Elevated LNG Dispersion
Effects of Topography & Phase Change

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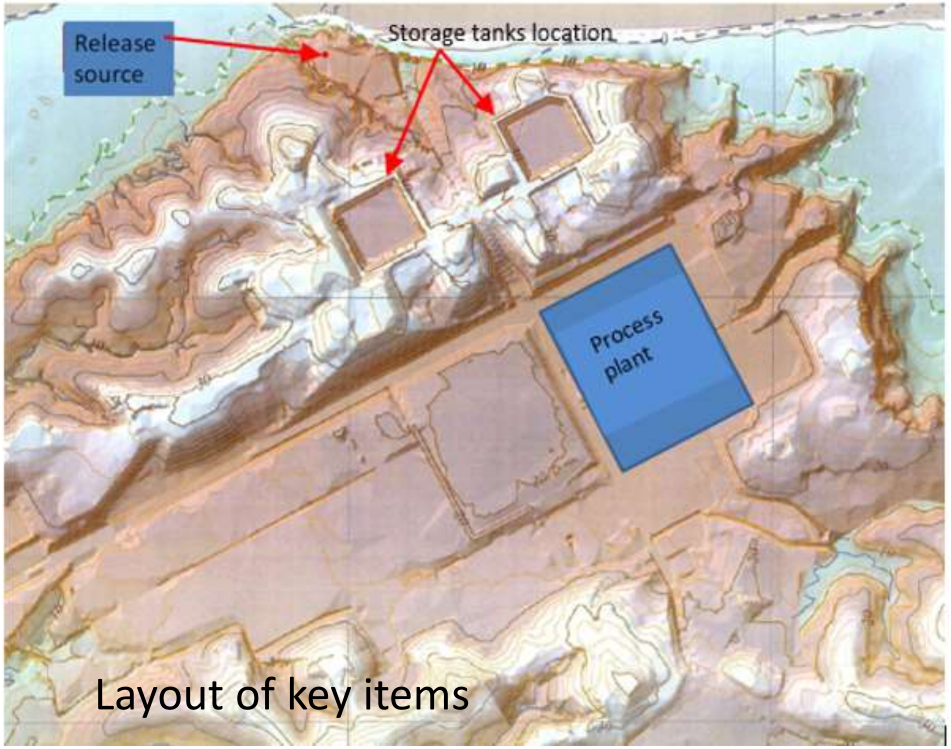
Outline

- Background - Cold vent event
- Objectives – Event reproduction
- Methodology
- Results & Discussion
- Conclusions

Background

- The Event:
  - LNG vapour was vented on October 2013 as a result of flare flame out
  - ~262 t of LNG was vented over ~ 5 hours
  - Line of sight gas detectors triggered alarm ~ 2-15% LFL reading.



- Location of vent
- Process area
- Topography
- High ambient humidity

The Plume!

- Plume captured on CCTV

CCTV picture of plume at 02:00

Objective

- Requested to model the dispersion of the cold venting of LNG vapour to establish flammable hazards during the venting episode in October.
- The objectives of this analysis:
  - To explore the effects of the common assumptions on conditions typically found on a LNG installation (e.g. topography and cold temperature of the LNG vapour
  - The results were also analysed against real-life data obtained from an unplanned cold venting of LNG vapour event due to failure of a pilot

