SMI MISHC
Minerals Industry Safety & Health Centre

Effective response to an emergency at an underground coal mine

David Cliff

The University Of Queensland
AUSTRALIA

Key questions

- What do recent events tell us about our capacity to react effectively to an emergency?
- What are the problems identified at these incidents?
- Are we different/better than them?

Emergency Response

or

Key things to remember

- Ideal gas law
- Conservation of mass
- How big atmospheric pressure is compared to the mine differential pressure
- You cant get negative gas concentrations
- Air moves from high pressure to low pressure
- A mixed gas atmosphere does not unmix
- Buoyancy is as much influence by the temperature of the gas as its density at RTP
- The ventilation officer is a very important role

Summary

- Computers are wonderful aids but there is no substitution for knowledge and the capacity to think.

Treat an underground coal mine just like a chemical processing plant.

- Exercise the same level of control and real time monitoring over key chemicals, i.e. flow and concentration
  - Air quality in returns
  - Real time velocity/differential pressure at key points in the mine
  - Temperature and humidity
  - Air quality in the intakes
  - Smoke detection

Ways forward and challenges

- Reliable personnel location in mines
- Explosion resistant communications systems
- The ability to assess the air quality at key locations in a mine after an explosion/incident where there is loss of underground power
- Robust self escape systems
- Better resourced ventilation management departments
- Better resourced and organised control rooms
- The ability to rapidly isolate part of a mine
- The ability to rapidly seal a mine
- The ability to inert part or all of a mine quickly

Window of opportunity

From available monitoring data we must be able to:

- determine current status throughout mine
- Predict future atmospheres, including:
  - rates of change
  - key influences on atmospheres including:
  - Air leakage
  - Flammable gas movement
  - Effect of barometer
- Estimate uncertainty in determinations so that margins for error and margin of safety can be established
- Find evidence of ignition source, absence of evidence is different to evidence of no ignition source
- Know how representative of the mine environment is the monitoring data

