Draft V2C

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TECHNICAL REPORT

Report for: **Investigation Unit, Mine Safety Performance, Industry & Investment NSW**
8 Hartley Drive, Thornton NSW 2322
PO Box 343, Hunter Region Mail Centre NSW 2310

Attention: **Mr Tim Flowers, Investigator**

Subject: **Analysis of Blakefield South Mine (BSM) Explosion**

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NON-STANDARD ABBREVIATIONS

BSM	Blakefield South Mine
UBB	Upper Big Branch Massey Mine, WV, USA
LW	Longwall
MG	Maingate Headings on Longwall
TG	Tailgate Headings on Longwall
CT	Cut Through Heading
SCMP	Spontaneous Combustion Management Plan
TARP	Trigger Action Response Plan

1. INTRODUCTION

The purpose of this report is to provide an evaluation and analysis of Blakefield South Mine (BSM) Explosion that took place on 5 January 2011 based on analysis of the facts (data and information provided) and evaluation of BSM's ventilation system prior to and up to the time of the explosion. A scope of work has been set out by the Investigation Unit, Mine Safety Performance of the NSW Department of Industry and Investment.

1.1. Scope

The scope of work for this report is set to be the following:

- Provide a timeline analysis of the data provided in a format showing the months prior to the event; day of the incident; the incident and post incident
- Analyse available data provided with respect to the possibility that spontaneous combustion could have been a factor in the 5/1/11 explosion.
- Compare and discuss data from BSM's Citect, deputies' reports, gas samples, monthly ventilation reports, and the gas drainage data.
- Discuss the content of the mines Spontaneous Combustion Management Plan and the TARP levels or Triggers in BSM's plan.
- Comment discussion of the mines Ventsim modelling
- Discuss comment on explosive fringe that existed in mine and its location relative to possible ignition sources eg boreholes, tailgate drive motor
- Discuss deputy's' eye witness account and how it relates to other evidence provided in the brief.
- Any recommendations relevant to the mine or to industry generally.
- Support all observations/comments with reference to the data provided on
- Include screen dumps, graphs, plans and any visual material etc that assists with understanding of the various issues.

1.2. Data and Information Provided

The following is a list of data and information provided

- Information obtained from Blakefield South under Notice issued under Section 62 of the Occupational Health and Safety Act 2000 on 7 September 2011 during the mine site visit. This information included the following
  1. CSV dump of Gas data (CH_4, CO and CO_2) from Citect for monitoring points LW TG, Gas Stations 10 and 16 (bottom of exhaust shaft) from 29/06/10 to 06/01/11.
  2. CSV dump of Shearer position on LW face data from 29/06/10 to 06/01/11.
  3. Seam roof (Blakefield Seam) contours at 1 m intervals overlain on the mine plan.

4. The latest Ventsim model prior to 5 January 2011 incident
5. Bag sample data for LW and LW TG districts from 29/06/10 to 06/01/11.
6. Procedure used for the collection of bag sample data
7. Additional data on procedure for stopping/starting/resetting fan site 3 ventilation fans, occasions of main fan shut downs in the 3 weeks prior to the 5 January incident and the reasons for fan shut downs. Explanations on the trip level of LW TG Drive changes and location changes of the LW TG CH4 sensor were also sought.

- Alarm Logs data sets for BSM from February 2010 to February 2011 were provided with the period Logs of 13/11/2011 to 31/12/2011 missing.
- BSM's Ventilation Monthly Reports and plans from June 2010 to January 2011.
- Records of Interviews conducted by Mr Tim Flowers, Inspector of the Investigation Unit with [redacted] and [redacted].
- Deputy statutory reports July – Nov 2010 and summary table for LW TG CH_4% extracted from Dec 2010 Deputy statutory reports.
- The spreadsheets used to create each of the monthly ventilation reports for the 12 Months prior to the incident on 5 January 2011.
- Updated Mine Ventilation Plan (dated 3 August 2011, drawing number 2011258, revision 5 dated 30 November 2011) for BSM as a result of the incident of 5 January 2011.
- Bulga Coal Pty Ltd, Blakefield South Coal Mine Project, Ventilation system design risk assessment - Final Report December 2006 by Hawcroft Miller Swan Consultants Pty Ltd.
- Ventilation plan Ventilation Plan marked noting that the Doors at 38-39 CT were found open when the inspection was undertaken immediately following re-ventilation on 14/12/2011. No confirmation on if these doors were open or closed at the time of the incident. It was noted that doors at 38CT buckled - pictures were also supplied with different exposures of the doors at 38CT which show evidence of some form of impact.
- Information relating to what occurred after the incident from BSM management.
- SIMTARS report tilted "Determination of the spontaneous combustion propensity of coal for the BSM Project", October 2006.
- Information on the gas chromatograph results after the incident on 5 January 2011.
- Mines Rescue Team re-entry records including diary notes of rescue teams on 11.08.30, 11.09.21, 11.09.22, 11.09.23, 11.09.28, 11.10.12, 11.12.02 and 11.12.12.
- Updated BSM Gas Monitoring Stations plan as at 2011.02.14.
- Plan and cross sectional view ERD03 path trace SIS over LW 1.
- Extract from [redacted] Interview - Connectivity to seams above - BSM.