Methodology: Preliminary Assessment

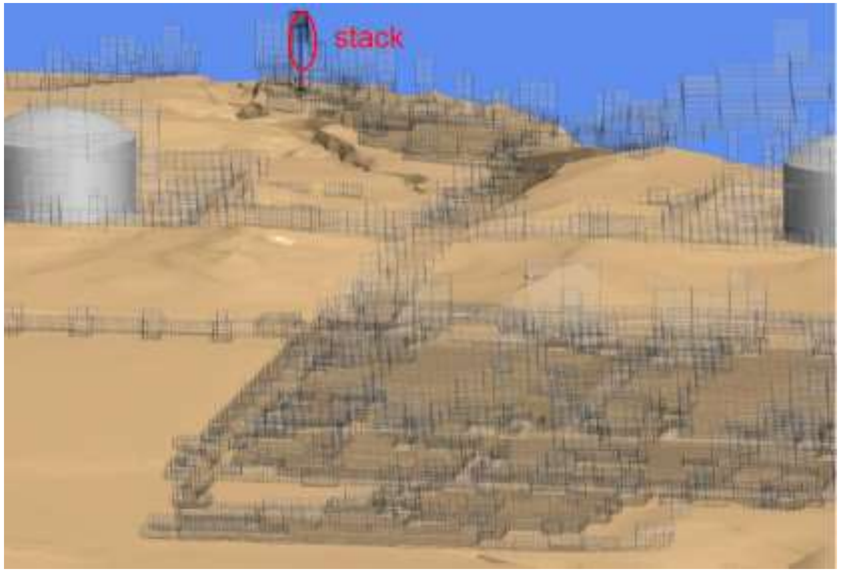
- Preliminary assessment using Integral Model for a 40 kg/s release:
  - If the release is modelled as an elevated release at the top of the stack, the gas plume was predicted to disperse without reaching the ground.
  - If the release is assumed to descend to the ground immediately, then the concentration on the ground is estimated to be about 30-40% LFL (vs 2-15% LFL gas detector reading).
- It is recognised that the Integral Model is not applicable in this situation because:
  - The topography is not flat, there is a hill between the vent and storage tanks.
  - Two large storage tank in the path of dispersed vapour
  - The topography and equipment could drag the plume towards the ground.
  - The very cold temperature could condense moisture in the atmosphere increasing the effective density of the plume.

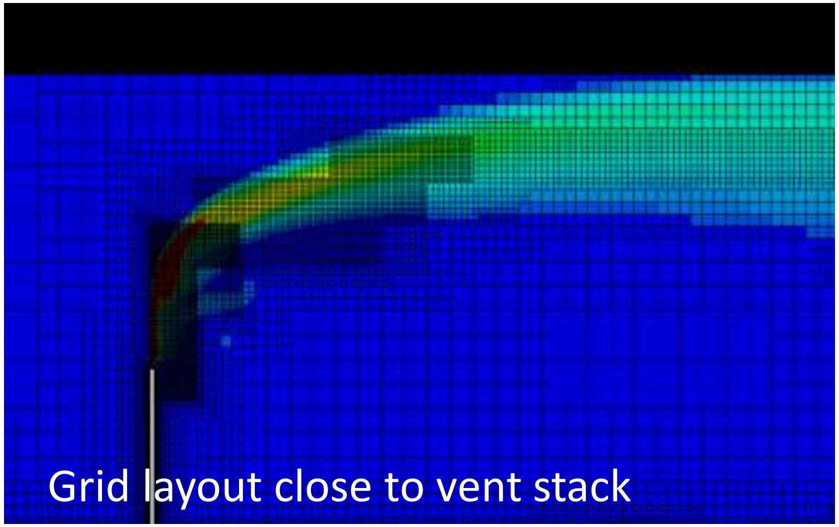
CFD Dispersion Modelling

- CFD analysis was then conducted:
  - Using CFD code Star CCM+
  - Taking account of topography, moisture in the atmosphere
  - Based on conditions close to those observed at the time of the cold venting.
- Steady-state modelling scenarios considered for different:
  - Vent rates
  - Wind directions

