‘Gas Capture Maximisation’ approach for avoiding methane emissions in ventilation air

Rao Balusu

EARTH SCIENCE AND RESOURCE ENGINEERING
www.csiro.au

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Presentation Outline

- Introduction
- Fugitive emissions from underground coal mining
- Ventilation strategies for VAM mitigation
- Current gas drainage scenario and challenges
- Gas capture maximisation strategies
- GHG friendly mine scenario
- Conclusions

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Introduction

- Australian coal industry – highly gassy mining conditions
  - Coal seams gas contents ranges from < 1.0 m^3/t to about 18 m^3/t
  - Specific gas emissions (SGE) up to 20 m^3/t of coal production (to 35 m^3/t)
  - Goaf gas emissions generally from 300 l/s to 3,000 l/s (even to 8,000 l/s)
- Complex mining conditions
  - Thick and multiple coal seams (& strata gas)
  - Depths approaching 600m, low permeability , structures, ..etc
  - Mines in remote areas, surface/environmental constraints, ..etc
- Coal seams are also prone to spontaneous combustion
  - Complicates goaf gas drainage issue (requires balancing/optimisation)

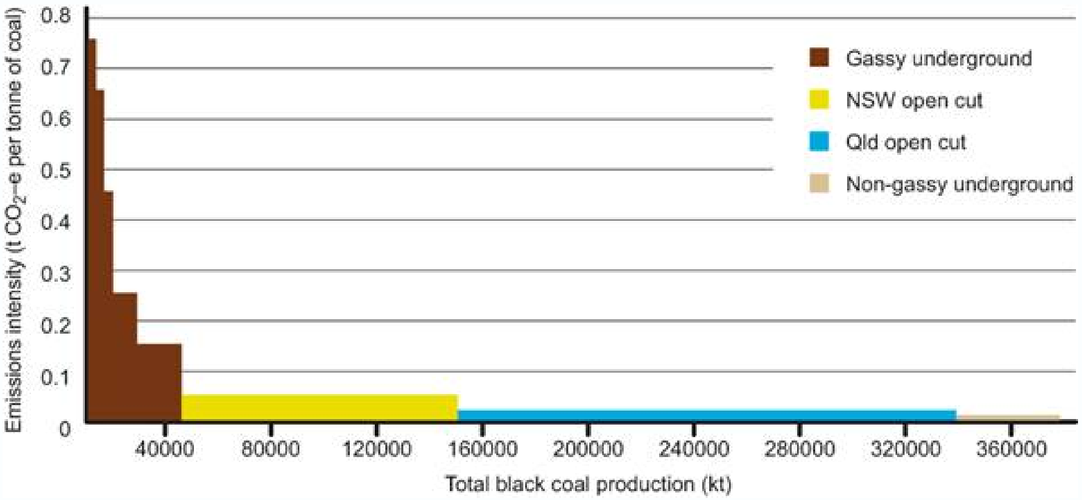
Fugitive emissions from UG coal mining

- UG fugitive emissions ~16 to 17 Mt CO_2-e (Total ~28 Mt)
- Total VAM around 30 m^3/s CH_4 (13 to 14 Mt CO_2-e)
- Total drained gas ~ 20 m^3/s CH_4
  - Drained gas ~ around 40% of total (20 m^3/s out of total 50 m^3/s)
  - 75% of pre-drained gas used for Power generation and in Flares

Gas emission rates and relationships

- CO_2-e and methane (CH_4) flow rates
  - 1 m^3/s CH_4 ~ 0.45 Mt/y CO_2-e (**10 Mt CO_2-e ~ 22 m^3/s**)
- CH_4 emissions and carbon charge
  - At A$23/t CO_2-e, **1 m^3/s (1,000 l/s) emissions ~ $10 M/year**

Coal mine fugitive emissions intensity



Emissions Intensity Figure by Australian National Greenhouse Accounts

- For example, gassy underground mine producing 5 Mt with intensity of 0.3 – total emissions around 1.5 Mt of CO_2-e, which equates to $35 M/yr (at cost of @$23/t)
- From this emissions intensity figure, we can see that
  - CO_2-e charge for a number of UG mines will be > $10 M/y (for some mines over $25 M/y)
  - Other mines will also face significant carbon charges
- Need to reduce fugitive emissions significantly from UG coal mines

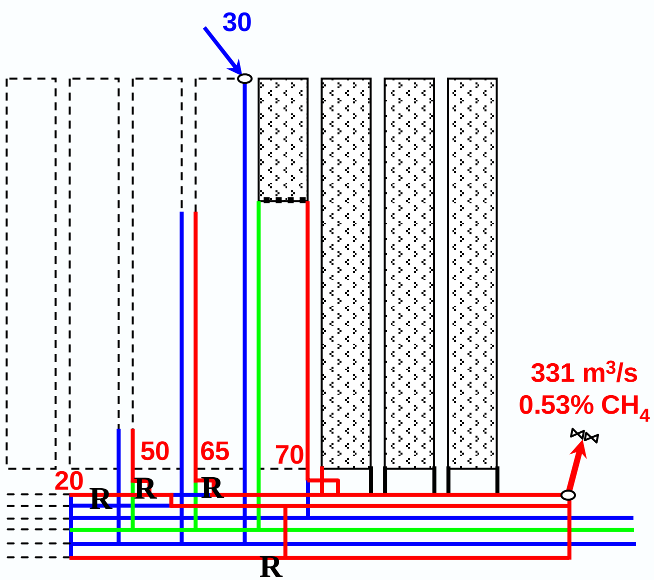
Ventilation Air Methane (VAM) – in Australia