- Information on Piezometer holes that contain a wire cable from the surface into the mine and goaf area, SIS 08 and 05 well casing tally, INV3A1 and INV6A1.
- Figures showing CO levels in the returns plus gas drainage wells from Citect monitoring system approximately 24 hrs, 10 days, 10 weeks before incident and also over the life of LW panel.

2. TIMELINE ANALYSIS OF BSM DATA AND INFORMATION

This section provides a timeline analysis of the data in a format showing the months prior to the event; day of the incident; the incident and post incident.

A total of 377 CSV dump gas and shearer positions data files were supplied by BSM in response to the Notice requesting information on 7 September 2011. At this stage only selective CSV dump of Gas data and Shearer positions (for period from 1 December 2010 to 6 January 2011) has been handled and merged into one Excel spreadsheet file for easier data manipulation and analysis. Further CVS dump of gas and shearer positions data file handling and merge will be undertaken if necessary.

The following figures show Citect gas readings of CO (in ppm) and CH_4 (in %) at Gas 16 (bottom of exhaust shaft - drawn in pink) and Gas 10 (LW TG Dogleg – drawn in blue) locations and positions (in m) of Shearer from MG end of LW face (in brown). It can be clearly seen that when shearer movement was intense, the CH_4 levels both at Gas Stations 16 and 10 were increased slightly with upward trends observed. When there were production stoppages, CH_4 levels were slightly decreased with downward trends observed. During Christmas holidays shut down period in 2010, LW production stopped (1:28pm 24/12/10 to 8:30pm 28/12/10) and two ventilation fans shut down events (1:26pm – 2:23pm 24/12/10 and 7:13am – 2:38pm 28/12/10) also took place in the period due to lost of power and planned HV maintenance and testing according to information obtained from BSM under Notice issued under Section 62 of the Occupational Health and Safety Act 2000 on 7 September 2011.