CFD Dispersion Modelling

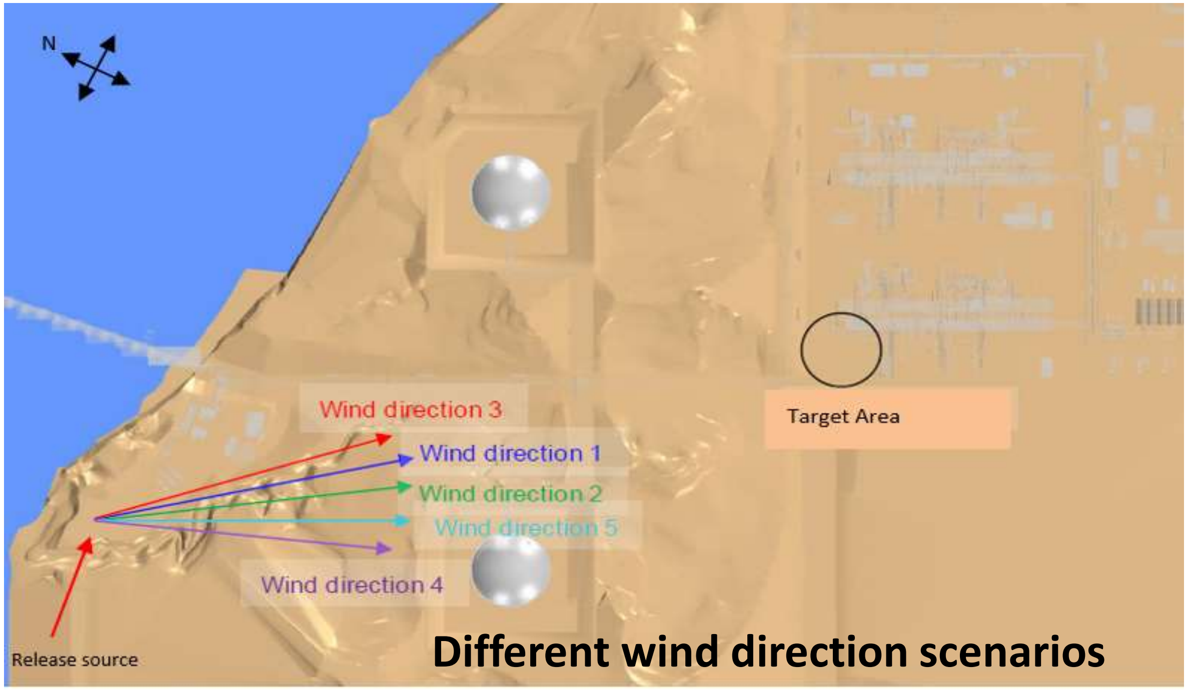
- Topographic model built from previous work on facility (see top right).
- Additional geometric modelling included:
  - Storage tanks and bunds were represented explicitly
  - Large pieces of equipment were represented explicitly
  - Effects of small pieces of process equipment, structures and pipework were represented by distributed porosity giving appropriate resistance to flow.