CAMGAS Operator 1992

CO > 10 ppm

H_2 > 50 ppm

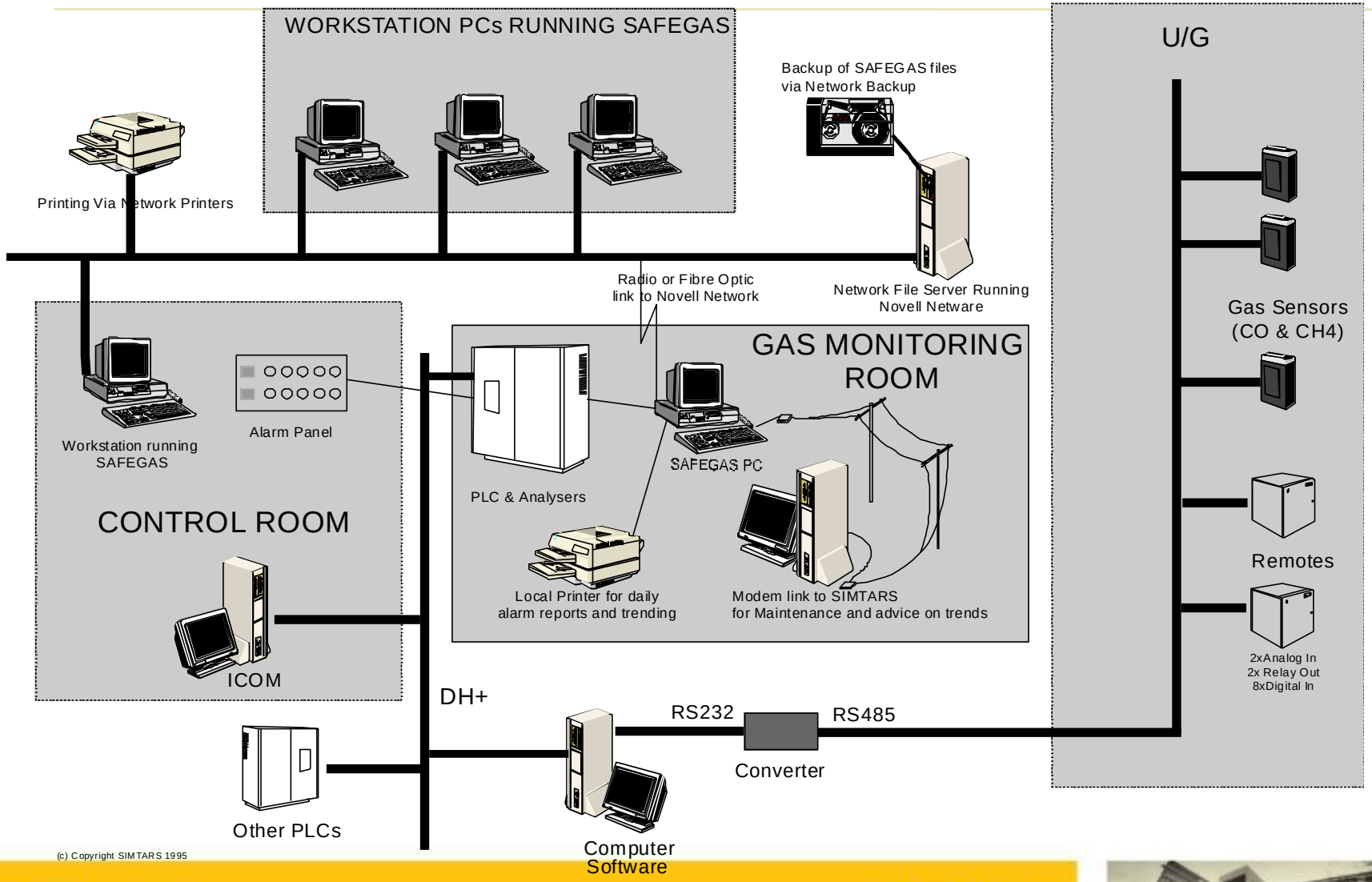
Runtime 30 – 45 minutes

SMARTGAS

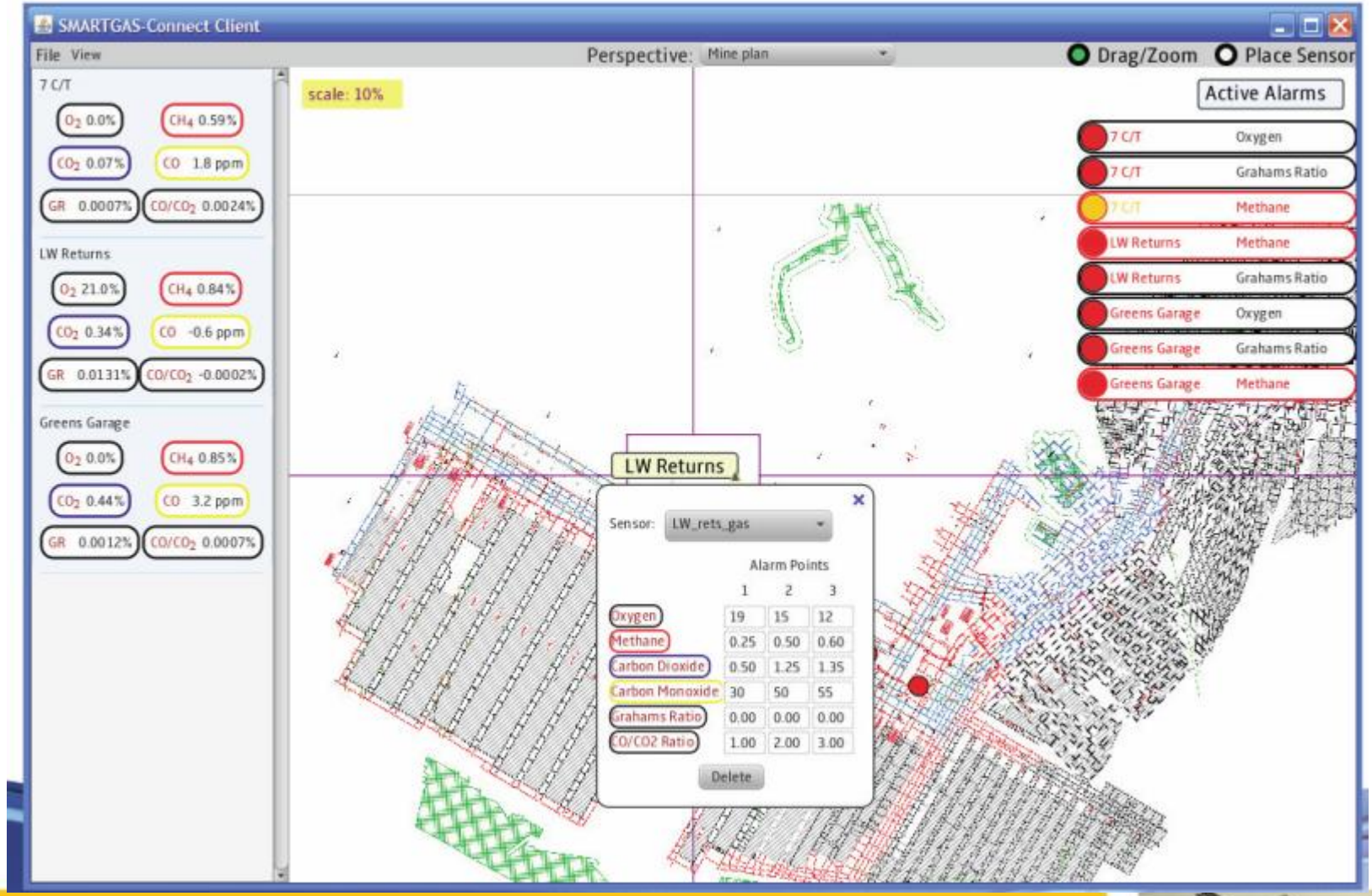
CO and H_2 < 1 ppm

Runtime < 60 seconds

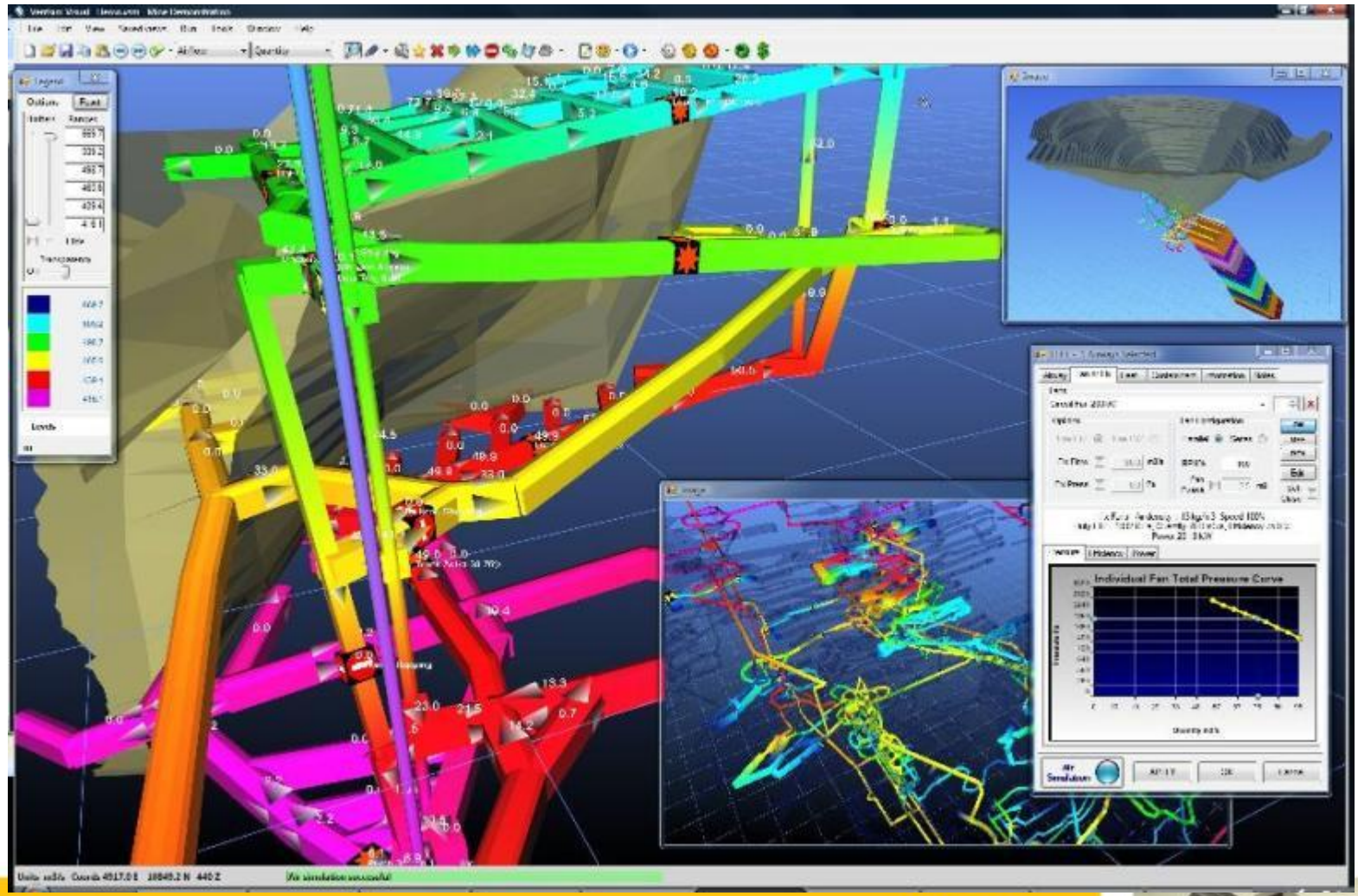
SAFEGAS System with Realtime Sensors



SMARTGAS - CONNECT



Ventilation simulation



Models never lie

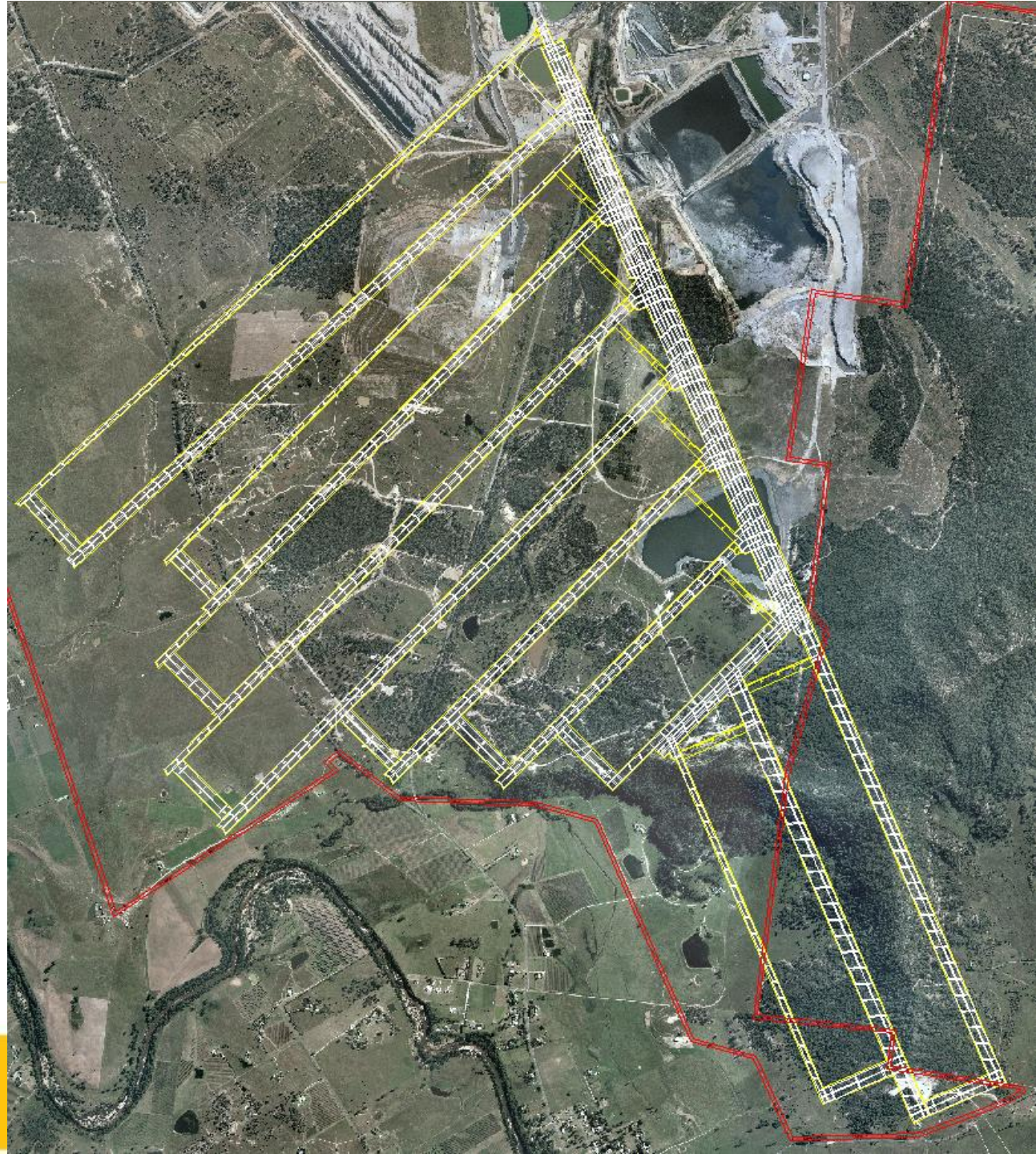
	CORE Sample gas % (AF)	As received
Helium	1.8876	0.006
Hydrogen	0.3146	0.001
Oxygen	0	20.9
Nitrogen	28.6914	78.0
Methane	72.3561	0.23
Carbon Monoxide	0.1573	<0.0005
Carbon Dioxide	5.3714	0.05
Ethylene	0.6292	<0.002
Ethane	0.6292	<0.002
Argon (calculated)	-10.0369	0.9

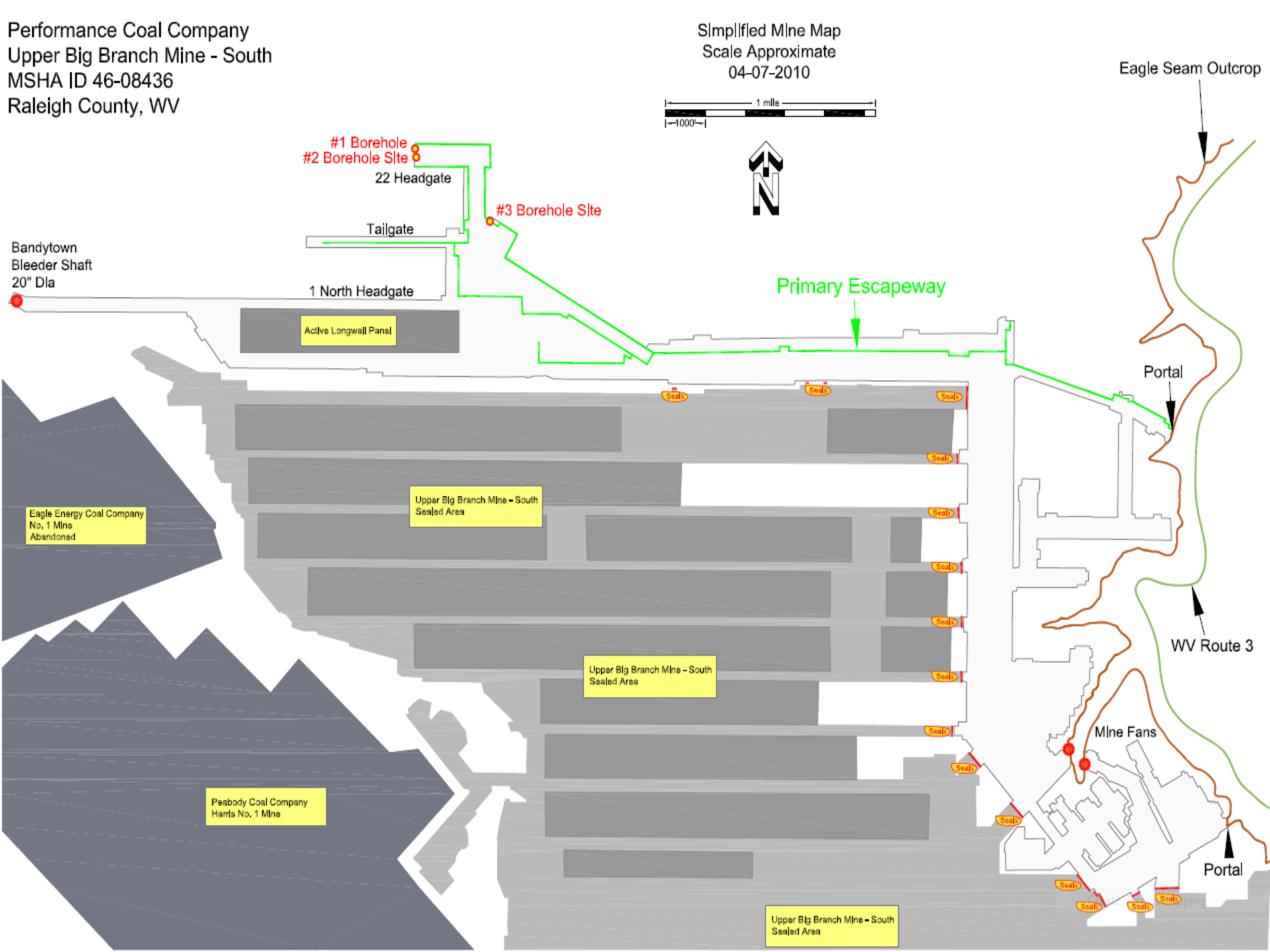
Mine Plan

Mine Layout

Key features:

- LW 400m wide (2.6-3.6m H) (LW1 325m)
- Development (min 3.2m x 5.4m)
  - 3 hdg gateroads
  - 7 hdgs mains
- Force / Exhaust Primary Ventilation System
- Used as access for Glen Munro, Woodlands Hill & Piercefield seams



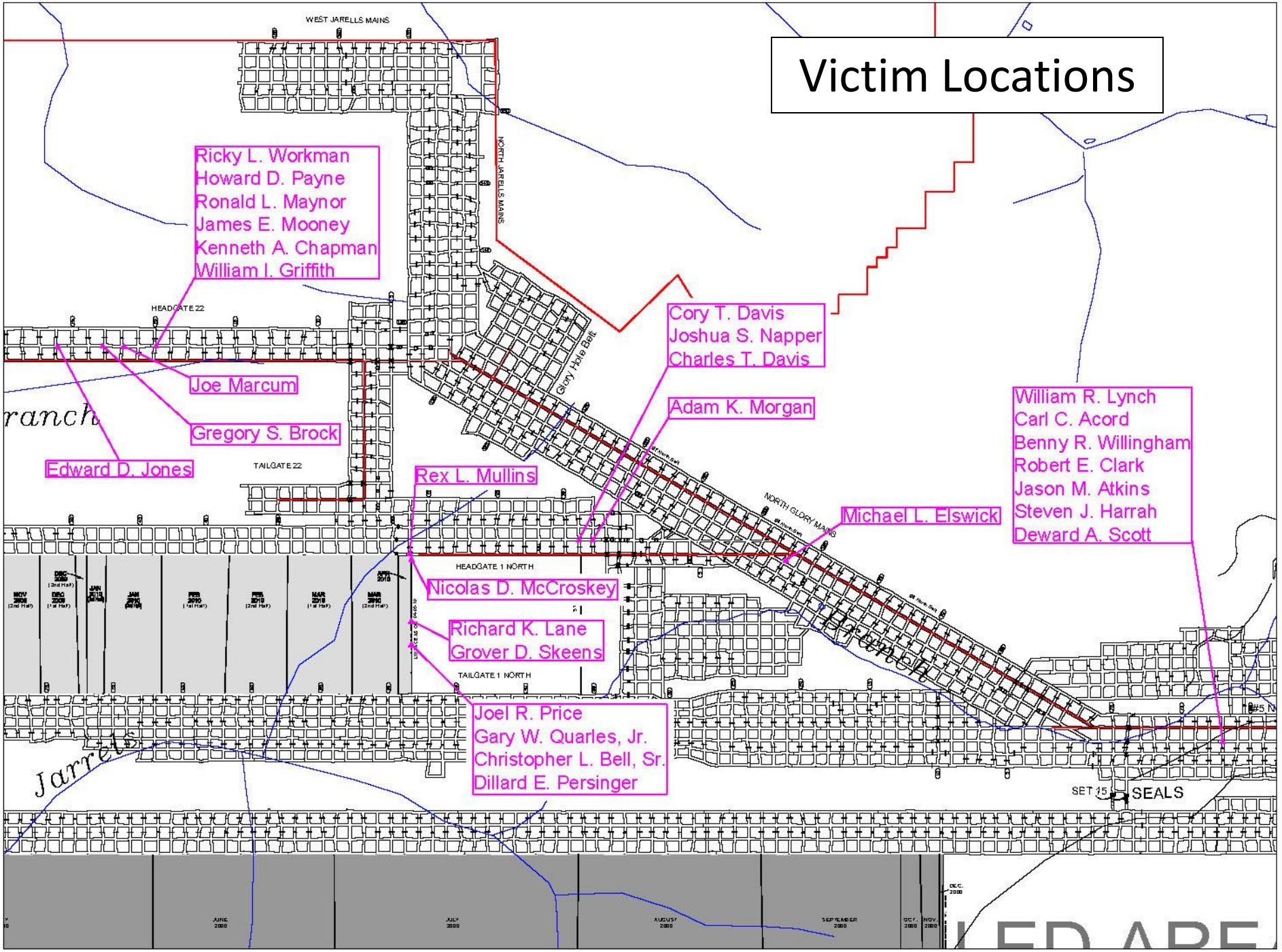

Performance Coal Company
Upper Big Branch Mine - South
MSHA ID 46-08436
Raleigh County, WV
Simplified Mine Map
Scale Approximate
04-07-2010
1 mile
1000'
N
Eagle Seam Outcrop
#1 Borehole
#2 Borehole Site
22 Headgate
#3 Borehole Site
Tailgate
Bandytown
Bleeder Shaft
20" Dia
1 North Headgate
Primary Escapeway
Active Longwall Panel
Portal
Seals
Upper Big Branch Mine - South
Sealed Area
Eagle Energy Coal Company
No. 1 Mine
Abandoned
WV Route 3
Mine Fans
Peabody Coal Company
Harris No. 1 Mine
Portal