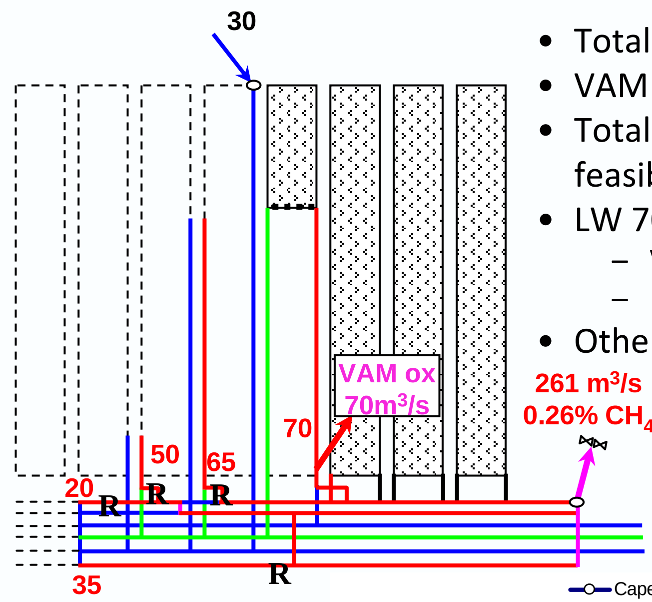
- Total VAM emissions - over 30 m^3/s (out of total 50 m^3/s from UG mines)
- As most of the drained gas is utilised/flared, VAM emissions represents 80-85% of the total fugitive emissions from UG mines
- Low CH_4% in VAM presents a challenge for utilisation or mitigation

VAM mitigation – Ventilation Options

- Example: LW mine 330 m^3/s @ 0.55% CH_4 = 0.8 Mt CO_2-e
- To minimise these emissions, options include:
  - Mitigating the entire main ventilation VAM with > 0.3% CH_4
  - Ventilation modification and targeting only part of vent system at higher CH_4%
- LW airflow is typically around 30% of mine ventilation, but may contain up to 70% of the gas reporting to main ventilation VAM

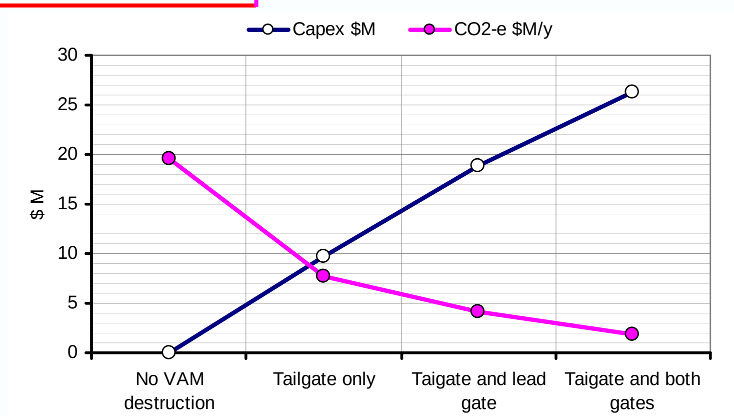
VAM mitigation – Ventilation options (1)





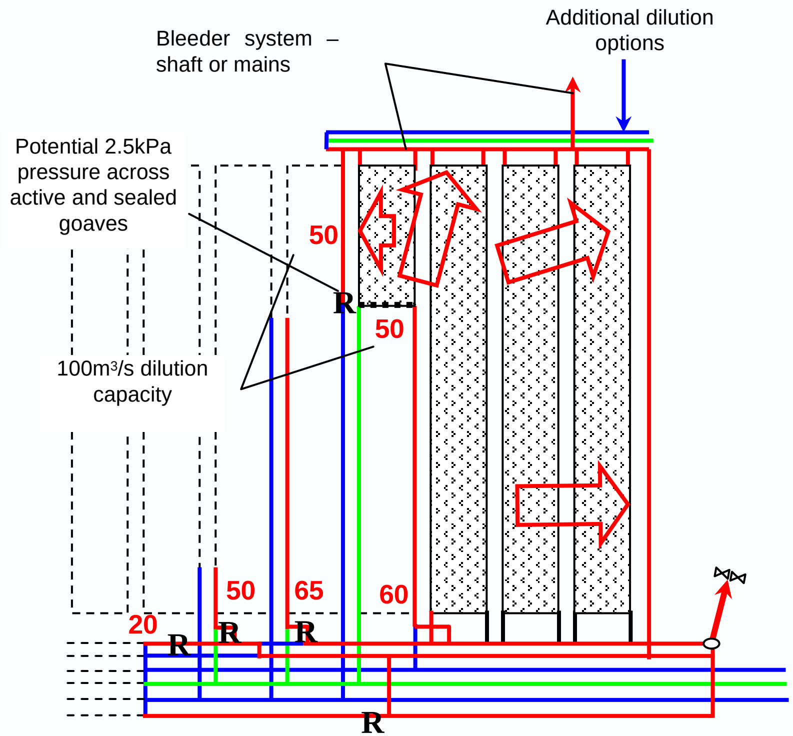
- Total VAM ~ 0.8 Mt CO_2-e
- VAM charge $20M/Y
- Total VAM mitigation –not feasible
- LW 70 m^3/s at 1.5% CH4
  - VAM mitigation $10M
  - Remaining carbon charge $7M
- Other VAM mitigation options

Scenario	Main Shaft m3/s	Main Ex Shaft CH4 %	VAM Shaft(s) m3/s	Capex $M	CO2-e Charge $M /year
No VAM destruction	331	0.53	0	0	19.56
Tailgate only	261	0.26	70	9.735	7.757
Taigate and lead gate	196	0.22	135	18.882	4.103
Taigate and both gates	146	0.11	185	26.265	1.855



