6 from Industrial Scientific via Airmet
- MSA from Protector Alsafe

Types of Monitoring (2. fixed)

Fixed location monitors

- Record concentrations to assist understanding of fume generated
- same instruments as personal samplers
- Battery operate and easy to transport
- Can be placed downwind close to blast
- Can easily be placed at neighbours facilities.
- Remain at fixed location.

Types of monitoring: 3. in-cloud

- tethered balloons
- open path spectroscopy
  - transmitter and receiver
  - sunlight and receiver
  - ~$50,000

- Simtars project with Ecotech

Types of Monitoring (4. environmental)

- to compare with the ambient air objectives at sensitive neighbours (1hr average of 120 ppb)
- ppb analyser
- A/C trailer
- Automatic calibrator
- Data logger, modem
- $50,000

Monitoring Protocol - Strategies

- Define all potentially exposed receptor locations.
- Record blast, environmental and monitoring data systematically.
- Store data from all blasts and report in periodic summaries.
- Report separately blast incidents resulting in symptoms, exceedences of exposure standards or coloured clouds leaving exclusion zone.
- Investigate causes of incidents.
- Increase monitoring of high risk blasts.

Monitoring Protocol - Locations

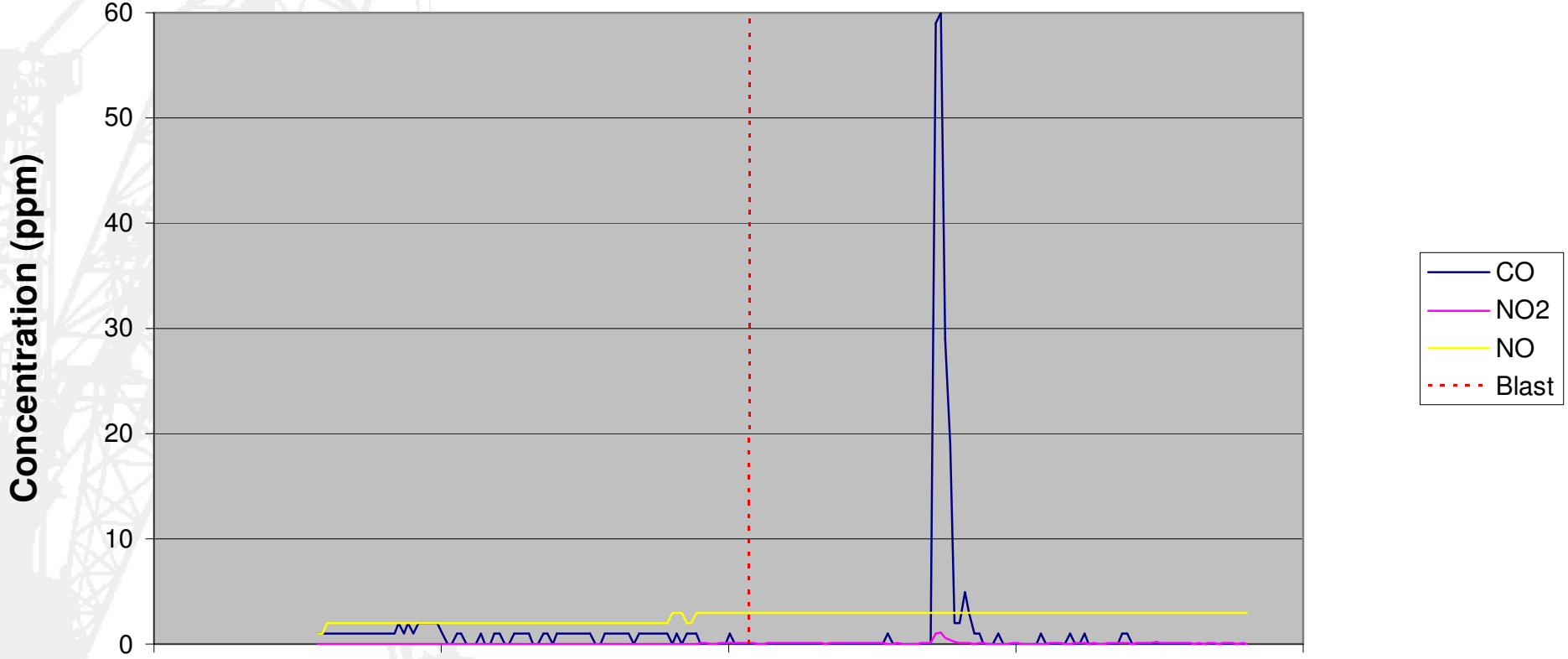
- Internal locations for personal monitoring eg:
  - blast crew, shotfirers, blast guards; and
  - workshops, pits, wash ports, offices.
- External workplaces including other mines and ventilation shafts
- External sensitive receptors eg:
  - schools and medical centres; and
  - residences

Monitoring Protocol – data recorded

- synchronise times
- time of monitor calibrations and the blast
- monitor coordinates and identification
- commence monitoring ~ 10 minutes before blast and finish ~ 1 hour after
- blast and environmental details
- etc.