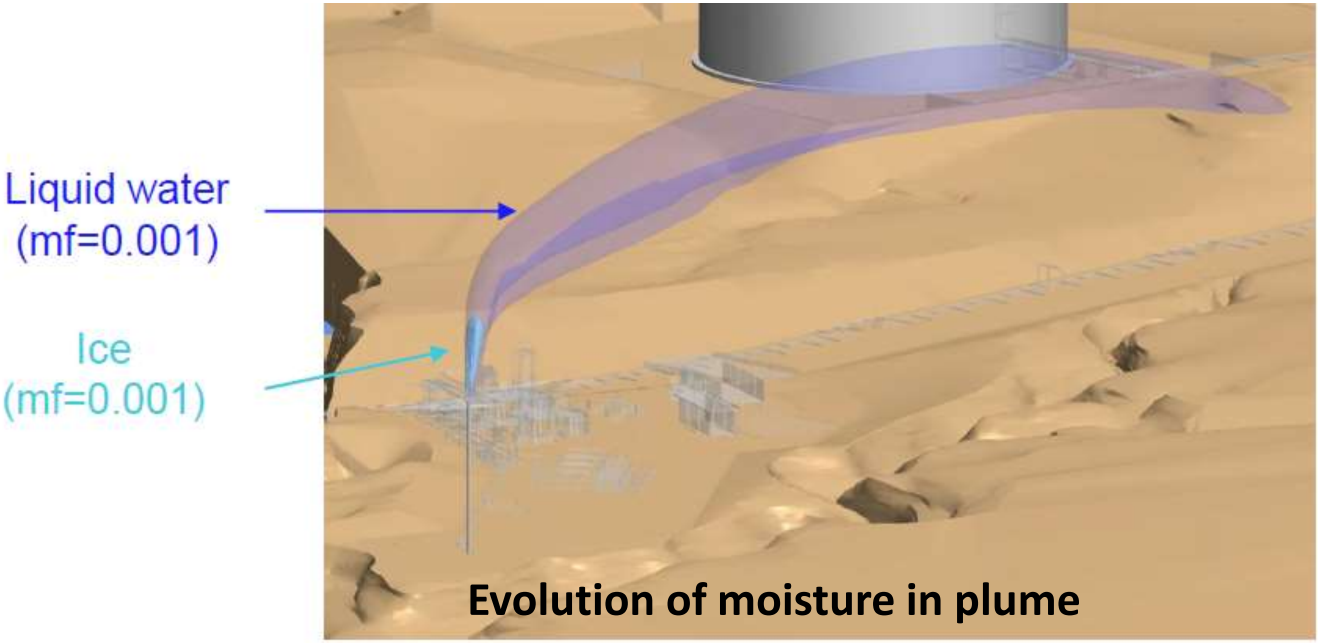
CFD Modelling – Venting gas

- Vent gas assumed to be pure Methane at -161°C
- Molecular weight of Methane = 17
- Venting flowrate = 16, 25, 30, 45 kg/s
- Flare height = 35 m from ground level
- Also considered, 5 wind directions towards process area



CFD Modelling – Venting gas

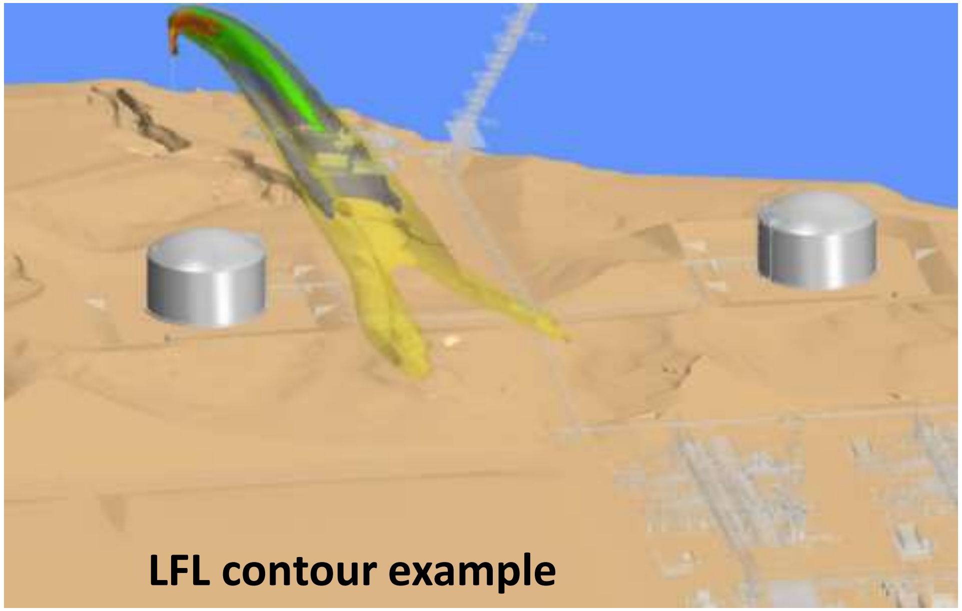
- Ambient moisture contents set at 90% relative humidity
  - Moisture allowed to change phase from ice to water to vapour depending on temperature of the gas/air mixture
  - Ice and water droplets increase effective density of the methane plume (in addition to the effect of the low temperature)