Targeting LW return/bleeder for VAM mitigation optimisation

VAM mitigation – Ventilation options (2)



- LW bleeder gas up to 2% CH_4
- Gas from adjacent goafs
- Alternative ventilation layouts
- Peripheral/split vent systems
- Changes in mine design/layouts

- Safety issues to be considered

Bleeder ventilation of longwalls and goaf bleeders – VAM mitigation

VAM mitigation – Key points

- VAM is 60% of UG CMM emissions and represents 80-85% fugitive emissions
- VAM mitigation – still an issue and difficult to mitigate all VAM emissions

- Targeting only part of ventilation at higher CH_4%
- Modifying mine ventilation to increase CH_4% in VAM for mitigation
- Increasing gas capture and using some gas for VAM mitigation

- **Increasing 'mine gas capture' to reduce total VAM emissions - best strategy**

- Gas drainage strategies/options to reduce VAM/fugitive emissions

Current gas drainage scenario

- Total gas drained ~ 20 m^3/s CH_4 (and 3 m^3/s CO_2)
  - Pre-drainage gas ~ 12 m^3/s and goaf drainage ~ 11 m^3/s
  - Drained gas ~ 40% of total 50 m^3/s (VAM ~ 30 m^3/s CH4)
- Total 14 mines using gas drainage (pre-drainage and/or goaf drainage)
- Pre-drainage for outburst prevention – only in working seam
- Goaf drainage to control gas in longwall panels
- **Gas drainage main objectives - Gas control and Outburst prevention – not necessarily 'Gas Capture Maximisation' at the moment**

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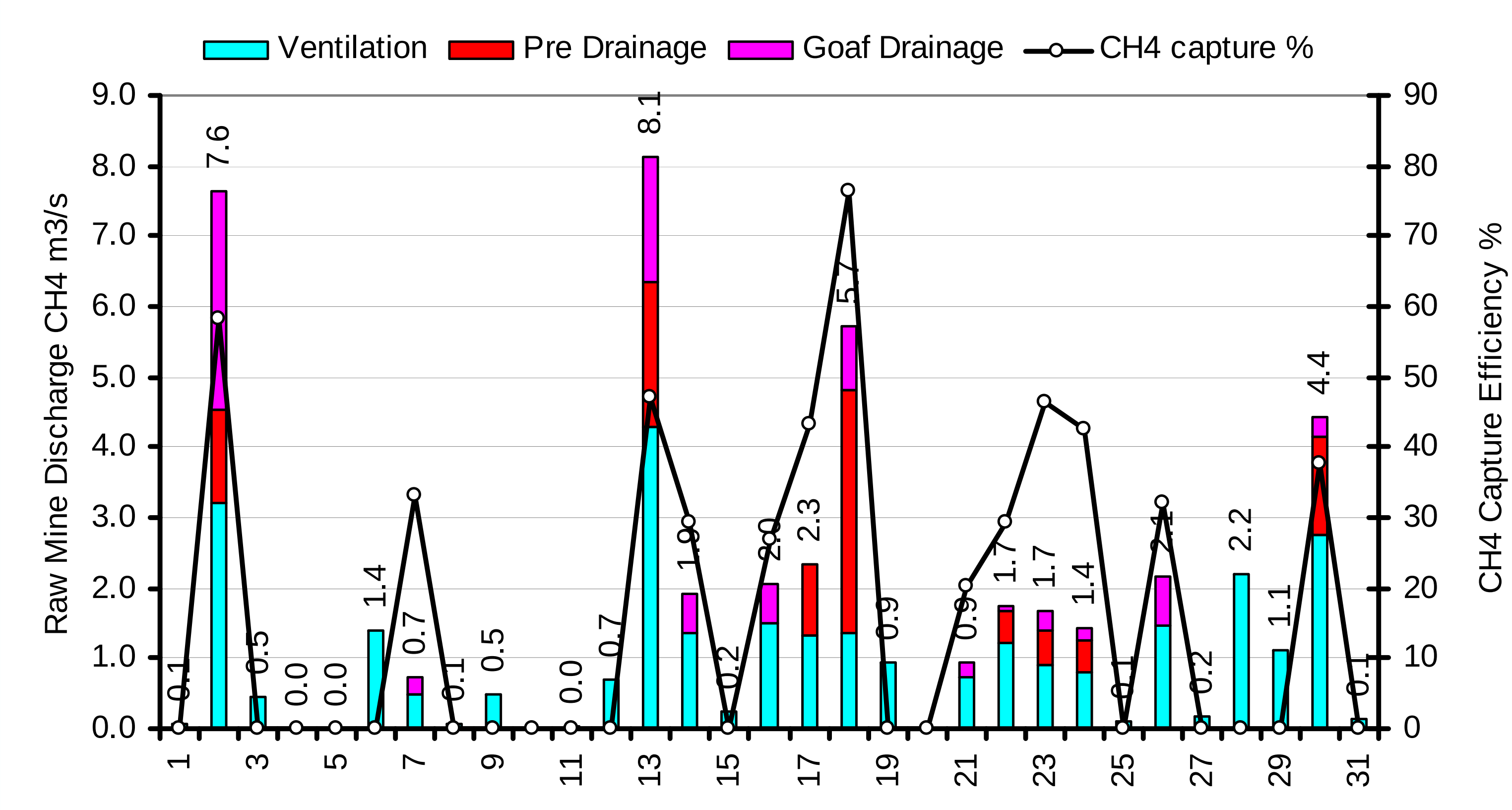
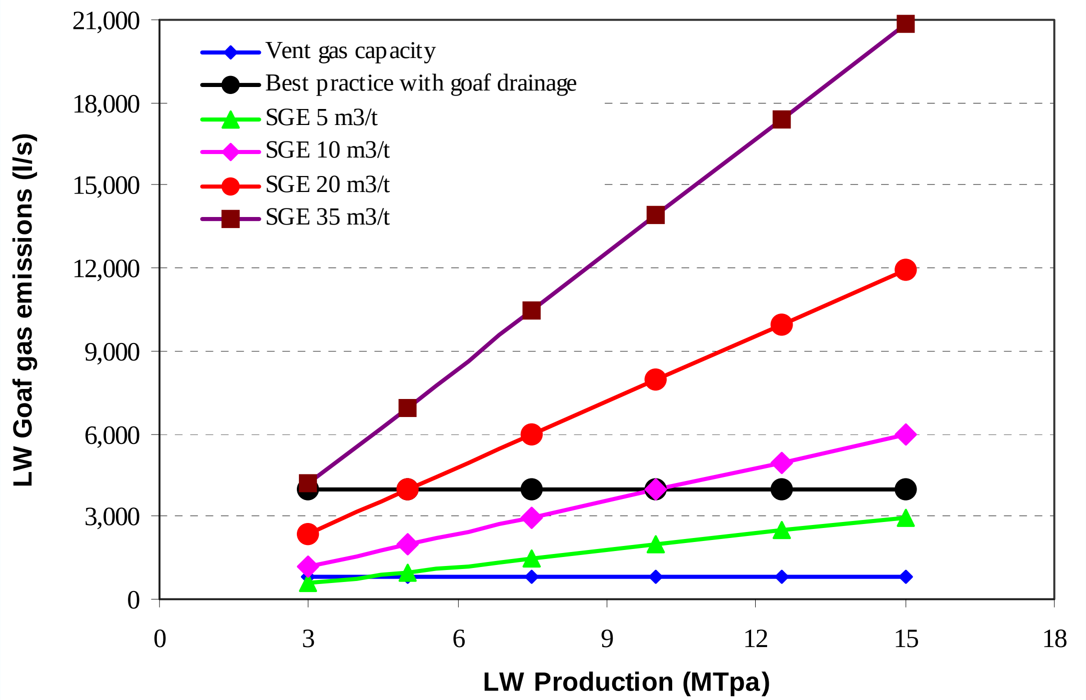
Typical gas drainage in mines