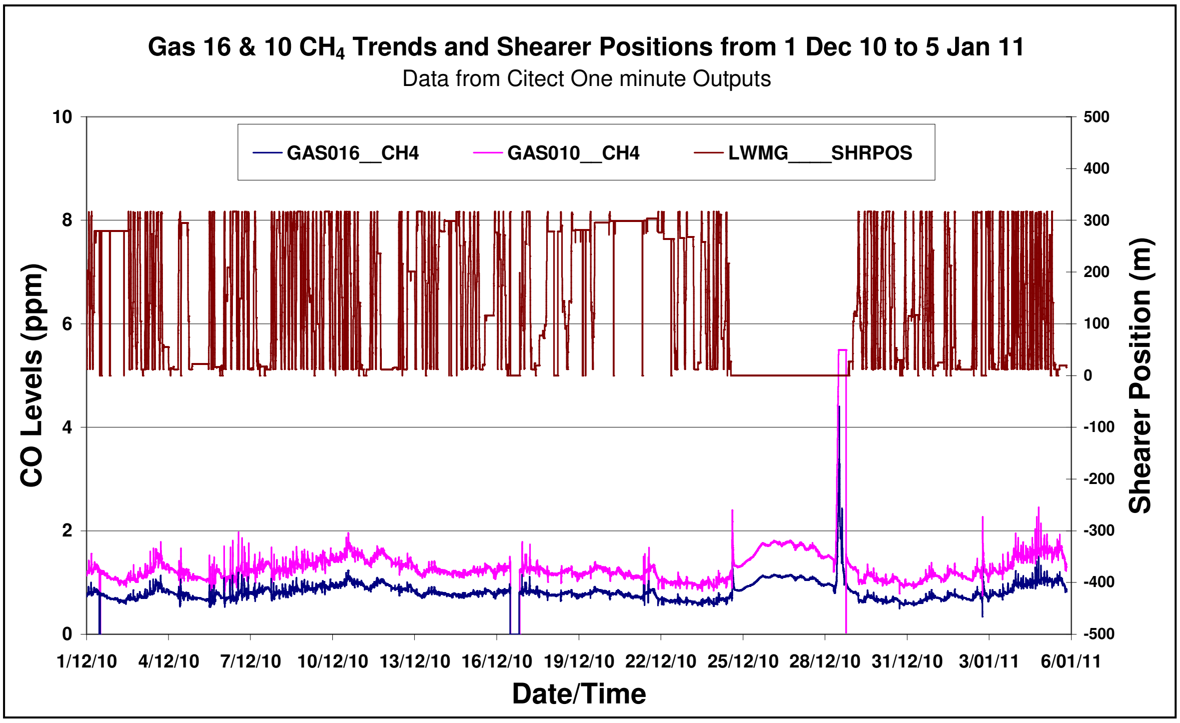

Figure 2.1 Methane gas trend recorded at Gas 16 & 10 Stations (1/12/10 – 05/01/11) and position of LW Shearer.

During the non production period from 24/12/10 to 28/12/10, CH_4 readings recorded at Gas Stations 16 and 10 gradually increased and stabilised. CH_4 readings shot up during the planned fan shut down on 28/12/10 but CH_4 levels decreased very quickly when fans were turned back on and the general trends of CH_4 levels were downward.

CO levels at both stations on the other hand remained steady during the Christmas shut down period. Correlation between CO levels at both stations and LW production was not as obviously as CH_4. However, the general trends of CO levels from 1 Dec 2010 to 5 January 2011 were steady and slightly downward in the second half the period.

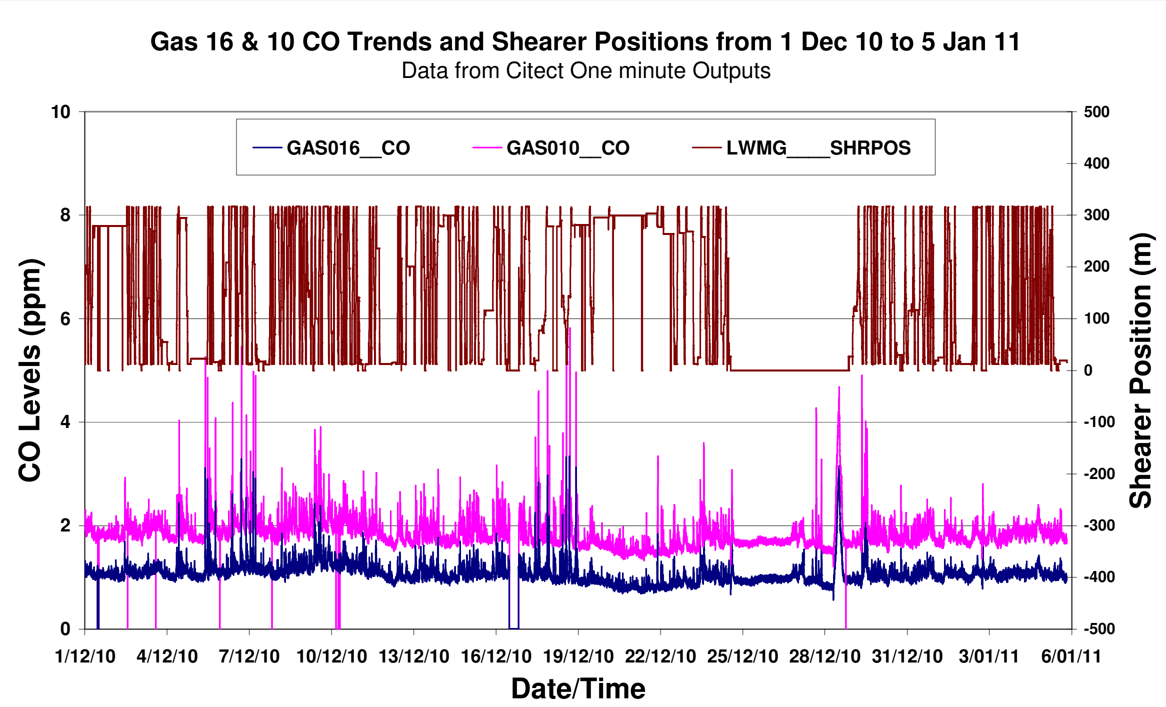

Figure 2.2 CO gas trend recorded at Gas 16 & 10 Stations (1/12/10 – 05/01/11) and position of LW Shearer.