- An example of water & ice density distribution is shown below, showing moisture fraction in the form of ice and water.



Evolution of moisture in plume

Results: CFD Steady state condition

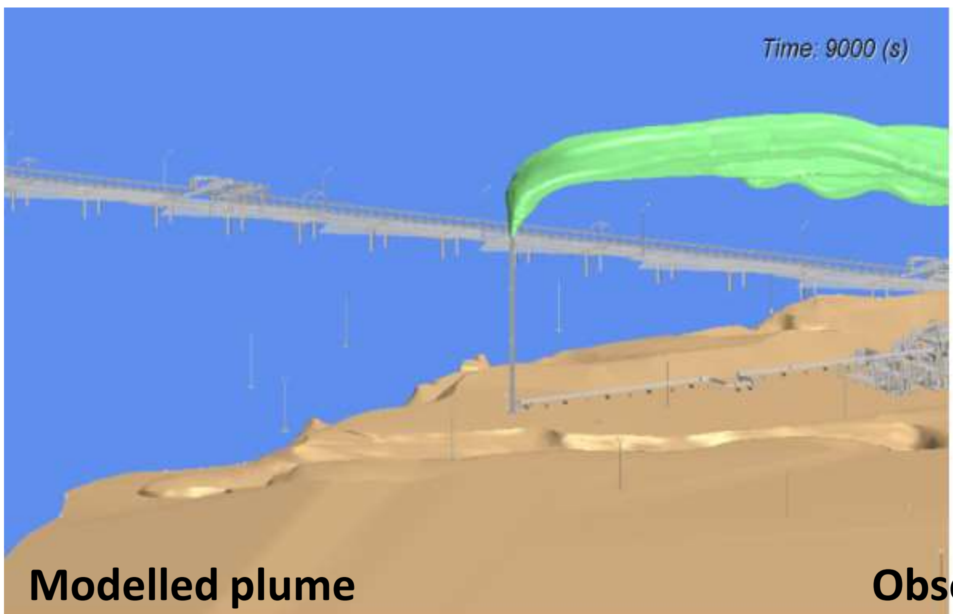
- 3D contours showing the plume dispersion in the general wind direction towards the train.
- The effect of topography, water contents and the low temperature is to drag the plume down.
- The plume touches down between the two LNG tanks.
- Dispersion becomes less efficient once the plume has touched down producing longer dispersion distance than if the plume is aloft.
- Low vent rate and low wind speed could lead to early touchdown of plume.