LW mines methane emissions and capture efficiency

Future challenges – in gas control



Expected increase in goaf gas emissions with coal production

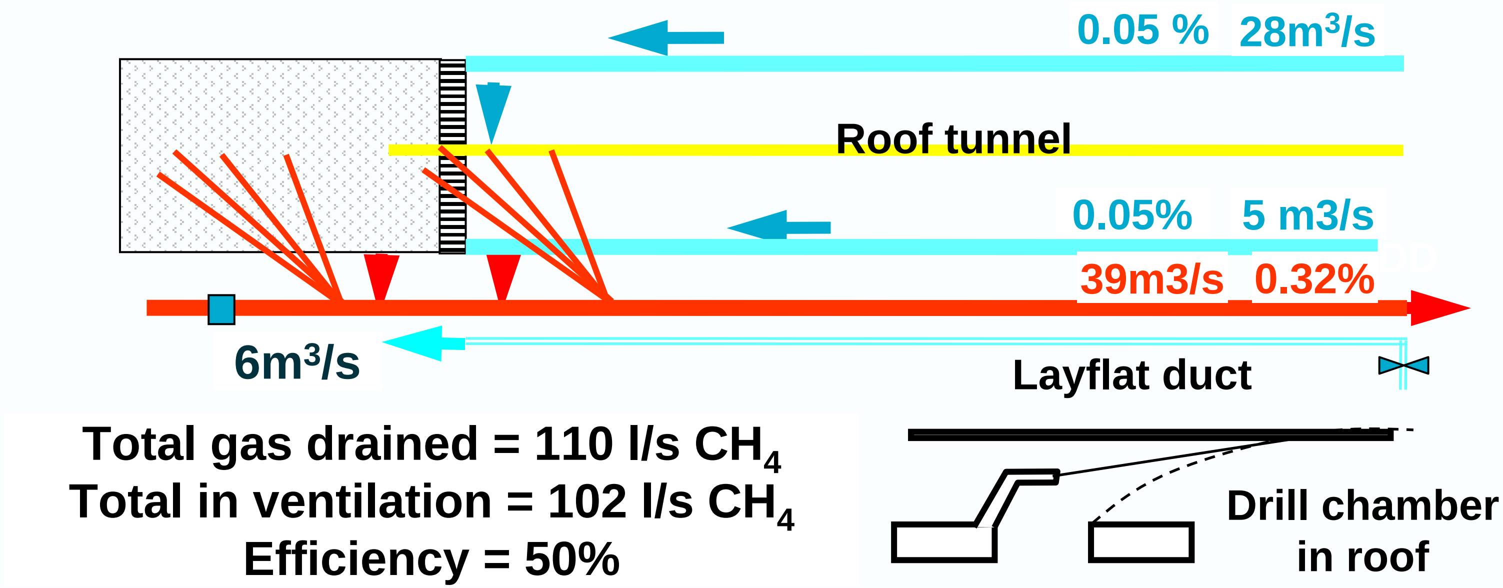
- Mines getting deeper – high gas & less perm
- Goaf gas drainage – surface restrictions
- Multiple seams mining – goaf drainage issue
- Thick seam extractions –more gas emissions
- Sponcom issues vs goaf gas drainage rates
- Remote mines (and less local demand) – issue for gas capture maximisation
- Safety issues – to capture CH_4 at < 30%