General Information

- Mine opened September 1, 1994
- Eagle coal seam
  - High Volatile Bituminous Coal
  - Average coal thickness 54 inches
  - Average mining height 84 inches
- Four producing sections
  - 3 continuous miner (CM) sections
  - 1 LW
  - LW moved to Logan's Fork Mine in 2006, returned to UBB in 2009
- Workforce
  - 234 underground, 2 surface
  - Numerous contractors
- Overlapping and staggered shift schedules
  - Two production shifts, one maintenance shift (midnight)
- Coal production, 1.2 million raw tons in 2009

Description of the Accident

- At approximately 3:02 PM
  - Electrical power at the Ellis Portal went off
    - Power cable ran through mine
  - Dust and debris blown out of the portals
  - Mine fans at the UBB portal stalled
  - CO monitoring system started alarming (belt monitoring)
- Several miners near the portals evacuated the mine
- Surface personnel began notifying underground (UG) personnel to evacuate
- 29 miners unaccounted for


Victim Locations
WEST JARELLS MAINS
NORTH JARELLS MAINS
Ricky L. Workman
Howard D. Payne
Ronald L. Maynor
James E. Mooney
Kenneth A. Chapman
William I. Griffith
HEADGATE 22
Joe Marcum
Gregory S. Brock
Edward D. Jones
TAILGATE 22
Cory T. Davis
Joshua S. Napper
Charles T. Davis
Glory Hole Belt
Adam K. Morgan
Rex L. Mullins
NORTH GLORY MAINS
Michael L. Elswick
William R. Lynch
Carl C. Acord
Benny R. Willingham
Robert E. Clark
Jason M. Atkins
Steven J. Harrah
Deward A. Scott
HEADGATE 1 NORTH
Nicolas D. McCroskey
Richard K. Lane
Grover D. Skeens
TAILGATE 1 NORTH
Joel R. Price
Gary W. Quarles, Jr.
Christopher L. Bell, Sr.
Dillard E. Persinger
SET 15
SEALS

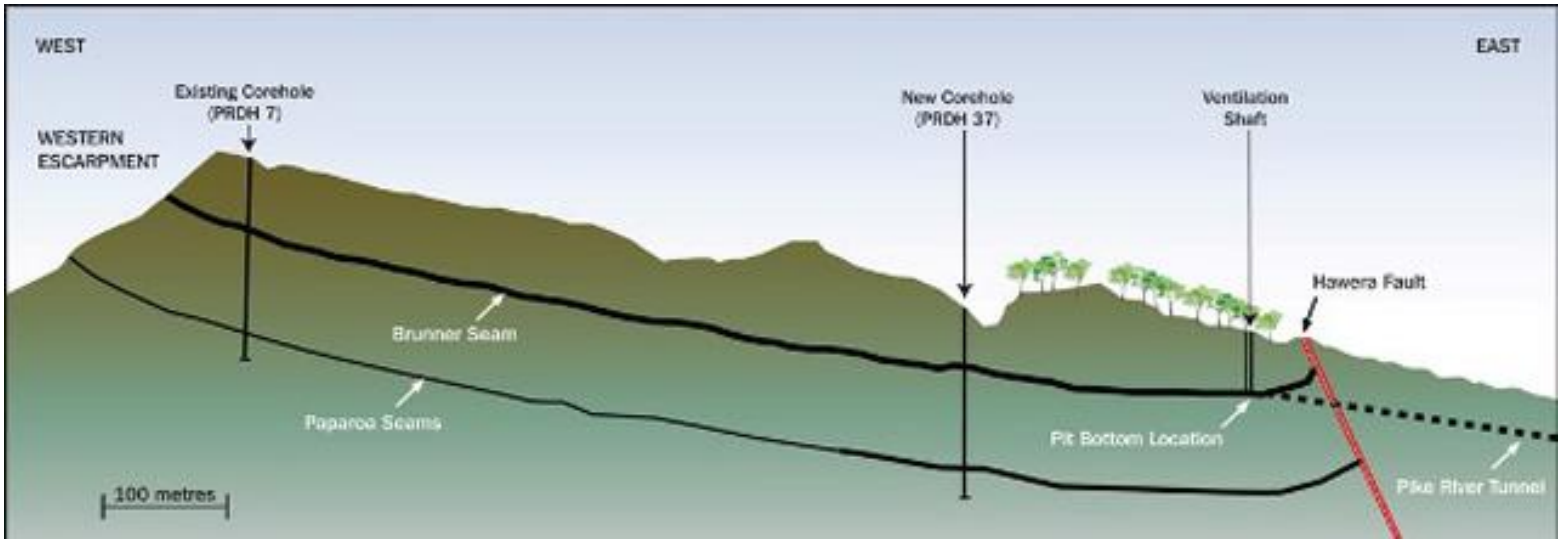
UBB actions

- Rescuers went straight into mine – got all the way to LW face
- Rescuers report over range CO and methane at HG22
- Boreholes drilled
- Thursday - borehole reports explosive atmosphere – rescue abandoned
- Rescuers re-enter mine Friday find high CO and smoke – ordered to exit mine – evidence of an active fire

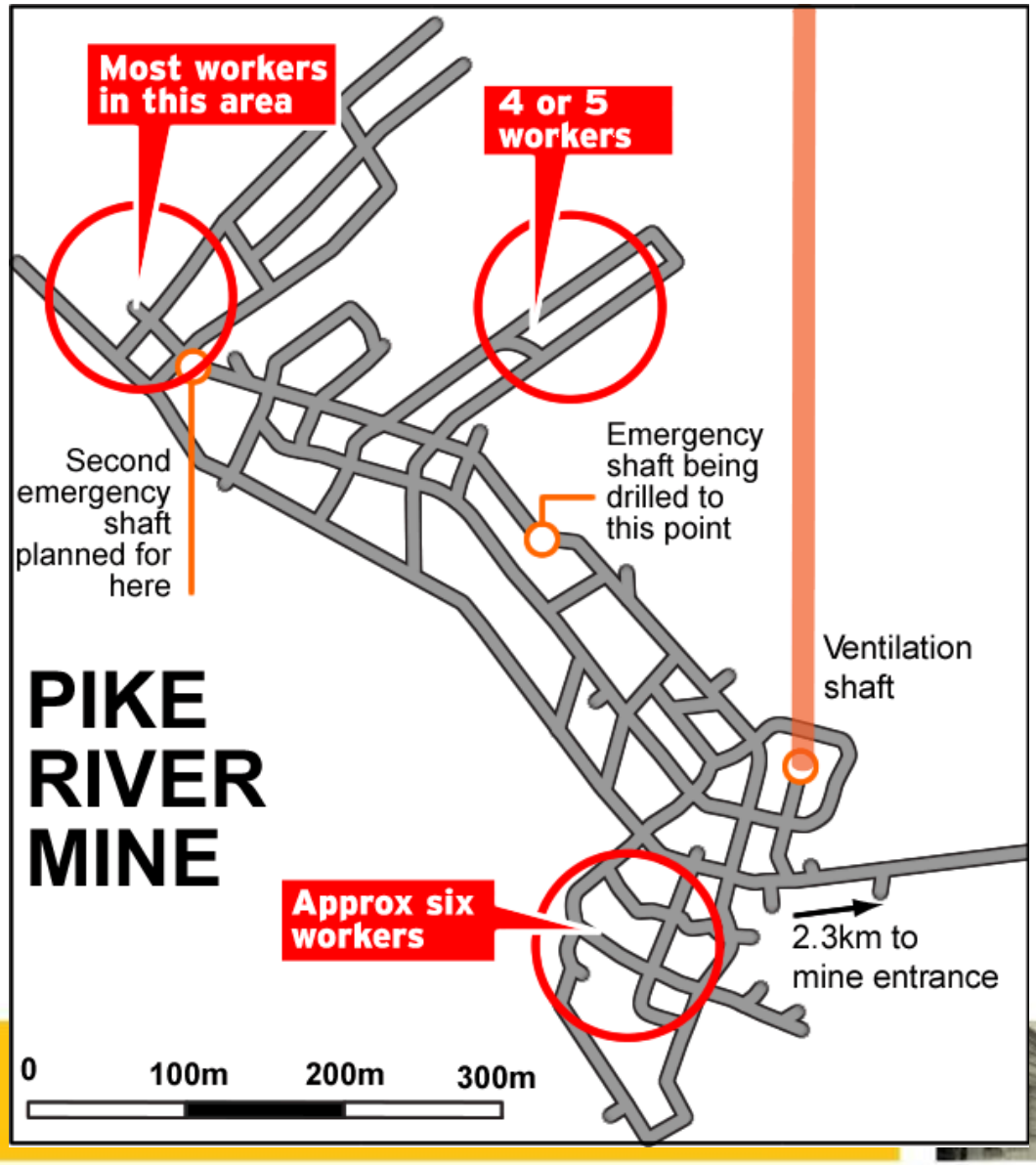
UBB actions

- Nitrogen inertisation used to render atmosphere non flammable
- Rescuers brave high CO concentrations to rescue bodies
- Once all bodies retrieved mine declared too dangerous for persons to remain underground.
- Investigators have to wait over two months before it is deemed safe to re-enter