LFL contour example

Results: CFD Steady state condition

- Side view of plume
- Good match to plume shape
- However, it was difficult to deduce the complete plume trajectory based on visible plume information.



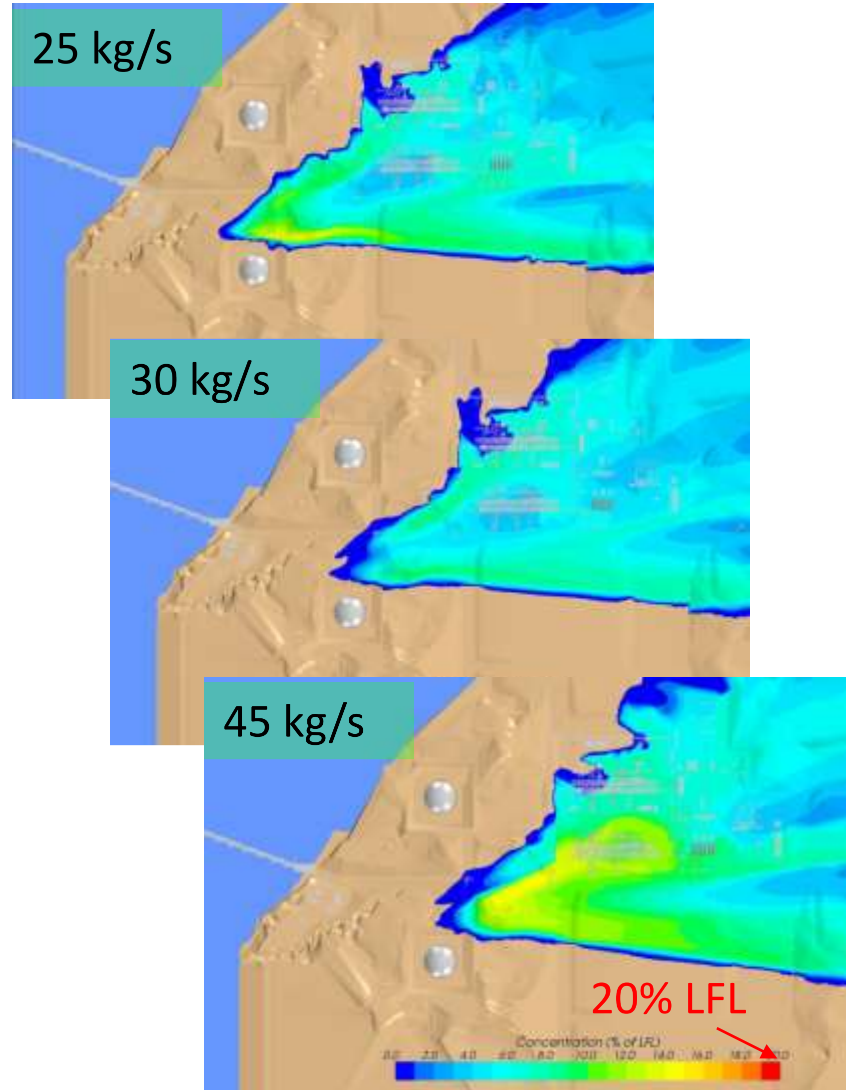
Modelled plume

Observed plume during venting

CFD Steady state condition
Vent Rates at 2 m/s wind speed

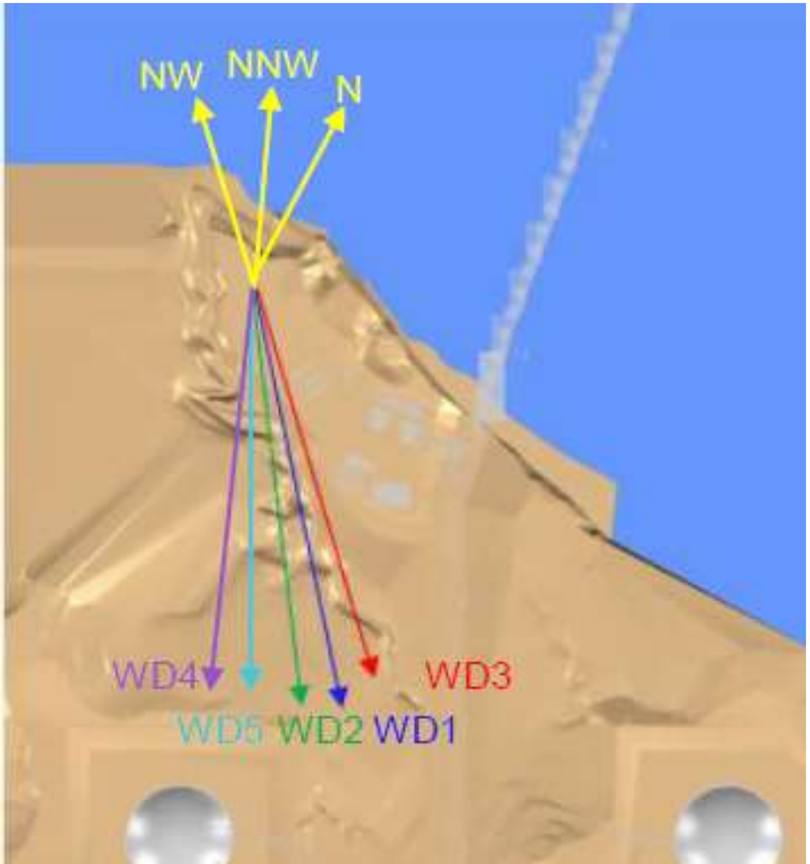
- Ground level concentration tend to increase in storage area generally with increasing vent rate.
- Low vent rate could lead to early touchdown of plume.
    - 25 kg/s - produces a higher ground level concentration close to the LNG tanks than the 30 kg/s vent rate.
- Maximum ground concentration ~ 10% LFL.
- Below point detector trigger point.
- Concentration at line detector level is estimated to be ~ 4% LFL.
- Could trigger line of sight detectors.