- Current CMM capture (both pre-drainage & goaf drainage) from all coal mines (around 12 to 14 mines) ~ 20 m^3/s = 20,000 l/s only
- In future, we get that much gas flow from just a few mines & more challenges

Gas drainage practices and approach

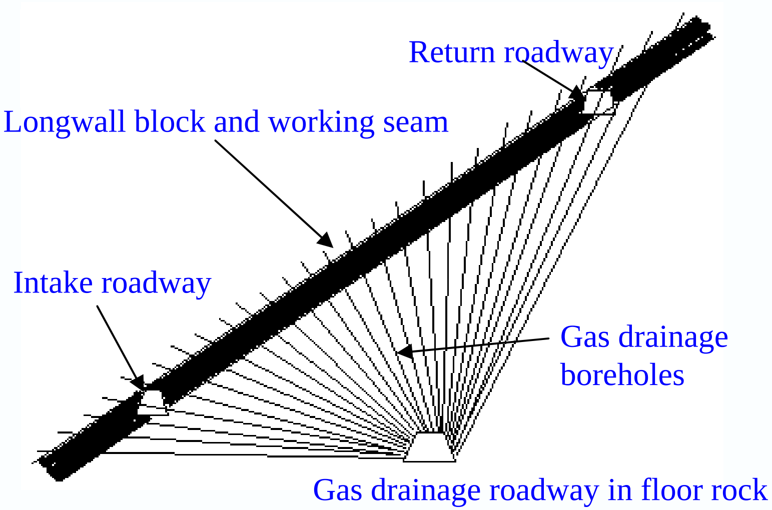
- Gas capture efficiency ~ 40% to 50% (highest 75%)
- Need to improve gas drainage efficiencies significantly
- Need to introduce additional gas drainage in mines - even if not necessary for statutory compliance purposes
  - For example, $10M/y to capture additional 1,000 l/s may be cost effective
- Current perceptions of 'more gas drainage results in more goaf gas emissions' need to change
- Need to change from current "Gas Control" approach to "**Gas Capture Maximisation"** approach

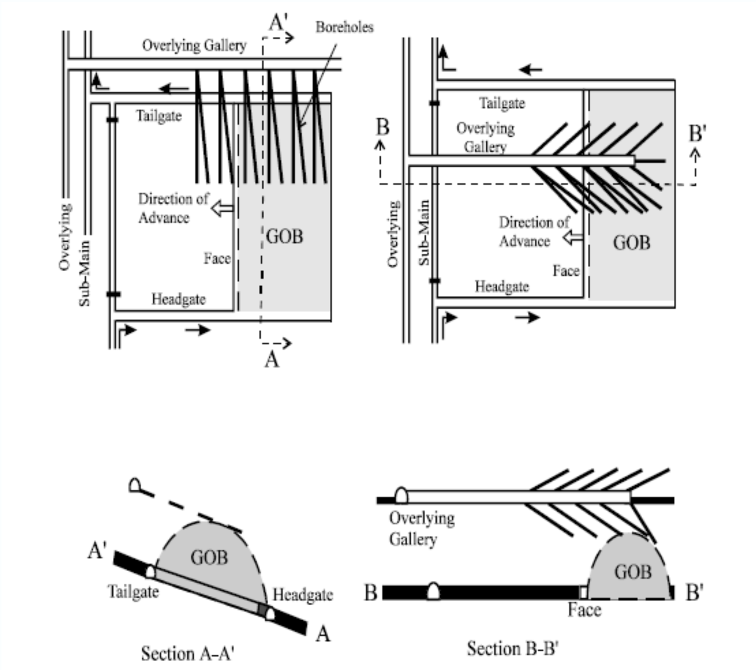
Gas Capture – UG goaf drainage in China & UK

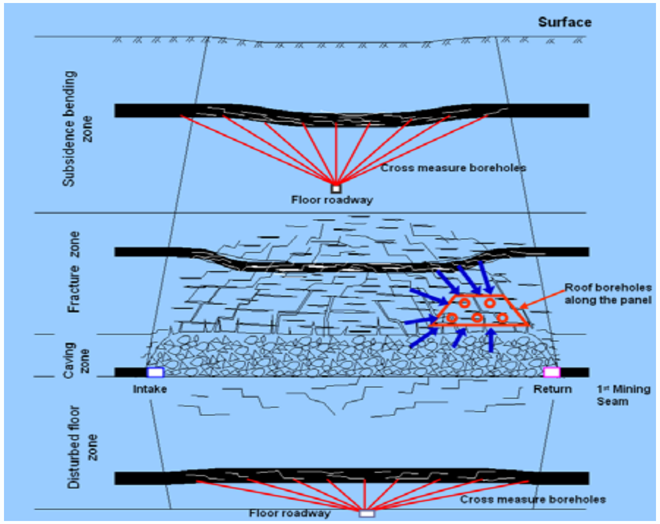


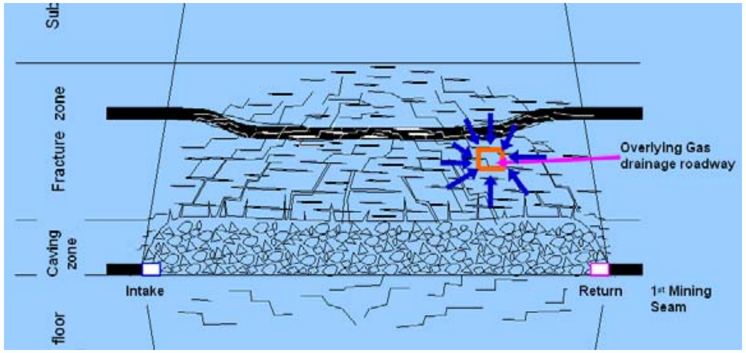
- Gas drainage focus on near face active zone (in front and close behind)
- <u>Note</u>: Capture efficiency of 50% achieved even at low flow rates
- Purity is an issue – some times < 30% CH_4