Pike River Coal Mine November 2010



Pike River November 2010



After the 3rd explosion


Multi-Trans
HEAVY HAUL
VOLVO
OVER
SIZE


HireQuip

The issues

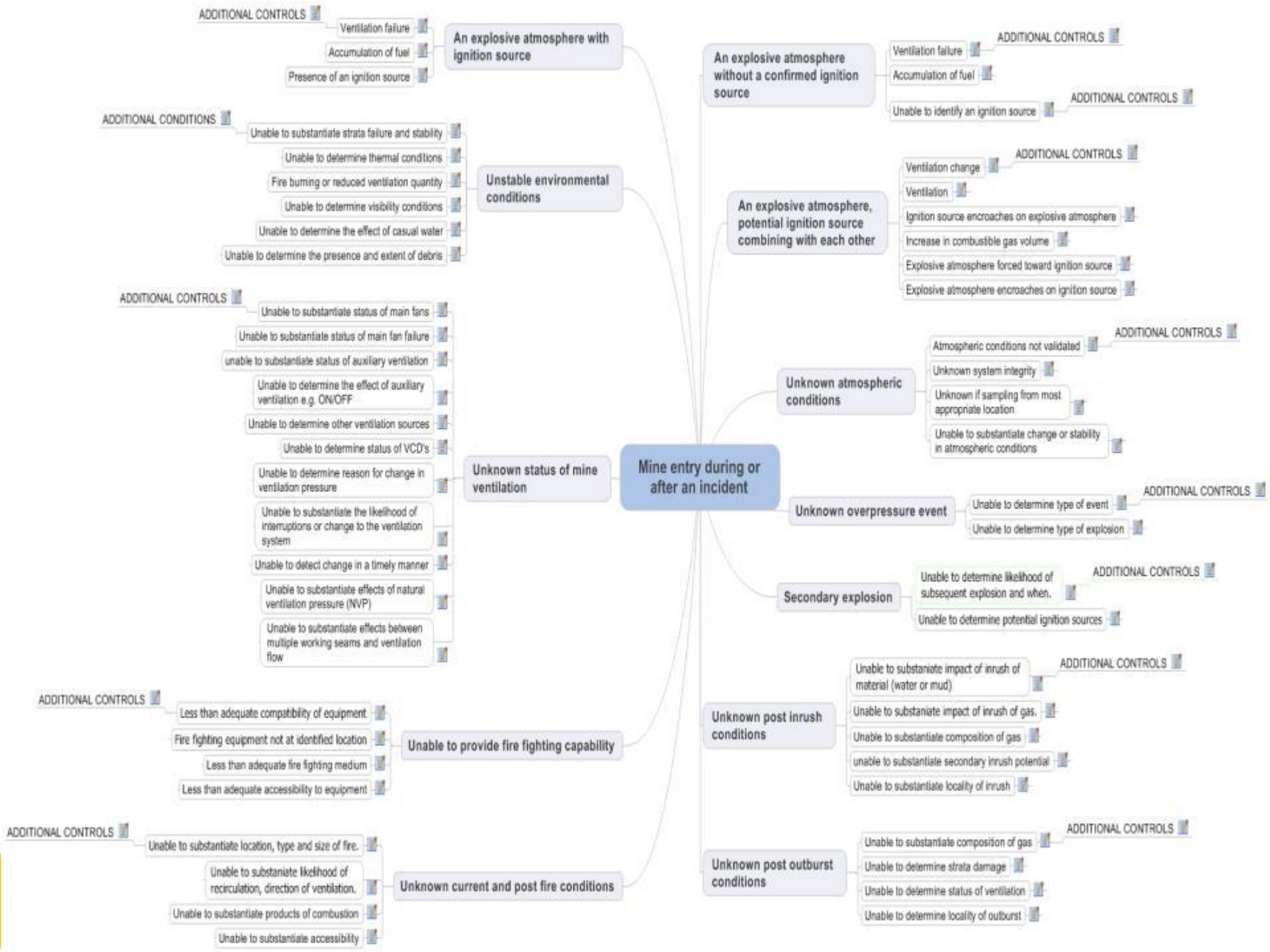
- In each case:
  - Explosion has occurred
  - People still underground
  - No gas monitoring in place
  - No communications with underground
  - Methane seam gas
  - Unknown ventilation circuits
  - In all cases fires found after explosion

Emergency Response

or

Why?

INADEQUATE INFORMATION TO MAKE INFORMED DECISIONS


Mine entry during or after an incident
An explosive atmosphere with ignition source
ADDITIONAL CONTROLS
Ventilation failure
Accumulation of fuel
Presence of an ignition source
Unstable environmental conditions
ADDITIONAL CONDITIONS
Unable to substantiate strata failure and stability
Unable to determine thermal conditions
Fire burning or reduced ventilation quantity
Unable to determine visibility conditions
Unable to determine the effect of casual water
Unable to determine the presence and extent of debris
Unknown status of mine ventilation
ADDITIONAL CONTROLS
Unable to substantiate status of main fans
Unable to substantiate status of main fan failure
unable to substantiate status of auxiliary ventilation
Unable to determine the effect of auxiliary ventilation e.g. ON/OFF
Unable to determine other ventilation sources
Unable to determine status of VCD's
Unable to determine reason for change in ventilation pressure
Unable to substantiate the likelihood of interruptions or change to the ventilation system
Unable to detect change in a timely manner
Unable to substantiate effects of natural ventilation pressure (NVP)
Unable to substantiate effects between multiple working seams and ventilation flow
Unable to provide fire fighting capability
ADDITIONAL CONTROLS
Less than adequate compatibility of equipment
Fire fighting equipment not at identified location
Less than adequate fire fighting medium
Less than adequate accessibility to equipment
Unknown current and post fire conditions
ADDITIONAL CONTROLS
Unable to substantiate location, type and size of fire.
Unable to substaniate likelihood of recirculation, direction of ventilation.
Unable to substantiate products of combustion
Unable to substantiate accessibility
An explosive atmosphere without a confirmed ignition source
ADDITIONAL CONTROLS
Ventilation failure
Accumulation of fuel
Unable to identify an ignition source
ADDITIONAL CONTROLS
An explosive atmosphere, potential ignition source combining with each other
ADDITIONAL CONTROLS
Ventilation change
Ventilation
Ignition source encroaches on explosive atmosphere
Increase in combustible gas volume
Explosive atmosphere forced toward ignition source
Explosive atmosphere encroaches on ignition source
Unknown atmospheric conditions
ADDITIONAL CONTROLS
Atmospheric conditions not validated
Unknown system integrity
Unknown if sampling from most appropriate location
Unable to substantiate change or stability in atmospheric conditions
Unknown overpressure event
ADDITIONAL CONTROLS
Unable to determine type of event
Unable to determine type of explosion
Secondary explosion
ADDITIONAL CONTROLS
Unable to determine likelihood of subsequent explosion and when.
Unable to determine potential ignition sources
Unknown post inrush conditions
ADDITIONAL CONTROLS
Unable to substaniate impact of inrush of material (water or mud)
Unable to substaniate impact of inrush of gas.
Unable to substantiate composition of gas
unable to substantiate secondary inrush potential
Unable to substantiate locality of inrush
Unknown post outburst conditions
ADDITIONAL CONTROLS
Unable to substantiate composition of gas
Unable to determine strata damage
Unable to determine status of ventilation
Unable to determine locality of outburst

Guideline for:

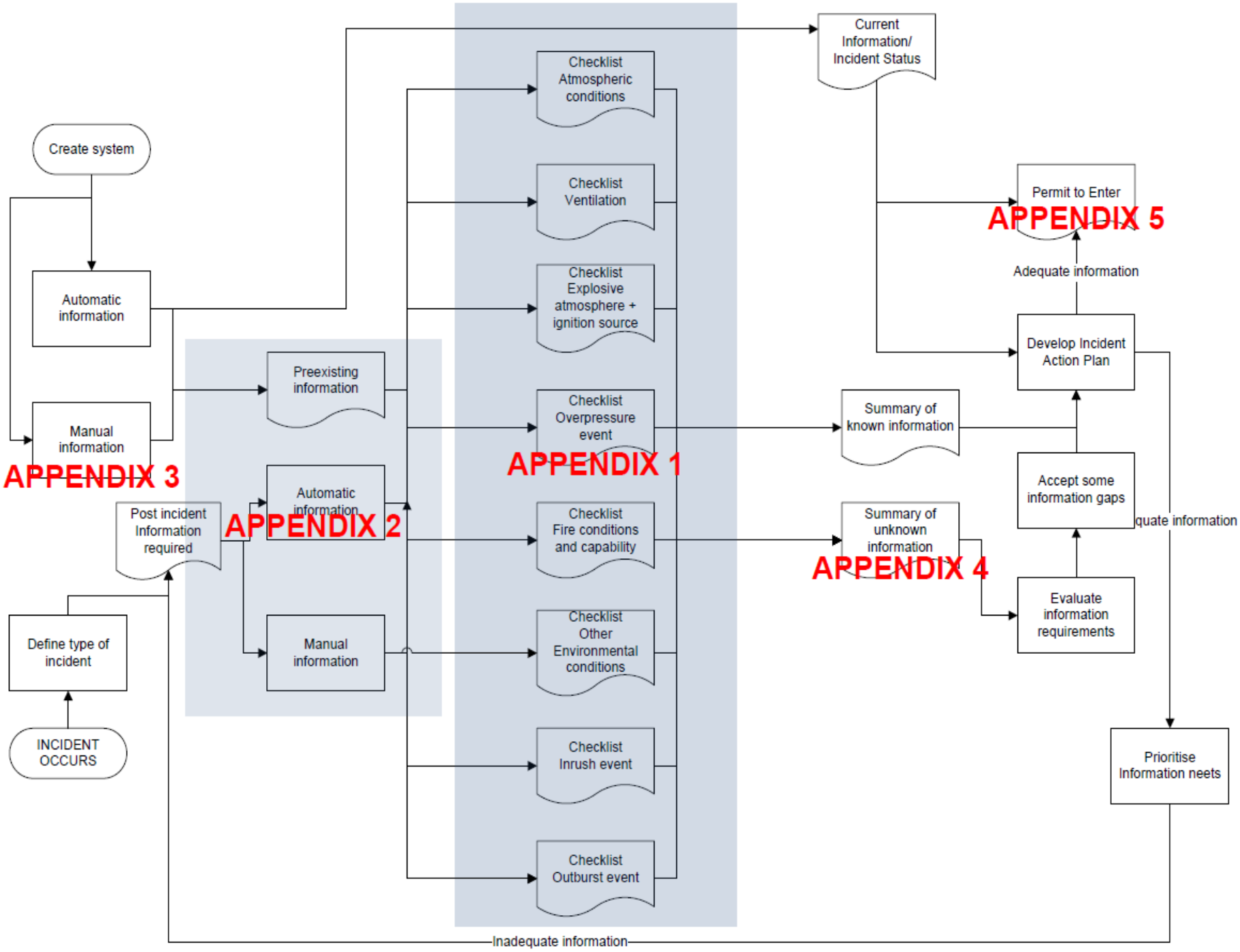
EMERGENCY MINE ENTRY OR RE-ENTRY

Produced by the Queensland Mines Rescue Service and NSW Mines Rescue Service

Queensland Mines Rescue Service Limited
49 Garnham Drive, Dysart QLD 4745
Phone 07 49582244
Fax 07 495827401
www.qmrs.com.au

Mines Rescue Pty Ltd
533 Lake Road, Argenton 2284
(PO Box 41 Boolaroo NSW 2284)
Ph: (02) 4922 4452
Fax: (02) 4950 6629
Email: info@rescue.coalservices.com.au

Rev	Date	Description	Initiated by	Checked by	Approved by
1	16/06/2010	Original	Geoff Nugent	Darren Brady	


Create system
Automatic information
Manual information
APPENDIX 3
Post incident Information required
Define type of incident
INCIDENT OCCURS
Preexisting information
Automatic information
APPENDIX 2
Manual information
Checklist Atmospheric conditions
Checklist Ventilation
Checklist Explosive atmosphere + ignition source
Checklist Overpressure event
APPENDIX 1
Checklist Fire conditions and capability
Checklist Other Environmental conditions
Checklist Inrush event
Checklist Outburst event
Current Information/ Incident Status
Summary of known information
Summary of unknown information
APPENDIX 4
Permit to Enter
APPENDIX 5
Adequate information
Develop Incident Action Plan
Accept some information gaps
Evaluate information requirements
quate information
Prioritise Information neets
Inadequate information

Document Information

Username: Geoff Nugent

Site: Carborough Downs Mine

Please choose the site from the list or create a new site.

Document date: 2010-11-16

Click to select a date for the document.

Scope of document:

- (•) Site Information
- ( ) Incident Information

Back Next

Mines Rescue Pty Limited

ACARP

SMI MISHC
Minerals Industry Safety & Health Centre

MRAS MINE RE-ENTRY ASSESSMENT SYSTEM

1. Firefighting

YES Are the fire fighting resources on site documented?

YES Is all site fire fighting equipment compatible both underground and on the surface?

Notes:

NO Is information readily available on the type of fire fighting equipment available on the mine site?

NO Is information readily available on the quantity of fire fighting equipment available on the mine site?

NO Is the mine self sufficient for all relevant fire fighting media for at least two hours?

NO Are the expected water pressures for fire fighting known?

NO Is the Mines Rescue Service aware of the capability and type of equipment used?

NO Are there adequate numbers of competency based trained persons to conduct fire fighting operations available on all shifts?