Bag sample data for the period from start of longwall mining to 5 January 2011 for longwall and tailgate districts were sought on 9 September 2011. Information provided by the mine management in response to the request was ACIRL reports of bag samples taken in July and August 2010 and CS Mine Rescue analyses for bag samples collected in October 2010. LW 1 goaf gas stream (adjacent to 158 Support) information based on a total of 57 bag samples analysed in the abovementioned reports was also supplied with some analyses done on gas makes, various ratios calculations and trending. No gas samples and analyses were supplied for the months of November and December 2010.

It can be seen that CO levels at both Gas 16 & 10 Stations are below 2.5ppm almost all the time and never record greater than 6ppm and then only for a very short period. Furthermore readings are very stable with no indication of a long term rising trend that may indicate onset of a heating.

The following figures show trends of Graham's Ratio and CO/CO_2 Ratio & Temperature trends generated from LW goaf bag samples collected adjacent to 158 Support from July to October 2010.

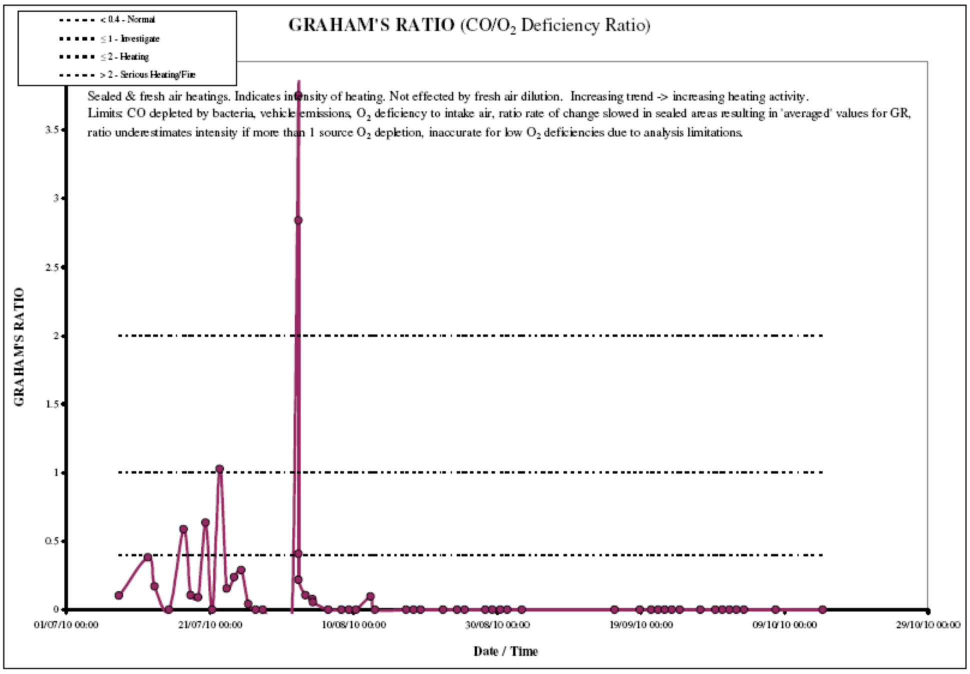

Figure 2.3 Graham's ratio trend from LW goaf bag samples.