Gas Capture – Unconventional hole patterns

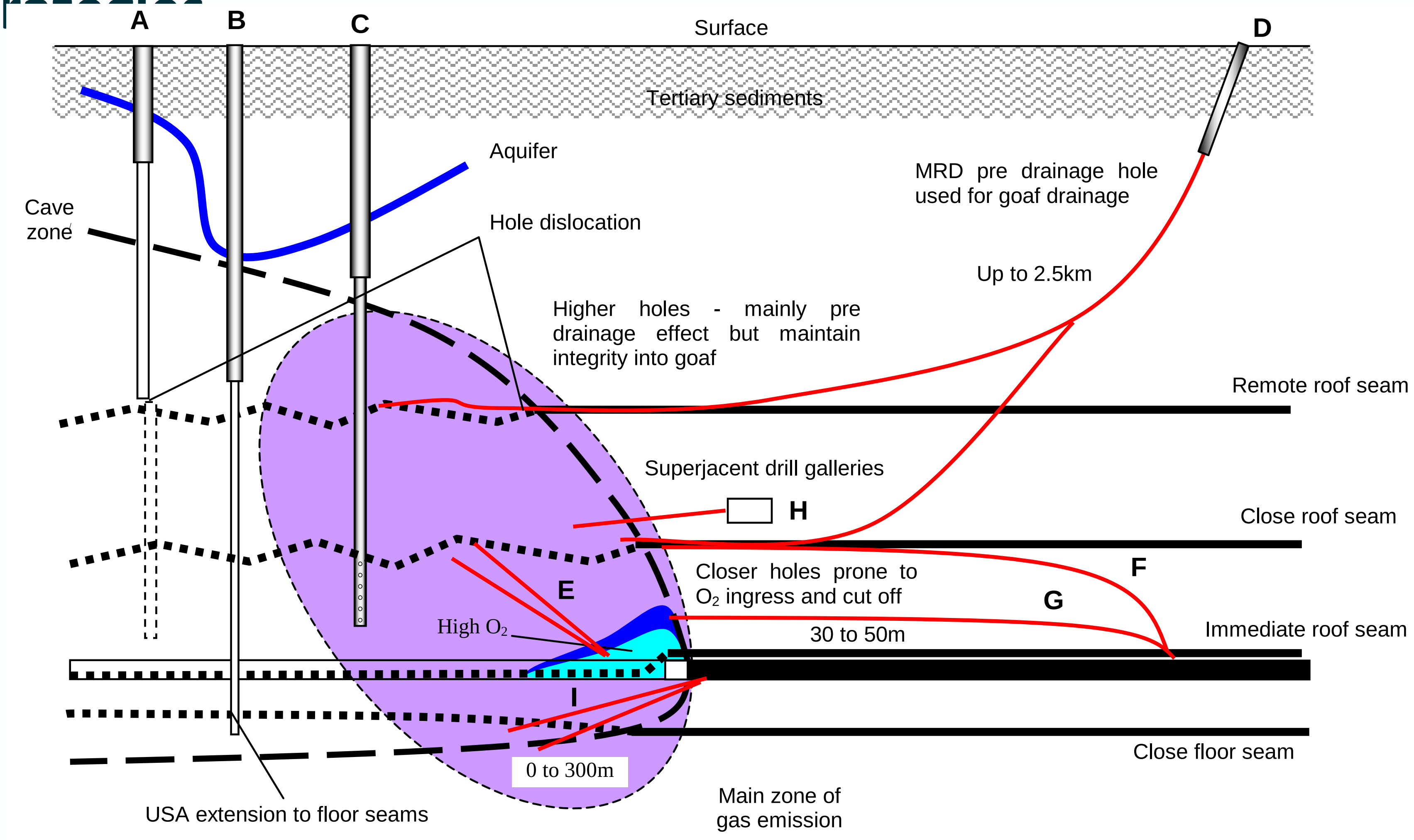




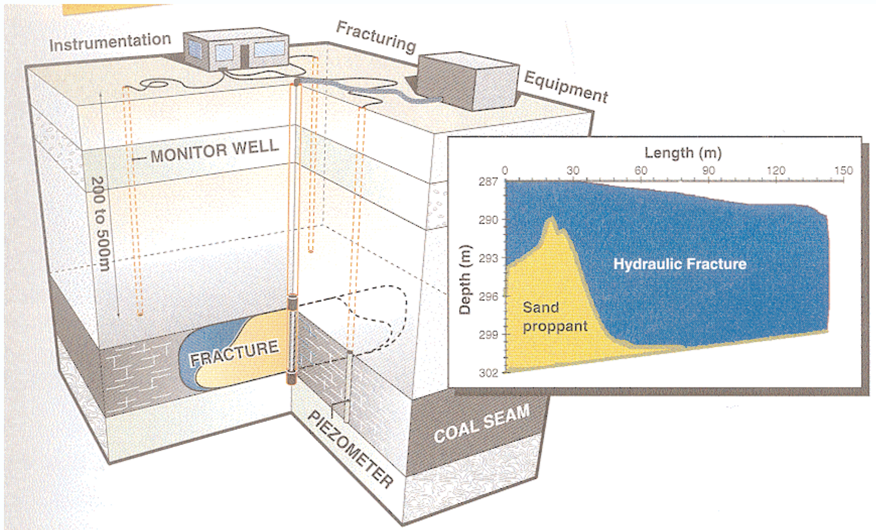


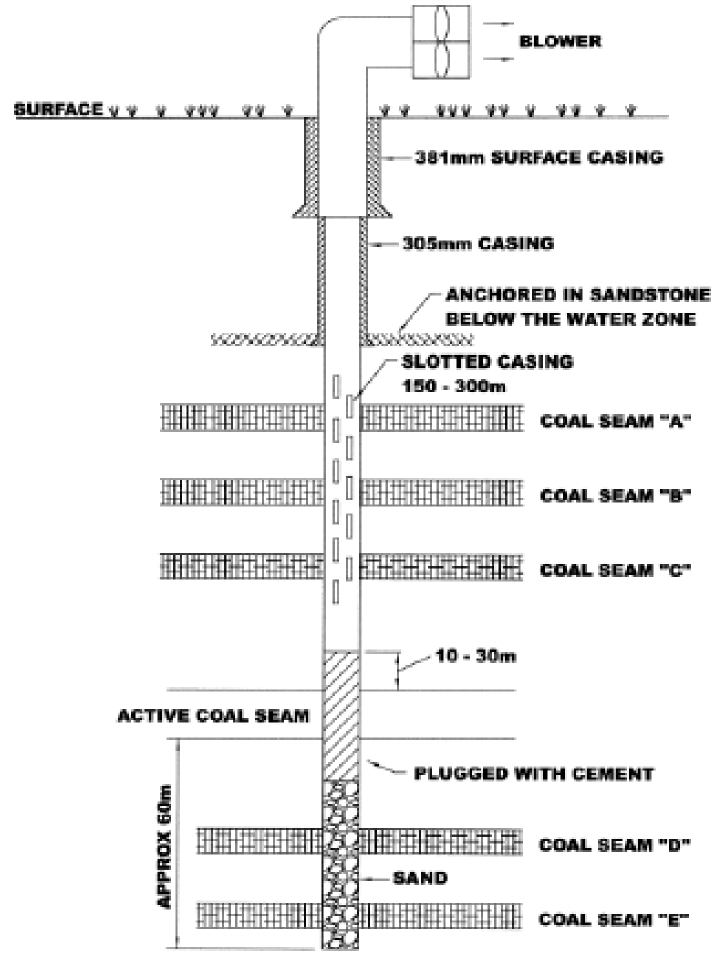


Gas Capture – Alternative post-drainage strategies



Gas Capture – Other techniques





- **Underground patterns +**
  - MRD – standard and reamed
  - Petroleum industry rig capabilities
  - Hydrofracture – multiple completion
  - Nitrogen flushing
  - Pre-drainage – 3 to 10 years ahead

Gas Capture Maximisation (Pre-drainage)

- SIS holes highly successful – but, WS only & 1 – 2 years ahead
  - SIS holes to be used for drainage of upper seams
  - SIS drainage to be implemented 3 – 10 years ahead
- Gas drainage to be carried out, wherever feasible
  - when capturing additional 100's l/s gas costs < CO_2-e charge. For example, capturing additional 1,000 l/s with $10M/y is feasible
- Additional UG gas pre-drainage (-OR- reduced hole spacing)
- Hydrofrac/stimulation to improve drainage rates & efficiency
- Extensive CBM operations ahead of mining

Gas Capture Maximisation (Post-drainage)

- Goaf gas drainage to be increased from 40% to 80%
  - Deep goaf gas drainage strategies to be implemented, even if not immediately effecting LW return gas levels
  - Gas drainage from overlying and underlying seams
- Both surface and UG goaf gas drainage strategies
- Goaf gas drainage even in low to medium gassy mines
- Trying to achieve 0.3-0.4% CH_4 in LW return (rather than <1%)