Equipment issues

- Electrochemical sensors semi-reliable and may flat-line
- Interferents eg SO_2
- Zero drift
- Span drift


Concentration (ppm)
60
50
40
30
20
10
0
CO
NO2
NO
Blast

Equipment Calibration and Maintenance

- Prior to every use must check response of sensors (challenge or bump tests) and replace where necessary.

- Recommend 6-monthly calibration, cleaning and maintenance.

Equipment calibration – Bump tests

Example of a docking station for carrying out bump (challenge) tests as well as single point calibrations

Influence of Meteorology

- wind speed
- wind direction & variability
- A to F stability classes
- rainfall
- cloud cover & sunlight
- inversion layers

Meteorological Monitoring

- At least measure wind speed and direction preferably on a 10m mast.
- Store five minute averages
- Sample every 10 seconds or shorter
- Other parameters that can be useful for modelling are temperature at 10m and 2m, the standard deviation of wind direction (sigma theta), solar radiation.
- Can use meteorological models to calculate other parameters required by complex dispersion models.

Simtars
Queensland Government

Dispersion Modelling – ?Quantity of fume

- Initial **quantities** based on mass balance & chemistry only gives upper limit.
- NPI uses emission factors based on lab simulation to estimate emissions.
- In-cloud measurement can be used to develop empirical database of concentrations.

Dispersion modelling – ?initial concentration

Ranking dependent on:

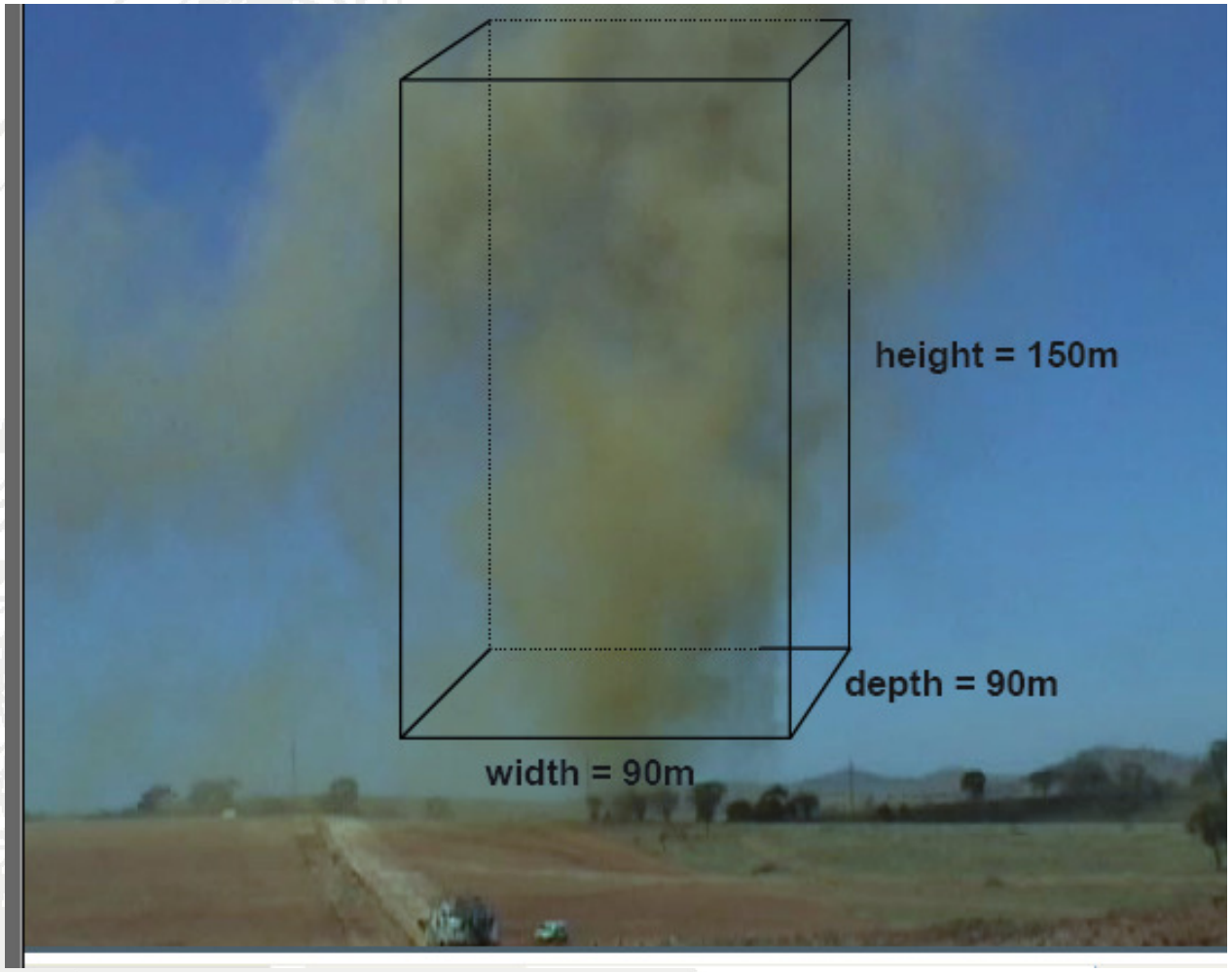
- depth of plume
- angle of view
- subjectivity
- sunlight
- variability within cloud