Ground level LFL



CFD Steady State condition
Wind Directions on ground level concentration

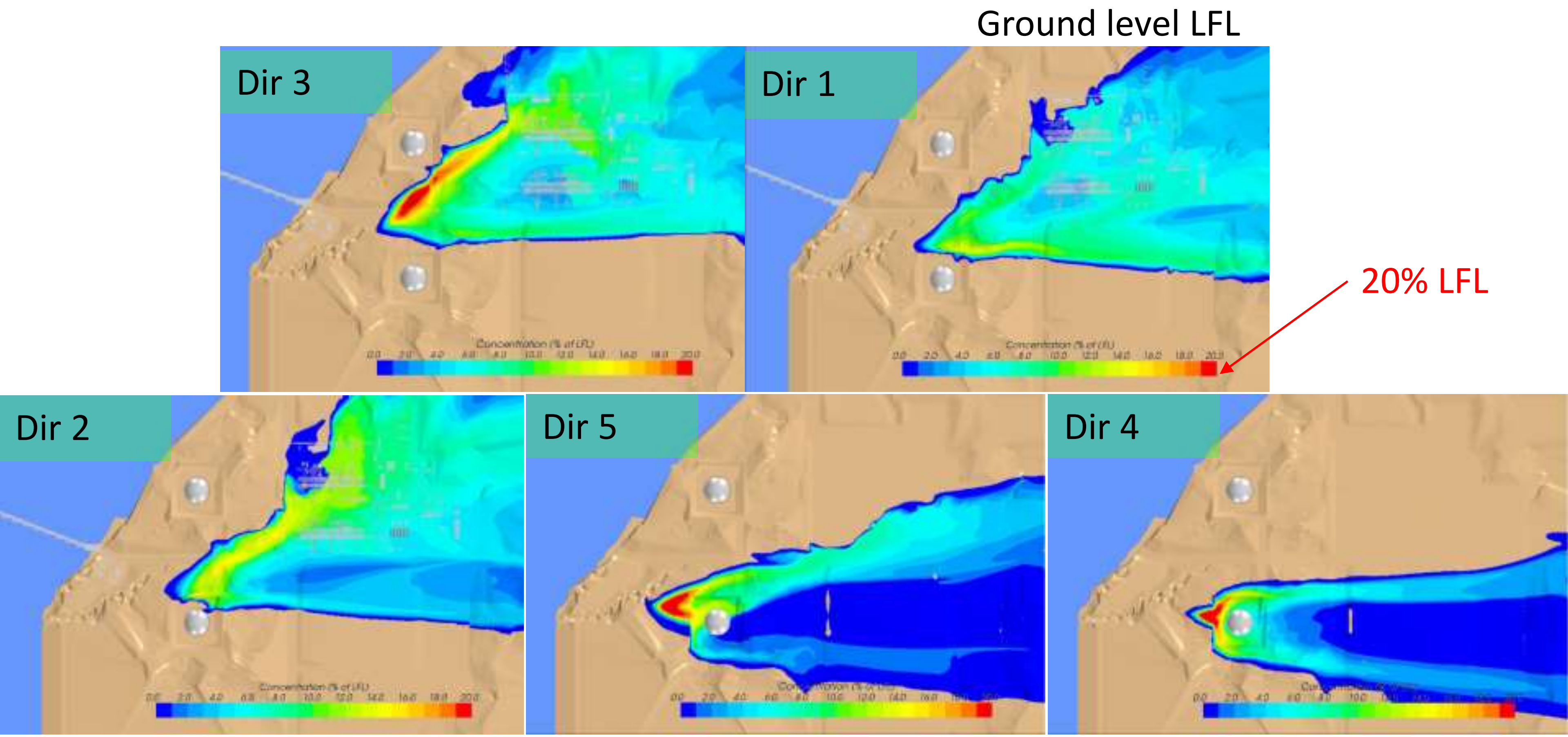
- Effect of storage tanks is expected to be significant.
- Five wind directions were assessed, at or near the point where the plume could be obstructed or deflected by the tanks.
- Directions are shown on the figure on the right (wind blowing from 316°N to 338°N).
- LNG tank changes the dispersion of vent gas resulting in different ground level concentration distributions



Wind direction & storage tanks

CFD Steady State condition
Wind Directions on ground level concentration

- Results below are for vent rate of 25 kg/s, wind ~2 m/s.
- Figures below show ground level concentration as wind direction rotates clockwise.



Summary of Steady State Calculations

- CFD calculation takes account of effects local to cold vent
  - The effect of topography, cold temperature of LNG vapour, moisture condensation was to ‘drag’ the plume towards the ground.
- Sensitive to wind direction
  - The two LNG storage tanks restricted the range of wind directions that would bring the plume towards the trains.
- Results show that
  - Concentration of gas is well below LFL at train boundary, thus did not present flammable hazards.
  - The range of release rates occurred during the cold venting could result in concentration that could trigger line of sight gas detectors but not point detectors.
  - This occurs in low wind speed (< 3 m/s) where the plume could descend to the ground early.

Conclusions

- Event modelling
  - Effects of different release rates, wind directions and speeds were demonstrated
  - Results from steady-state CFD analysis broadly agrees with key event observations.
- Methodology
  - Commonly used integral jet dispersion models underestimates the flammable hazards as it does not predict descent of plume.
  - Dense gas model overestimates the hazards by not accounting for the initial momentum mixing
  - CFD analysis would be advisable to be used.
- Further consideration
  - In unsteady conditions, it is possible that the range of wind speed and directions could be larger than those suggested by steady state conditions
  - Gas detector locations & settings.