- Mine design/vent changes – to maximise gas capture
- Gas capture maximisation practices not widely used
- Increased gas capture – reduces VAM & fugitive emissions

Gas Capture Maximisation – Potential Strategies (1)

- Very low gas emission mines (GRS < 30 m^3/m^2, WS gas < 3 m^3/t)
  - Conventional pre-drainage may not be feasible
  - Consider sealed area goaf drainage, if significant
- Low gas emission mines (30 < GRS < 50 m^3/m^2, 3 < WS < 5 m^3/t)
  - Viability of stimulated pre-drainage to be considered
  - Consider goaf drainage of active and sealed areas
- Medium gas emission mines (50 < GRS < 80 m^3/m^2, WS < 7 m^3/t)
  - Consider pre-drainage of both working and other seams
  - Goaf drainage of active and sealed areas required
  - VAM mitigation with or without split ventilation

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Gas Capture Maximisation – Potential Strategies (2)

- High gas emission mines (80 < GRS < 110 m^3/m^2, WS > outburst)
  - Pre-drainage required – and consider increased intensity
  - Pre-drainage of non-working seams too
  - Goaf and sealed area drainage required - and increased efficiency
  - VAM mitigation required for part or all (with or without split vent)
  - Additional gas capture strategies to be considered
- Very high gas emission mines (GRS > 110 m^3/m^2, WS > outburst)
  - All of above +
  - Gas reservoir stimulation techniques
  - Pre-drainage of any interburden/roof gas reservoir strata

GHG Friendly Mine – Ideal Scenario (1)