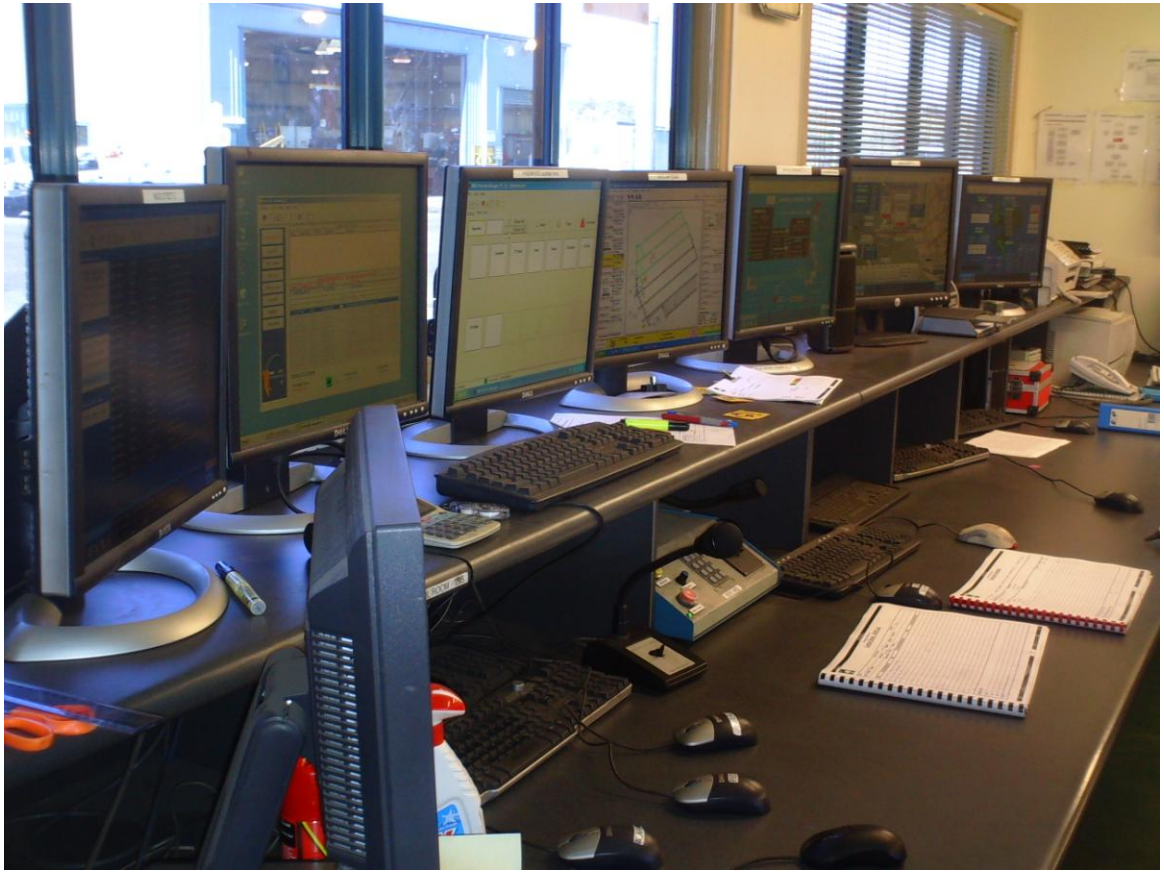
NO Are the mine fire fighting plans up to date?

NO Do the the mine fire fighting plans conform to AS 4368 - 1996?

NO Do MSDS exist on the mine site in readily accessible locations for all fire fighting media?