Uncertainties

- NO to NO2 conversion and others
- say factor of 4

Ranking	NO_2 (ppm)
0	2
1	4
2	7
3	17
4	70
5	500

Dispersion Modelling – Cloud size



temperature?

Source: CSIRO

Dispersion Modelling – NO and NO_2

- **Conversion** to NO_2 is dependent on:
  - time, unburnt hydrocarbons (VOCs), sunlight

- NO + reactive VOCs (or O_3) $\rightarrow$ NO_2 + stable VOCs (or O_2)
- $NO_2 + O_2$ + sunlight $\rightarrow$ $NO + O_3$

- So VOCs drive formation of NO_2 and O_3
- VOCs from explosion byproducts of fuel oil and emulsion

Dispersion modelling – Dispersion factors

- **Dispersion** (pathway, dilution and spread) dependent on
  - wind,
  - ground contours,
  - surface roughness,
  - land use and surface reflection of heat

Dispersion Modelling – Other issues

- Computational models good at statistical probability (ie. 1 in 10 will reach X metres) but not so good at individual events.

- Model software needs to:
  - model instantaneous release
  - consider terrain effects

Dispersion Model – Types

- Gaussian distribution models
  - instantaneous release puffs
  - continuous release plumes / multiple puffs
- Eularian models more complex
- Computational fluid dynamics complex but good for small well-defined domains

Dispersion Modelling – software

- ***Aermod*** / ***Ausplume*** *Gaussian continuous plume*
- **Fluent** CFD: complex but good for in-pit applications
- **Degadis** assumes flat terrain and continuous release
- **Slab** assumes flat terrain
- **Alloha** assumes flat terrain
- **Aftox** is Gaussian puff assumes flat terrain
- **Calpuff** is Gaussian puff
- **CHARM** Eularian model of explosion shockwaves
- **Obodm** puff model of detonation of munitions

Preliminary modelling

- used Slab
- ran for different stability classes and corresponding wind conditions
- assuming no thermal buoyancy
- predicted 15 minute NO_2 averages and compared to STEL
- defined fume management zones

Preliminary Modelling Results

Subjective Ranking	Initial NO2 (ppm)			
0	2			
1	4			
2	7			
3	17			
4	70			
5	500			

Preliminary Modelling Results

Subjective Ranking	Initial NO2 (ppm)	Downwind occupational fume management zones (m)		
		A (very unstable)	D (neutral)	
0	2	100	100	
1	4	130	150	
2	7	400	500	
3	17	600	1200	
4	70	900	3000	
5	500	1600	5000	

Preliminary Modelling Results

Subjective Ranking	Initial NO2 (ppm)	Downwind occupational exclusion distance (m)		Potential extend of environmental goal contour (m)
		A (very unstable)	D (neutral)	
0	2	100	100	1,200
1	4	130	150	3,000
2	7	400	500	4,000
3	17	600	1200	8,000
4	70	900	3000	13,000
5	500	1600	5000	20,000

Conclusions

- Ground level monitoring essential to measure exposure.
- Need systematic approach to monitoring.
- Dispersion modelling necessary to avoid overly conservative fume management zones.
- Need research:
  - measuring in-cloud concentrations
  - ratio of NO to NO_2
  - cloud temperature