- Gas drainage – not just for 'gas control', but for 'gas capture'
- Mine/Vent design – allows max gas capture & minimises VAM
- Increased pre-drainage of all coal seams (even when not required)
- Pre-drainage 3 to 10 years ahead
- Active/sealed/deep goaf drainage (even when not required)
- Goaf gas capture – even at low flow rates with low CH_4
- Introducing alternative strategies to increase gas capture

- All captured gas is used for power generation or flared

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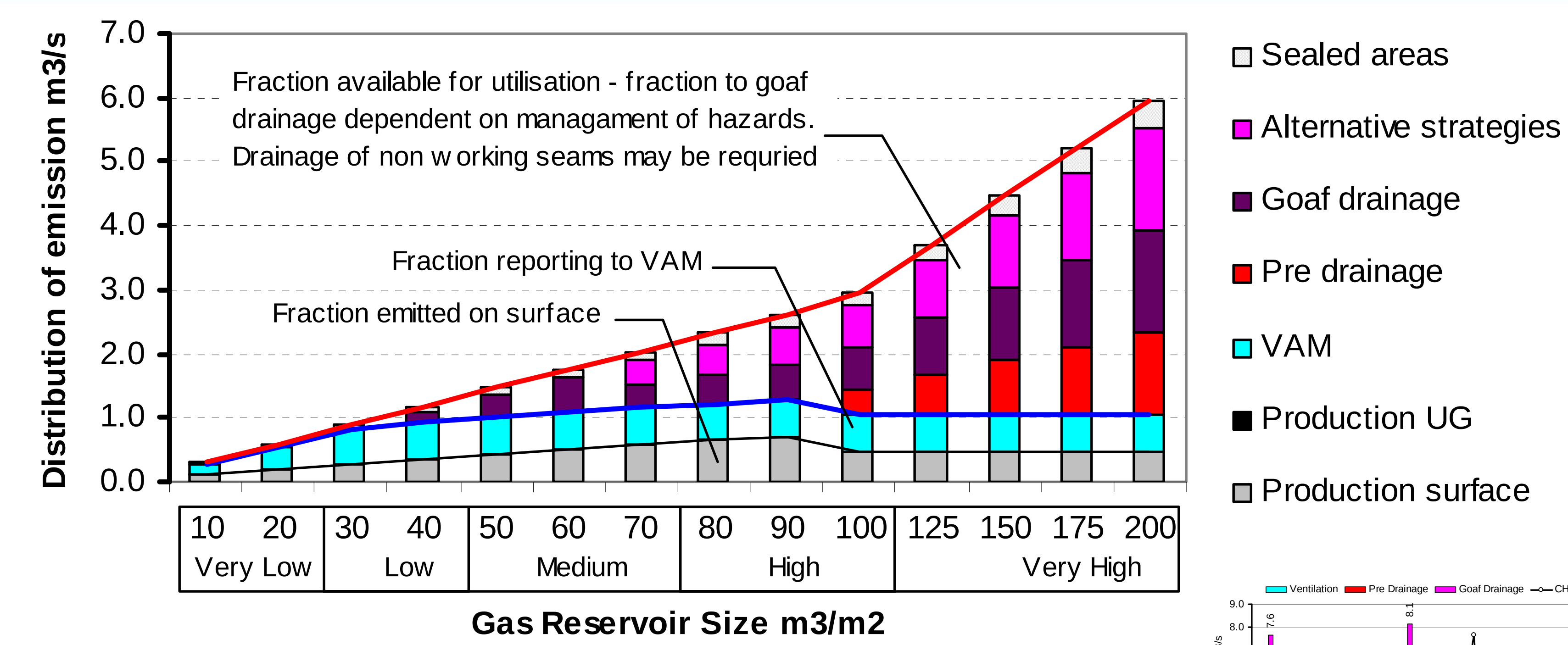
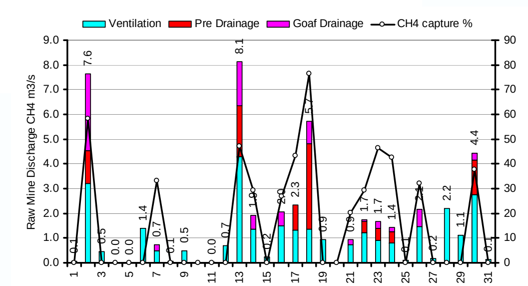
GHG Friendly Mine – Ideal Scenario (2)

- Avoiding methane emissions in ventilation air



LW gas emissions in m^3/s at 3.0Mtpy – ideal gas capture scenario



Typical gas drainage scenario

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Gas Capture Maximisation – Research Requirements

- Improved gas reservoir characterisation & Q3 determination
- Gas content measurement of all seams after LW retreat
- Gas capture maximisation strategies
- Mine design/layout optimisation for increased gas capture
- Vent design changes for optimum VAM mitigation
- Gas capture in low gassy mines & safe systems for low CH_4% drainage
- Gas reservoir stimulation techniques
- Accurate measurement of air flows and fugitive emissions

Conclusions

- Fugitive emissions > 27 Mt CO_2-e (impact on UG mines is large)
- Current gas drainage practice – for outburst and gas control
- VAM 30 m^3/s out of 50 m^3/s from UG mines (~80-85% fugitive emissions)
- The concept of VAM mitigation alone should be the main focus, as 85% fugitive emissions are VAM – requires a change in approach
- Scope to reduce VAM significantly, through improved gas capture
- Requires a fundamental shift in our approach (from “Gas Control” to “Gas Capture Maximisation”) - to achieve “near zero emissions”

Thank you

Dr Rao Balusu
Mining Research Group Leader

t +61 7 3327 4614
e rao.balusu@csiro.au
w www.csiro.au