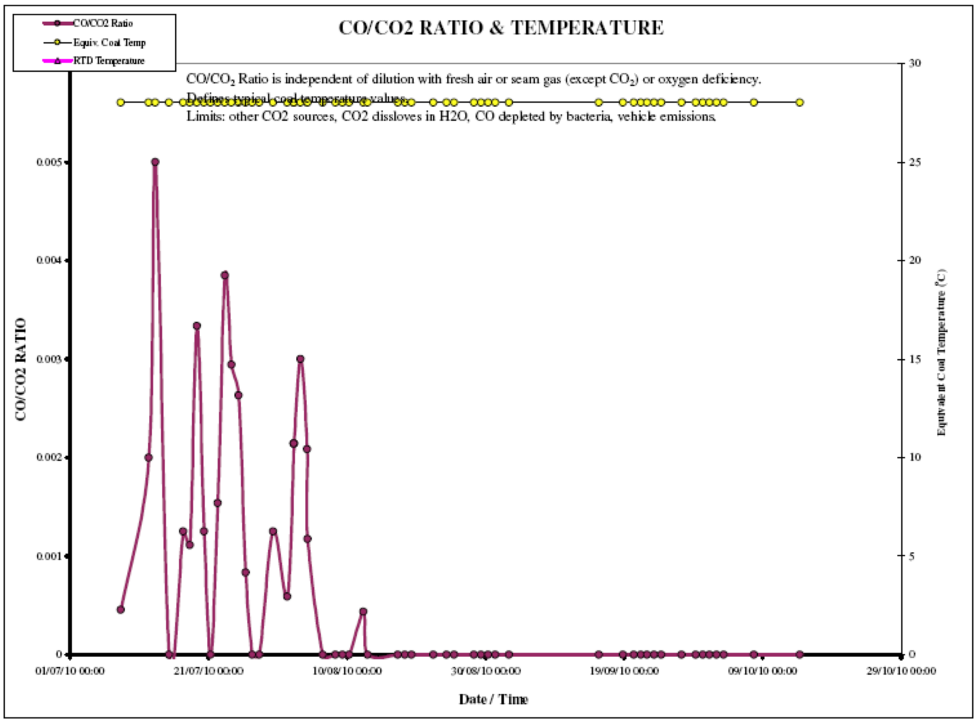

Figure 2.4 CO/CO_2 ratio and temperature trends from LW goaf bag samples.

It can be seen that from these two figures that LW goaf gas environment after initial unstable period in July 2010 and by early August 2010 LW goaf gas environment had settled and stabilized.

3. POSSIBILITY OF SPONTANEOUS COMBUSTION

The section covers analysis of available data with respect to the possibility that spontaneous combustion could have been a factor in the 5/1/11 explosion. The following figures show the trends of CO levels (per minute, shift average, maximum and minimum) based on recorded data by Citect mine control and monitoring system at Gas 16 (bottom of exhaust shaft - drawn in pink) and Gas 10 (LW TG Dogleg – drawn in blue) locations.

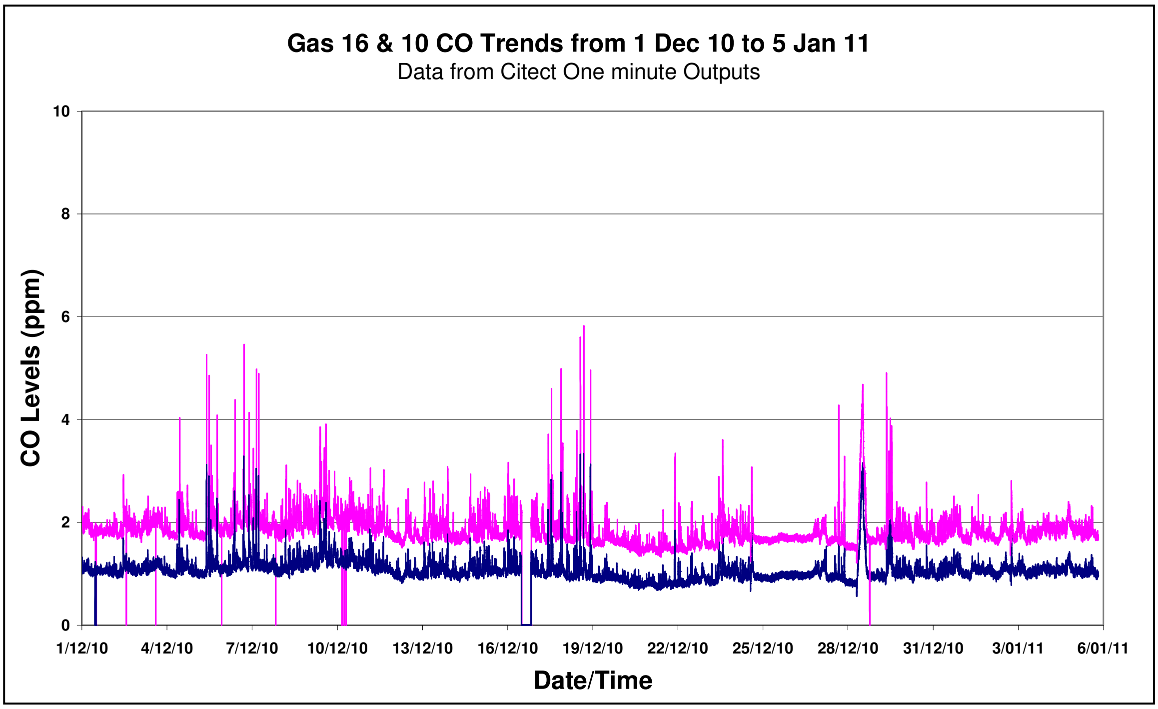

Figure 3.1 CO gas trend recorded at Gas 16 & 10 Stations (1/12/10 – 05/01/11).