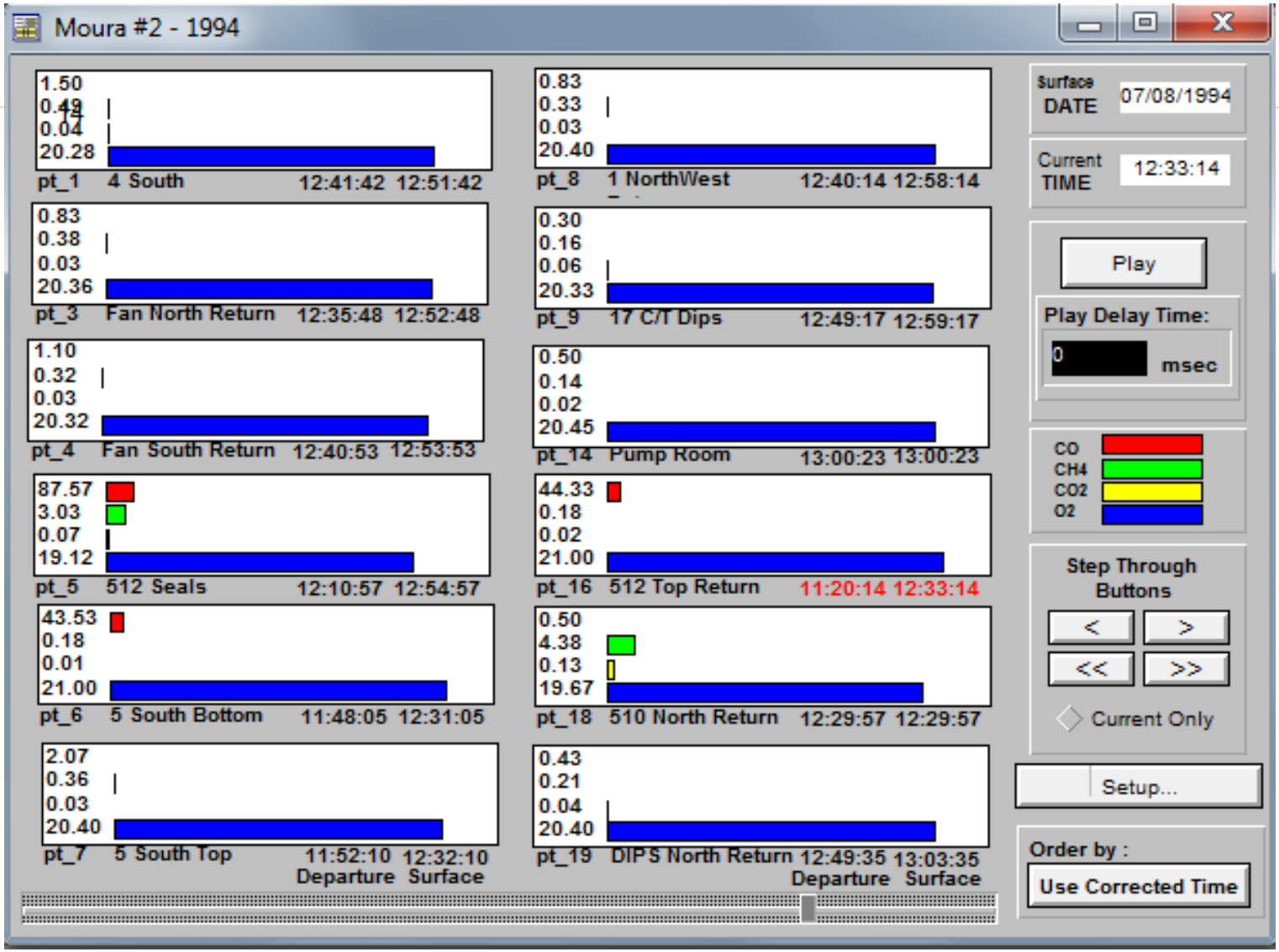
Back Next

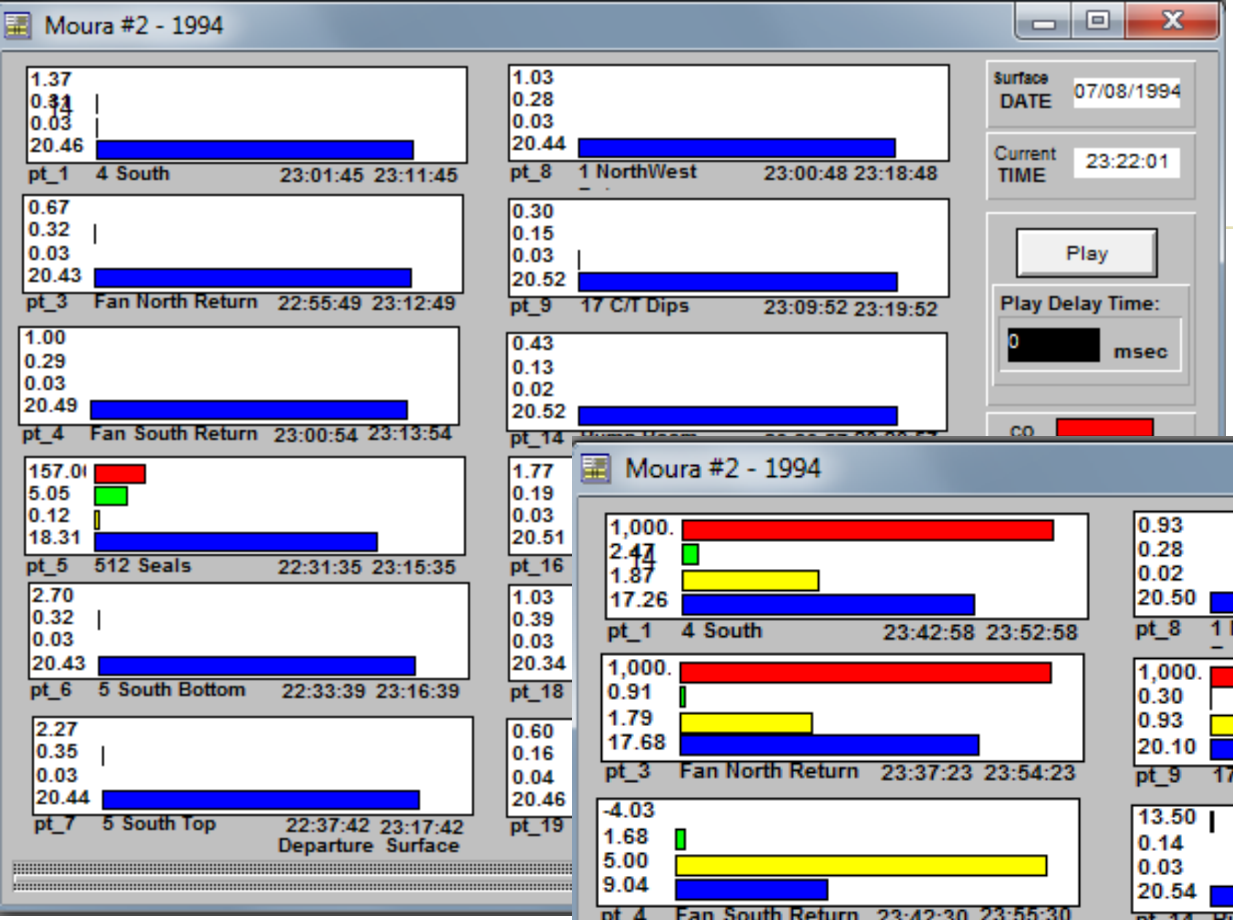
Control Rooms

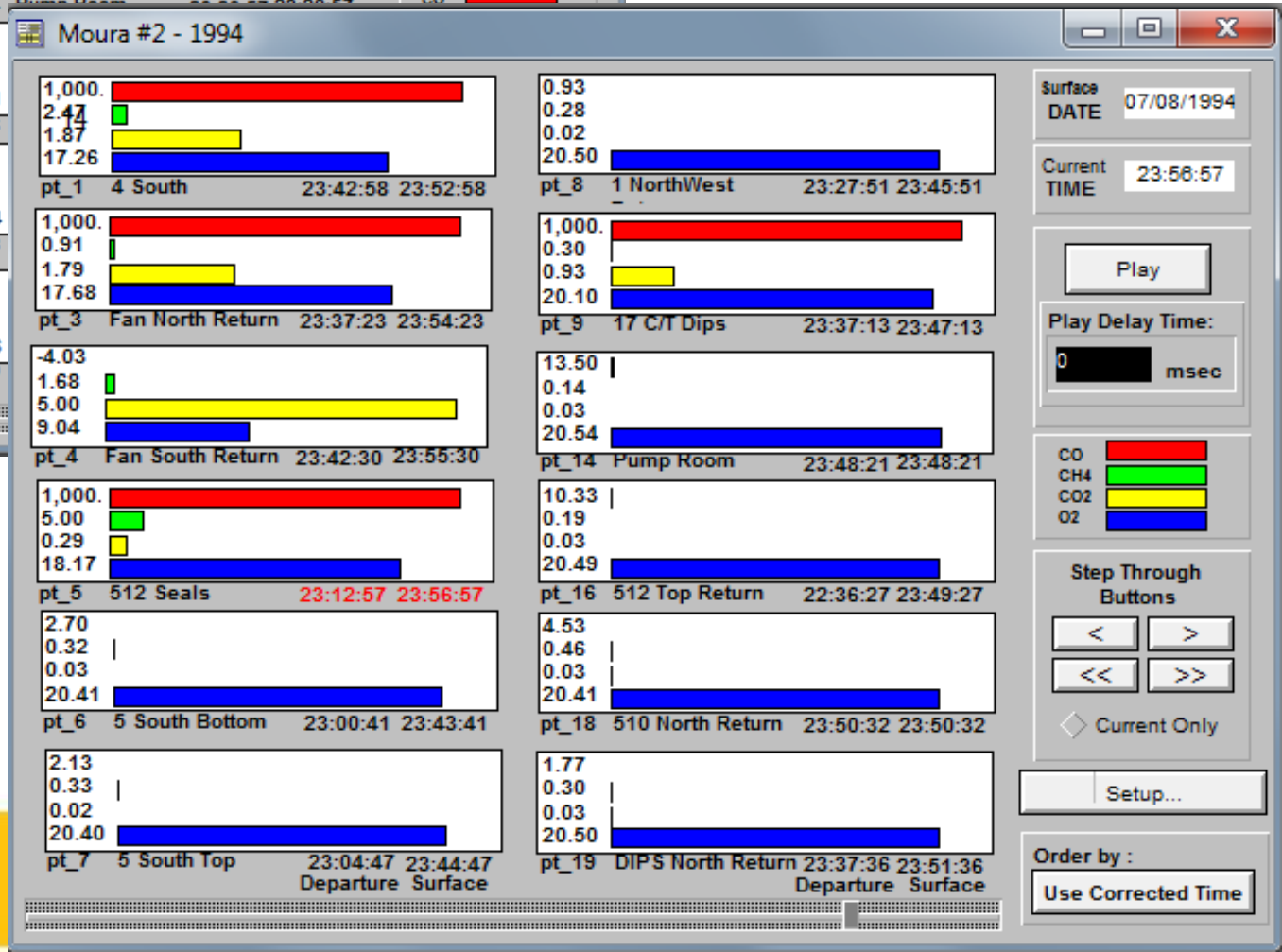


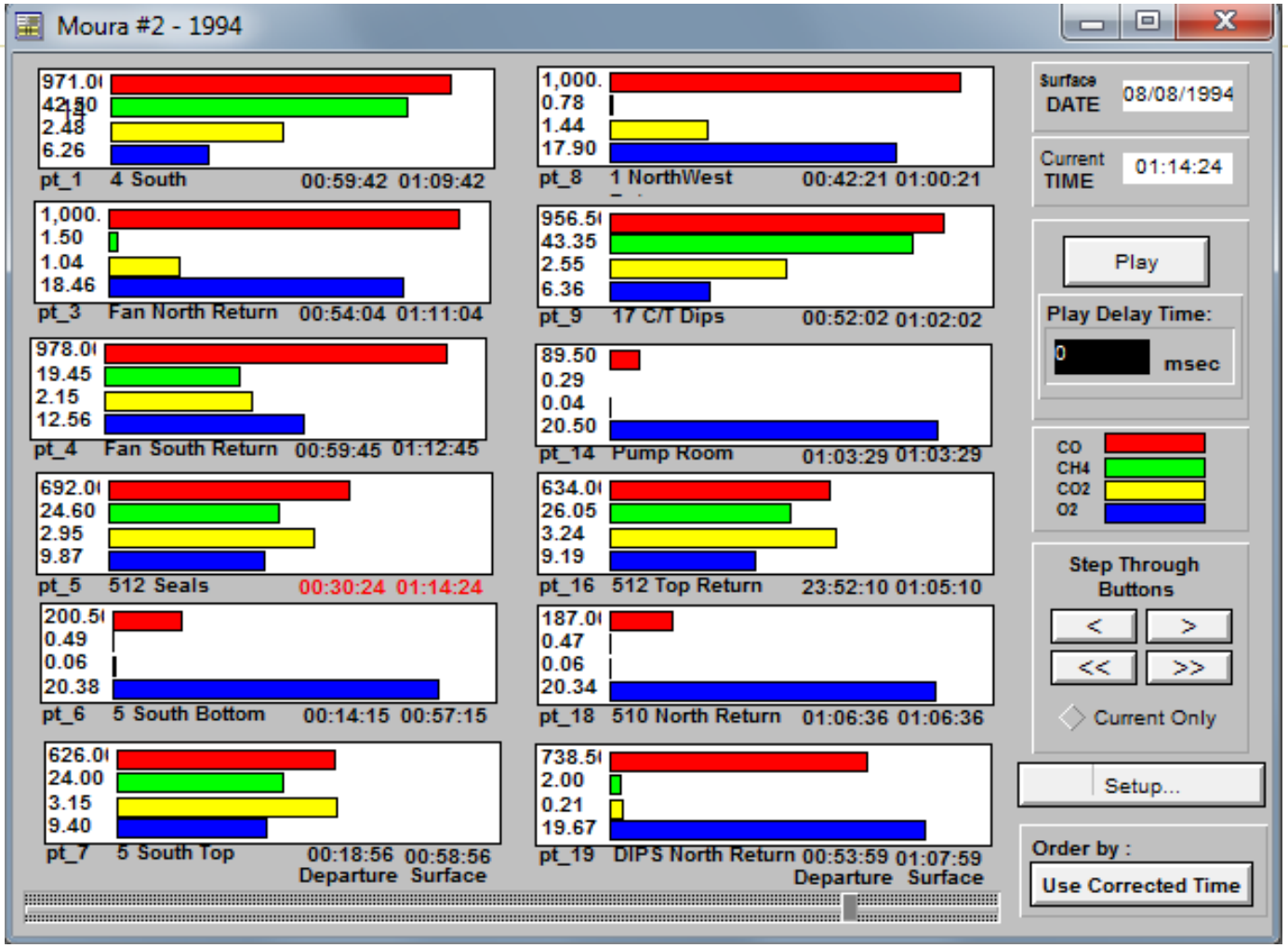
Control Rooms

- Properly trained operators
  - Front line in an emergency
  - Ability to detect abnormality
- Simplify displays
- Simplify alarms
- Discriminate between process alarms and safety alarms
- Know where people are underground


Moura #2 - 1994
1.50
0.49
0.04
20.28
pt_1 4 South 12:41:42 12:51:42
0.83
0.33
0.03
20.40
pt_8 1 NorthWest 12:40:14 12:58:14
0.83
0.38
0.03
20.36
pt_3 Fan North Return 12:35:48 12:52:48
0.30
0.16
0.06
20.33
pt_9 17 C/T Dips 12:49:17 12:59:17
1.10
0.32
0.03
20.32
pt_4 Fan South Return 12:40:53 12:53:53
0.50
0.14
0.02
20.45
pt_14 Pump Room 13:00:23 13:00:23
87.57
3.03
0.07
19.12
pt_5 512 Seals 12:10:57 12:54:57
44.33
0.18
0.02
21.00
pt_16 512 Top Return 11:20:14 12:33:14
43.53
0.18
0.01
21.00
pt_6 5 South Bottom 11:48:05 12:31:05
0.50
4.38
0.13
19.67
pt_18 510 North Return 12:29:57 12:29:57
2.07
0.36
0.03
20.40
pt_7 5 South Top 11:52:10 Departure 12:32:10 Surface
0.43
0.21
0.04
20.40
pt_19 DIPS North Return 12:49:35 Departure 13:03:35 Surface
Surface DATE 07/08/1994
Current TIME 12:33:14
Play
Play Delay Time:
0
msec
CO
CH4
CO2
O2
Step Through Buttons
<
>
<<
>>
Current Only
Setup...
Order by :
Use Corrected Time






Moura #2 - 1994
971.0
42.50
2.48
6.26
pt_1 4 South 00:59:42 01:09:42
1,000.
0.78
1.44
17.90
pt_8 1 NorthWest 00:42:21 01:00:21
1,000.
1.50
1.04
18.46
pt_3 Fan North Return 00:54:04 01:11:04
956.5
43.35
2.55
6.36
pt_9 17 C/T Dips 00:52:02 01:02:02
978.0
19.45
2.15
12.56
pt_4 Fan South Return 00:59:45 01:12:45
89.50
0.29
0.04
20.50
pt_14 Pump Room 01:03:29 01:03:29
692.0
24.60
2.95
9.87
pt_5 512 Seals 00:30:24 01:14:24
634.0
26.05
3.24
9.19
pt_16 512 Top Return 23:52:10 01:05:10
200.5
0.49
0.06
20.38
pt_6 5 South Bottom 00:14:15 00:57:15
187.0
0.47
0.06
20.34
pt_18 510 North Return 01:06:36 01:06:36
626.0
24.00
3.15
9.40
pt_7 5 South Top 00:18:56 00:58:56
Departure Surface
738.5
2.00
0.21
19.67
pt_19 DIPS North Return 00:53:59 01:07:59
Departure Surface
Surface DATE 08/08/1994
Current TIME 01:14:24
Play
Play Delay Time:
0 msec
CO
CH4
CO2
O2
Step Through Buttons
<
>
<<
>>
Current Only
Setup...
Order by :
Use Corrected Time

Ventilation management system requirements

- Quality of information
- Capacity to interpret information
- Calibrated ventilation model – understand the ventilation system of the mine and what influences it
- Properly calibrated and maintained monitoring systems

Ventilation management system requirements

- Understanding of mine environment monitoring system
  - Lag times for tubes
  - Ranges of analysers/sensors
  - Integrity checks
- Understanding of the sources of gas in the mine
- Understanding of what is normal anywhere in the mine
- Understand the limits of what you know
- Understand what you don’t know

The Future

- High operating efficiency longwalls > 100 hours per week
- 7 kilometre gate-roads
- 500 m wide faces
- Top coal caving
- 10 million tonne per year mines
- 1000 m^3/sec mine ventilation

Back to the Future

- The ability to seal parts of the mine in an emergency
- The ability to adjust the ventilation in a mine remotely
- The ability to rapidly inert parts of a mine

However:

- Massive skills shortage
- Loss of practical knowledge and experience in dealing with abnormal conditions
- Lack of recognition of the importance of VO skills

Mine Environment Monitoring in the 21st Century

- To move forward with MEMS we need to treat the underground mine the same or better than a chemical plant with the same level of process control and quality monitoring systems.
- Improved MEMS will:
  - Increase safety
  - Optimise ventilation
    - Create a better working environment
    - Minimise cost
    - Improve productivity

Key things to remember

- Ideal gas law
- Conservation of mass
- How big atmospheric pressure is compared to the mine differential pressure
- You cant get negative gas concentrations
- Air moves from high pressure to low pressure
- A mixed gas atmosphere does not unmix
- Buoyancy is as much influence by the temperature of the gas as its density at RTP
- The ventilation officer is a very important role

Summary

- Computers are wonderful aids but there is no substitution for knowledge and the capacity to think.