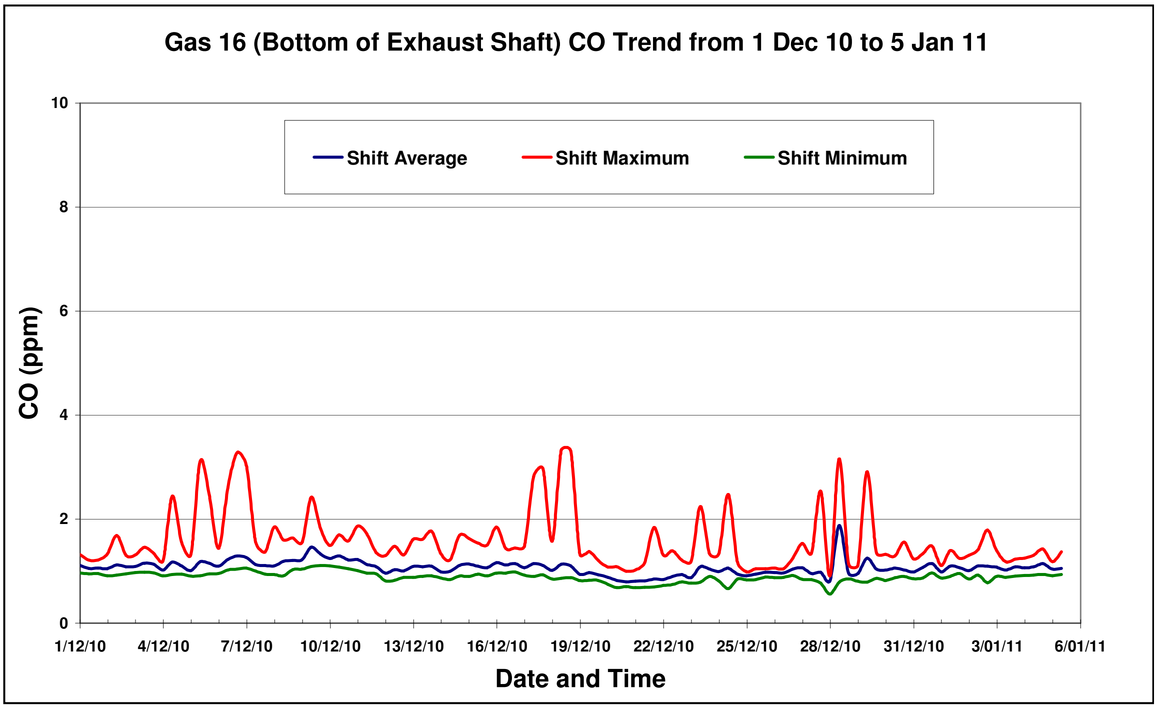

Figure 3.2 CO gas trends of shift average, maximum and minimum at Gas 16 Station – Bottom of Exhaust Shaft (1/12/10 – 05/01/11).

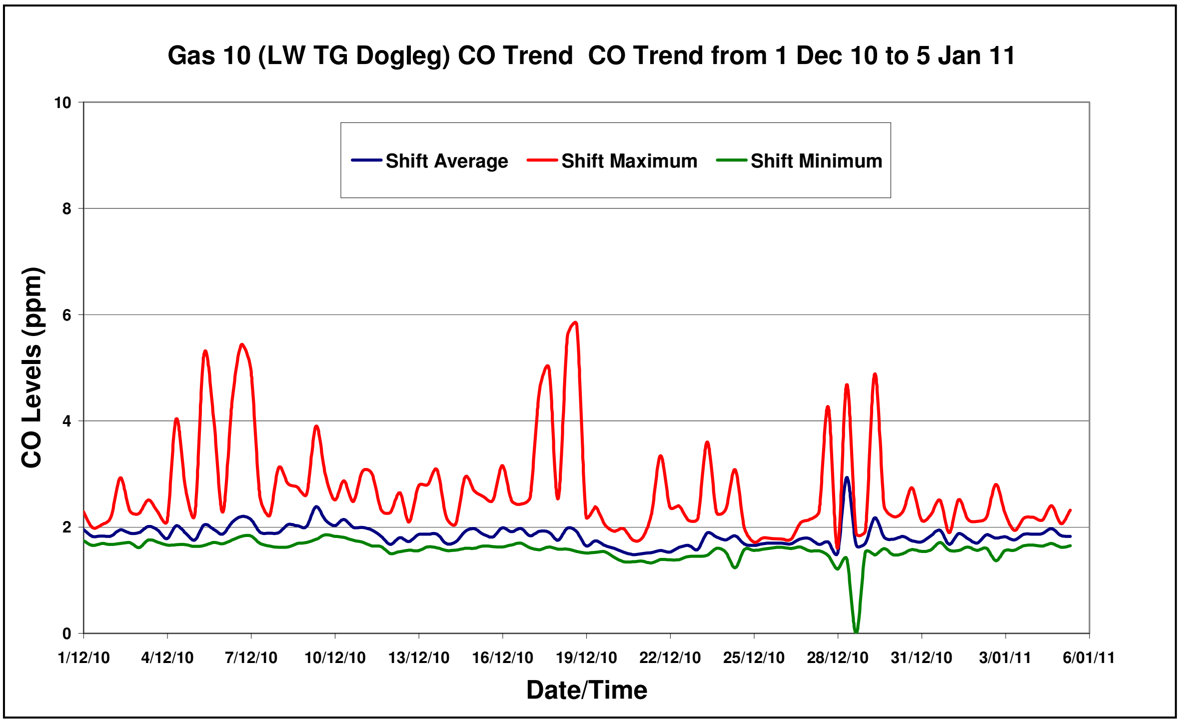

Figure 3.3 CO gas trends of shift average, maximum and minimum at Gas 16 Station (1/12/10 – 05/01/11)

CO gas levels in a mine atmosphere are of interest as they may indicate the onset of a fire or spontaneous combustion heating (or may show an indication of exhaust fumes from a diesel powered vehicle). In the various figures above both Gas 16 & 10 Stations' data indicate that CO levels are below 4.0ppm almost all the time and never record greater than 6ppm and then only for a very short period. Furthermore readings are very stable with no indication of a long term rising trend that may indicate onset of a heating.

The relationships in Chapter 2 indicate that the spontaneous combustion Graham's Ratio and CO/CO_2 indices indicate that after the goaf has settled from the initial formation period that the indices' numbers are very low.

Transcripts of interview from BSM Geologist [redacted] gave professional opinions on propensity to spontaneous combustion from information focused on the conditions and behaviour of the 80m thick interburden strata immediately above the worked seam, the BSM seam, up to the next seam of economic interest, the Wybrow seam. Further he also commented on his understanding of general propensity to spontaneous combustion of all coals in the surrounding measures, the Whittingham coal measures. He states that as far as he is aware they all have moderate propensity as defined in SIMTARS reports. He does not believe that the Blakefield South seam has a higher or lower propensity than the Wybrow or other seams above that have been mined in the past.

Additional gas monitoring information is made available on the CO levels in the returns plus gas drainage wells from Citect approximately 24 hrs, 10 days, 10 weeks before incident and also over the life of LW panel as shown in the following figures.

Figure 3.4 CO in the returns plus gas wells approximately 24 hours before incident