Coward Triangle

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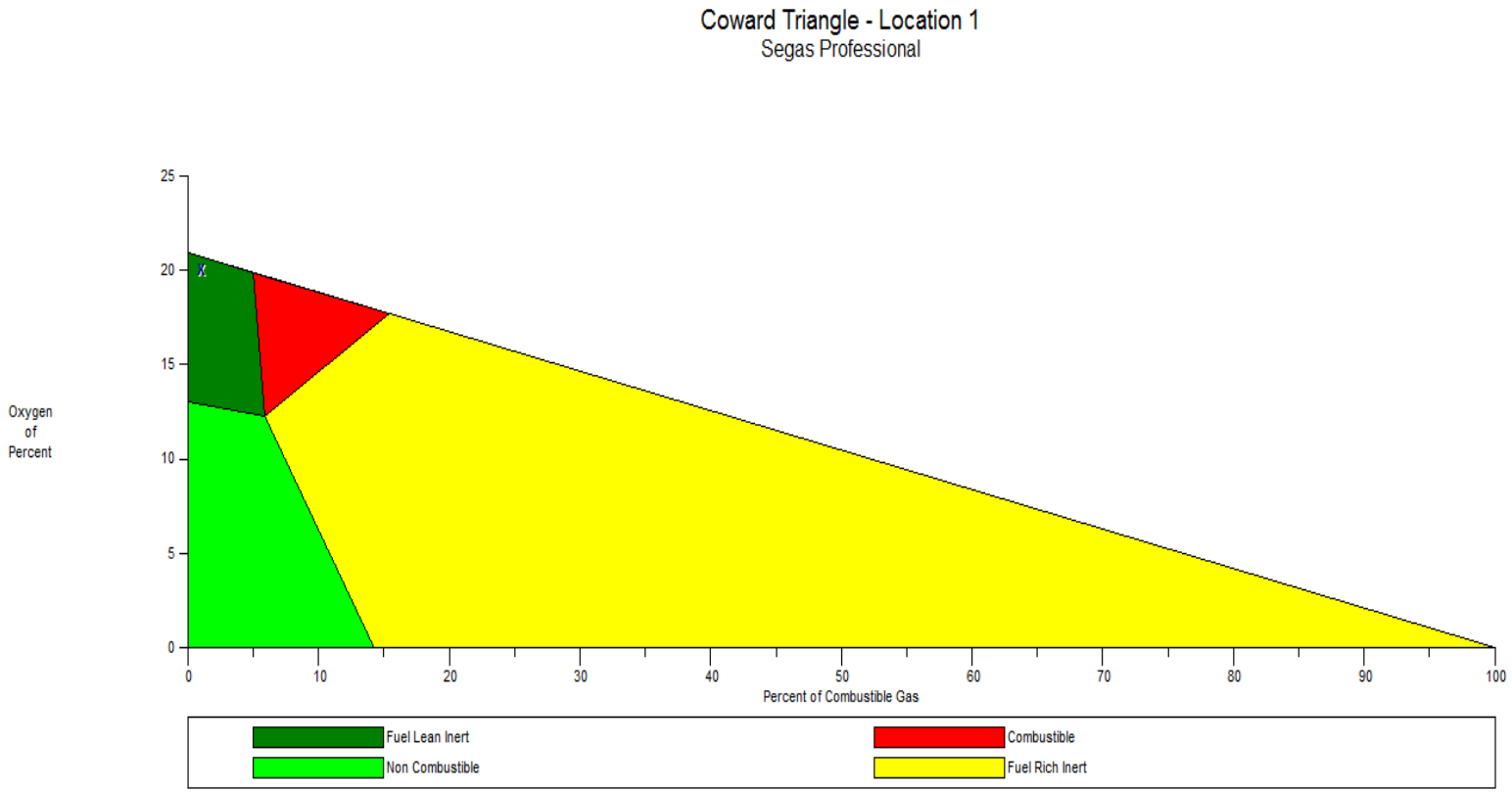
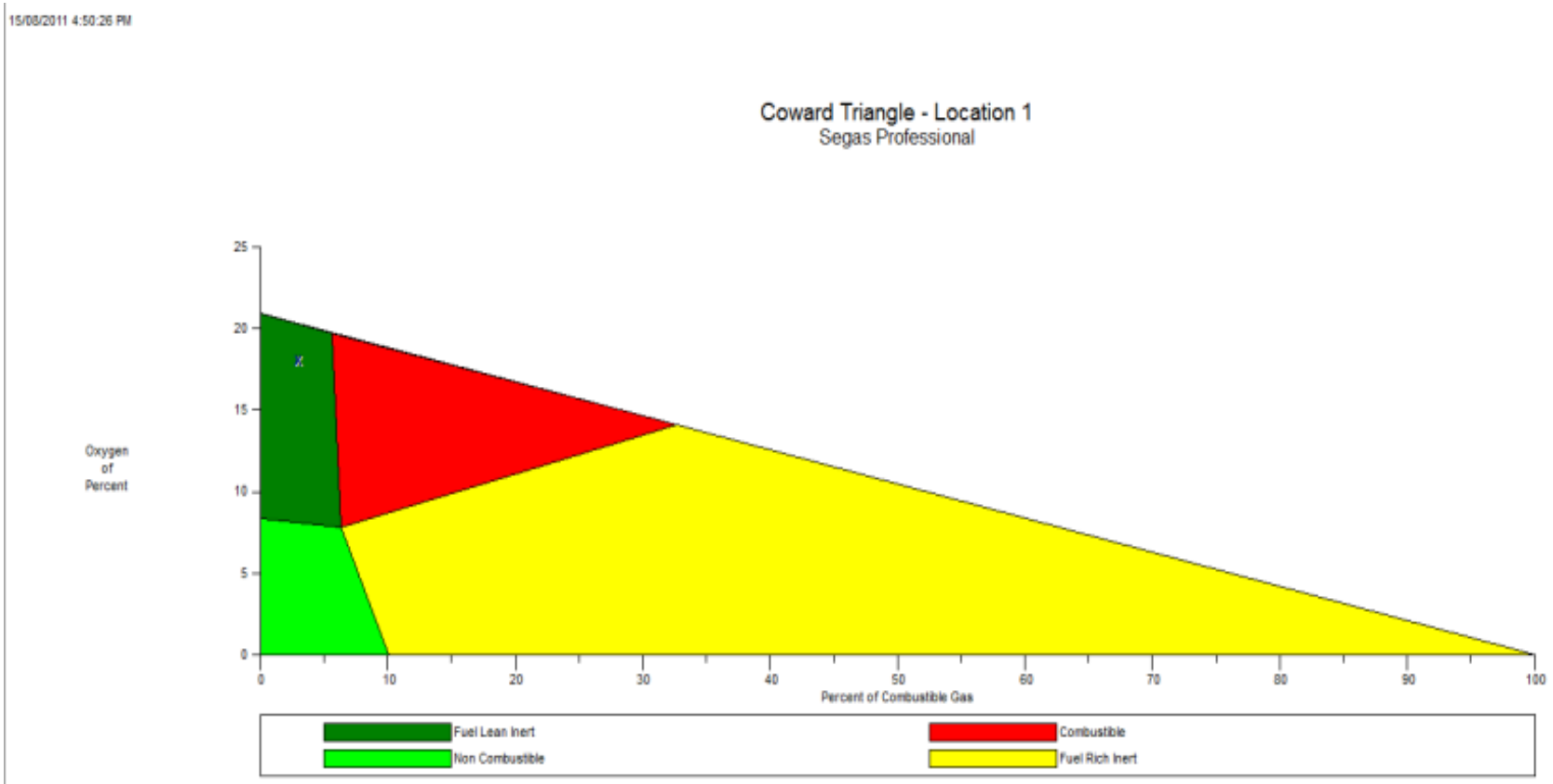


Hughes and Raybould Diagram



Ellicott diagram

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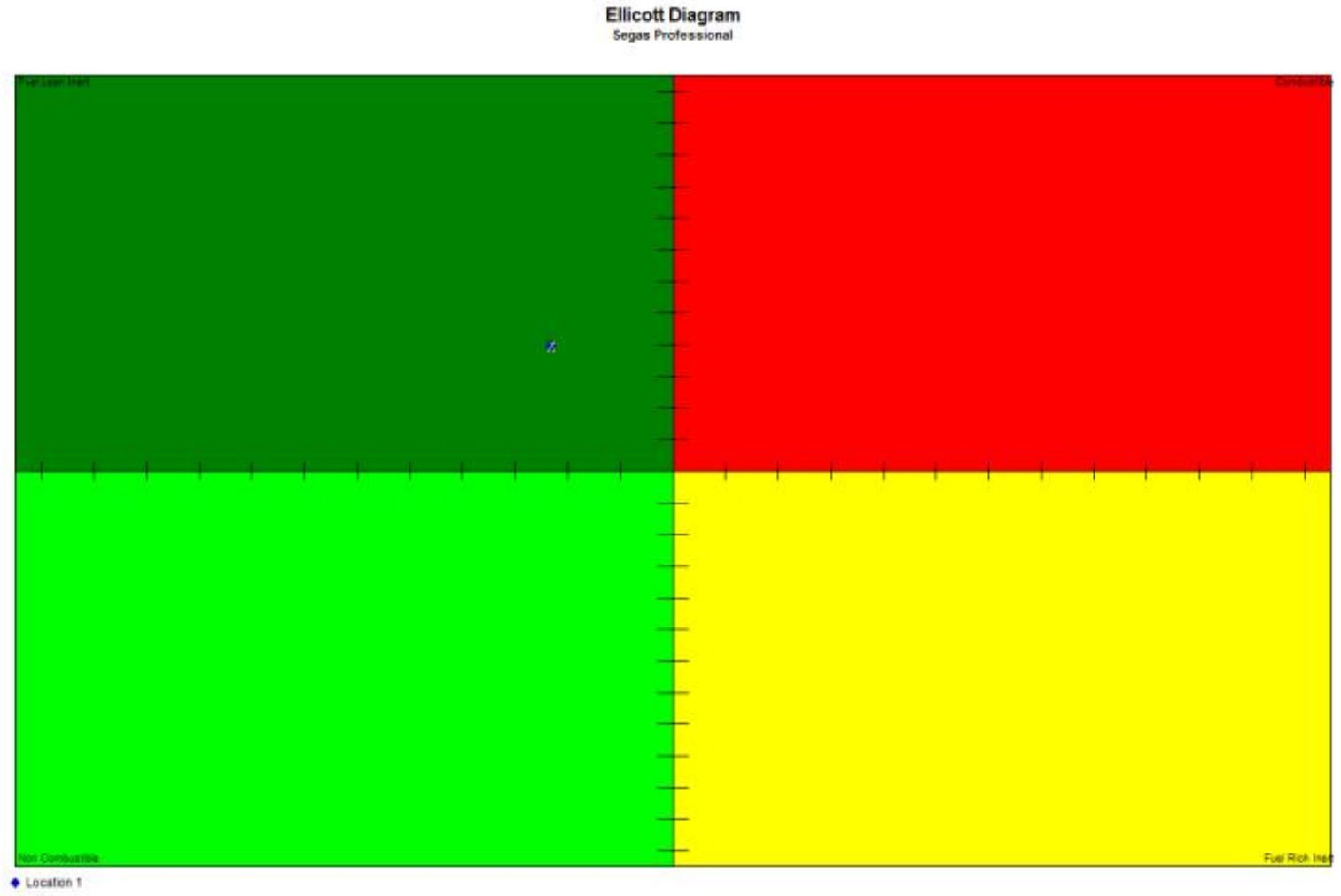
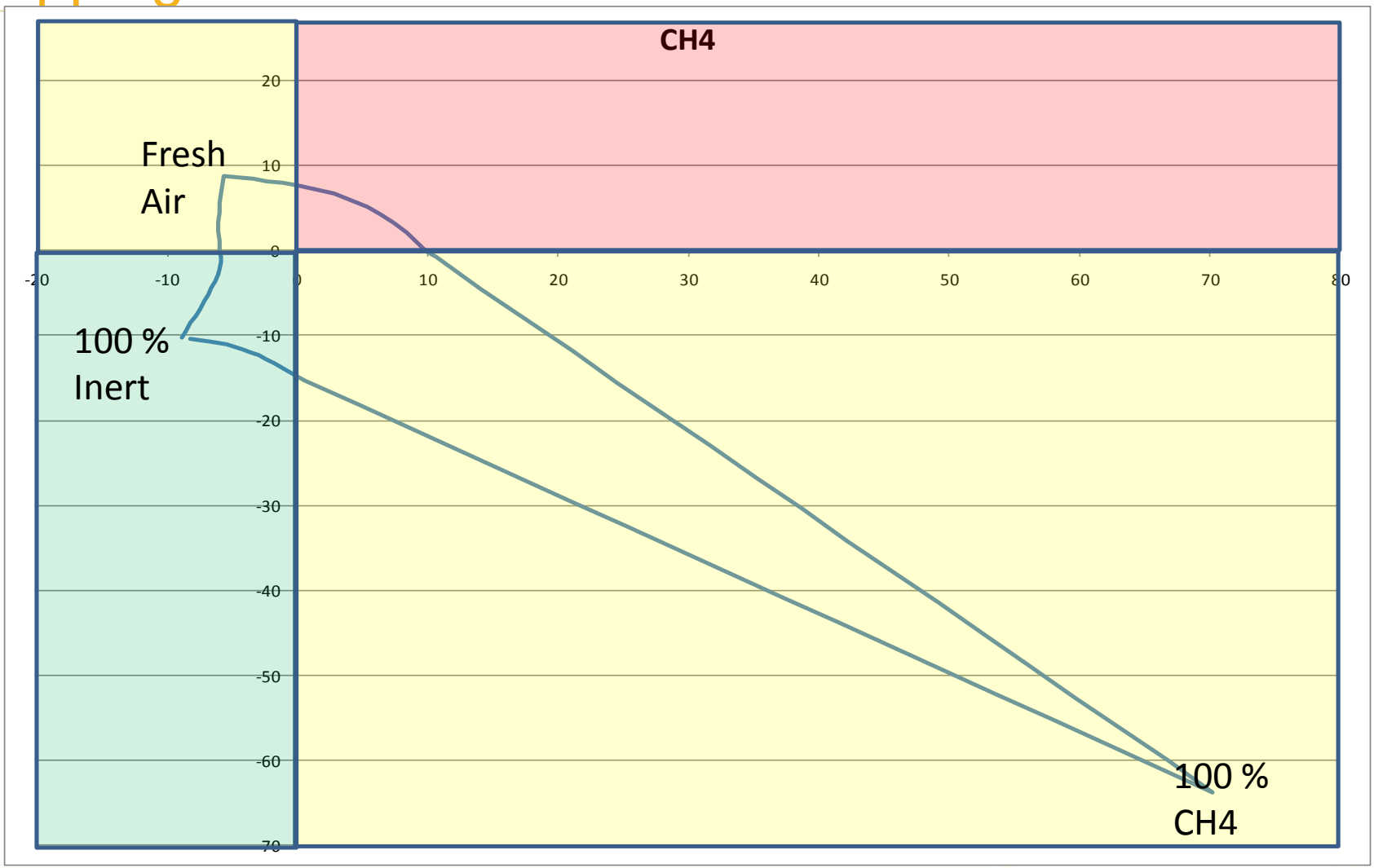
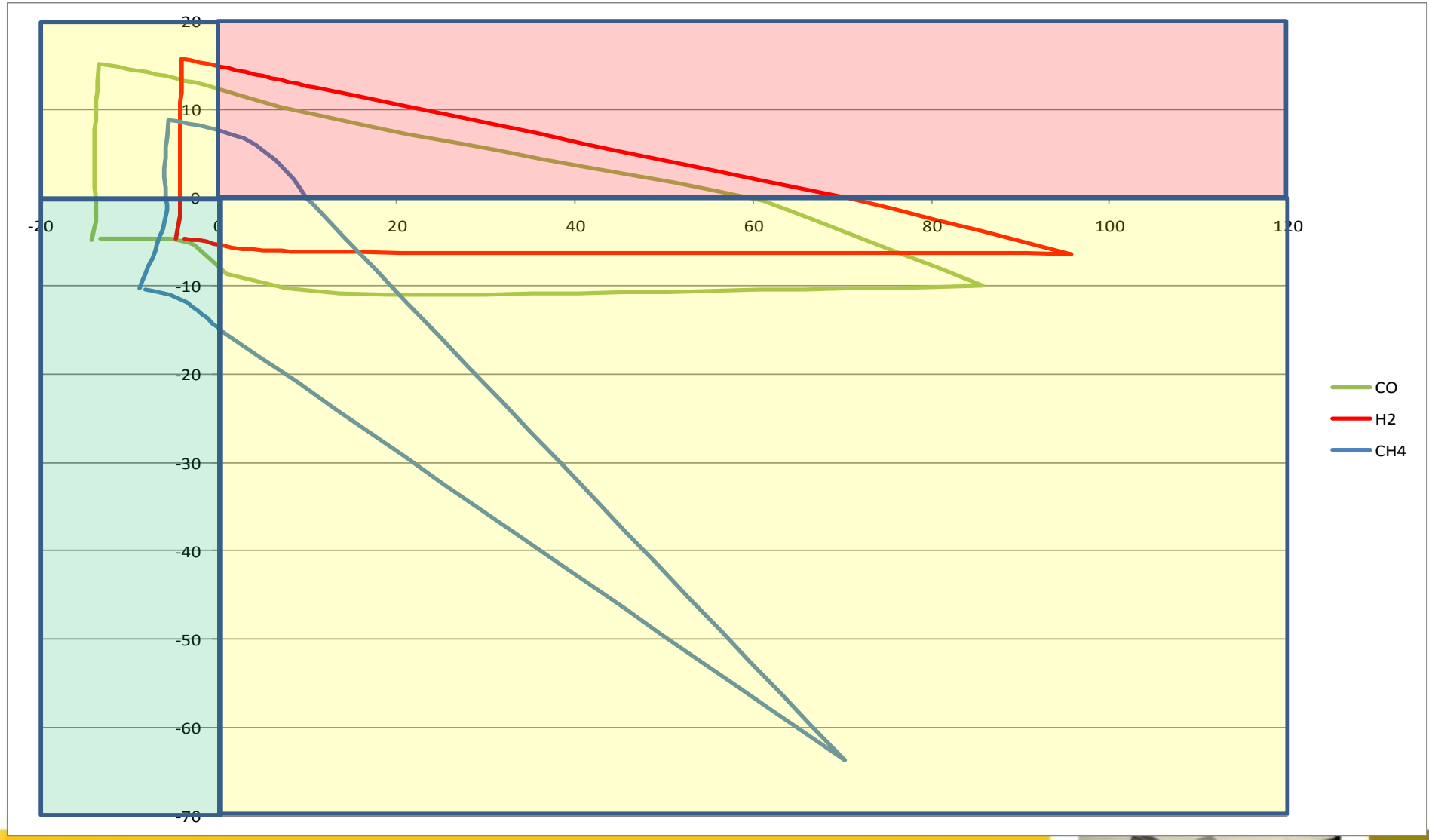


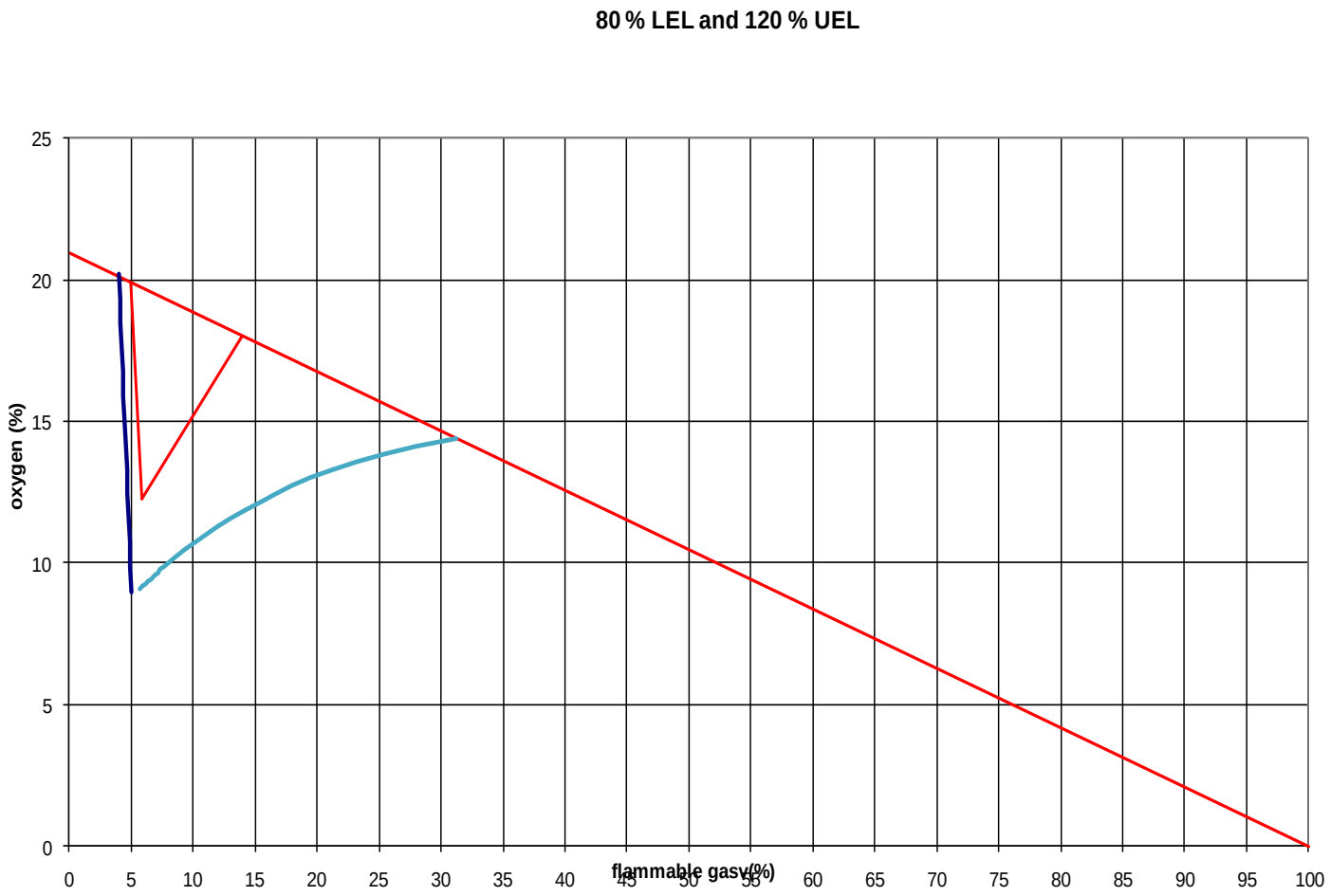
Mapping Coward onto Ellicott – CH4



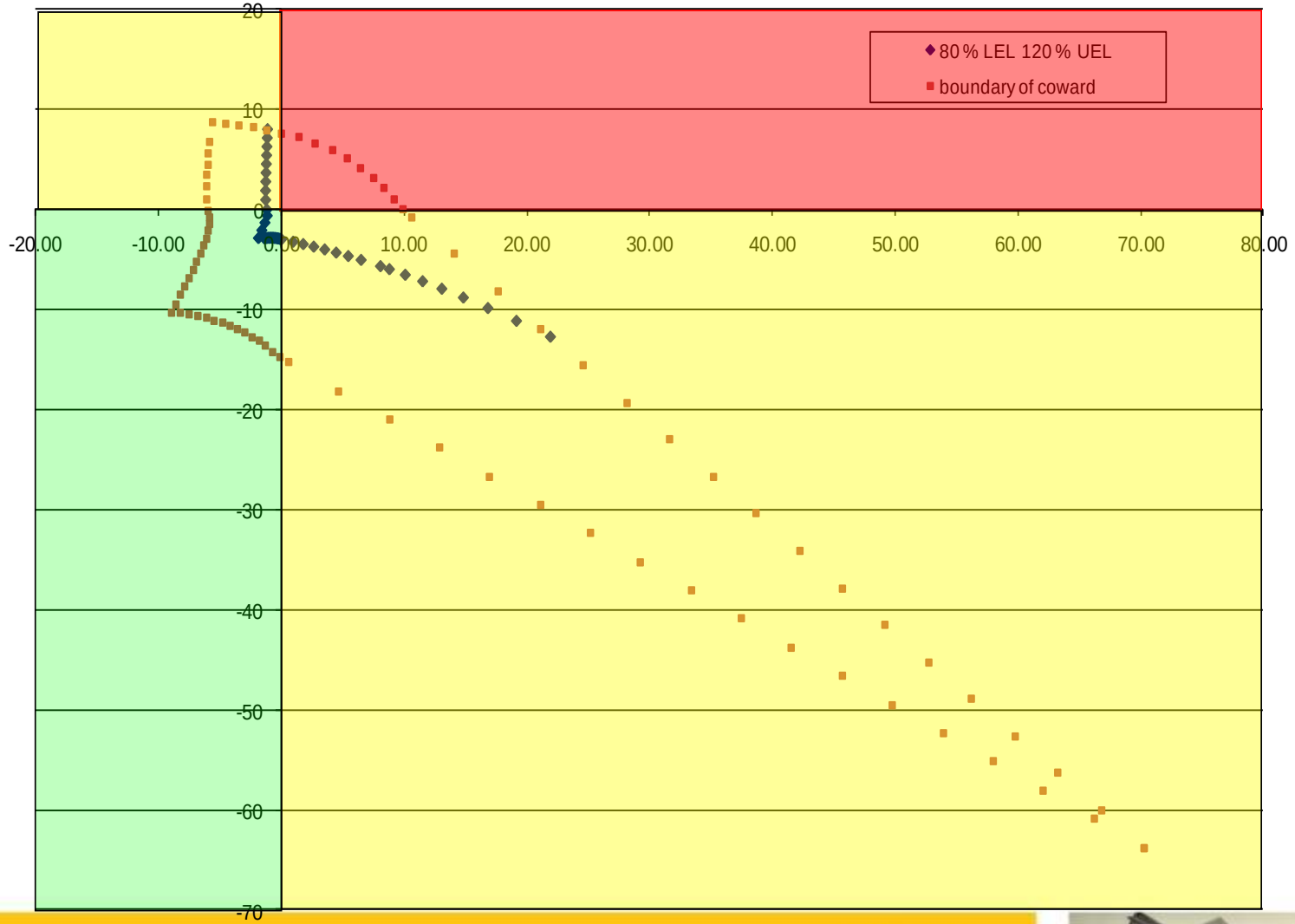
CH_4 , CO and H_2 mapped onto Ellicott



Buffer zones



Mapping buffer zones onto Ellicott diagram



Time based Ellicott coordinates

Proposed QMRS/NSW MR P/L diagram