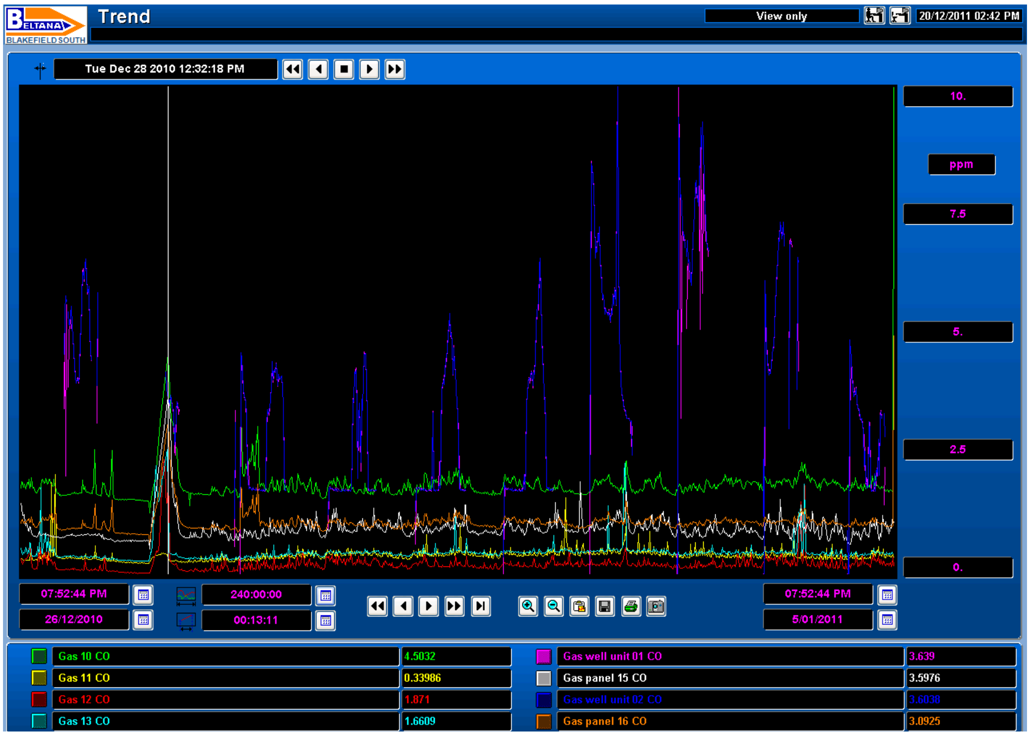

Figure 3.5 CO in the returns plus gas wells approximately 10 days before incident

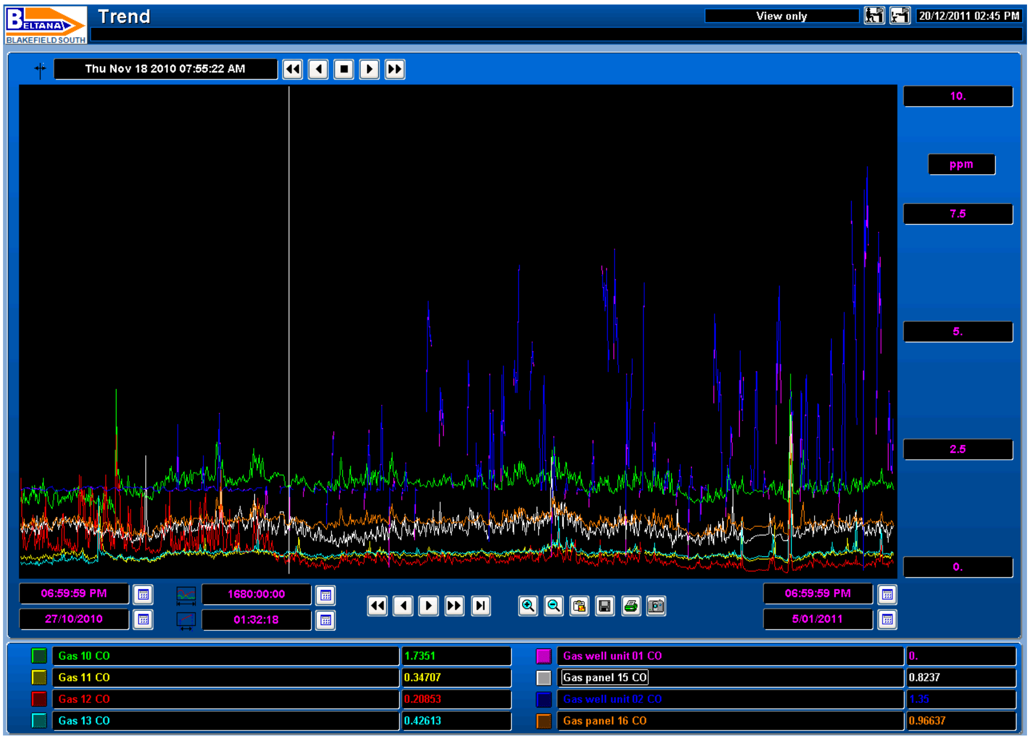

Figure 3.6 CO in the returns plus gas wells approximately 10 weeks before incident

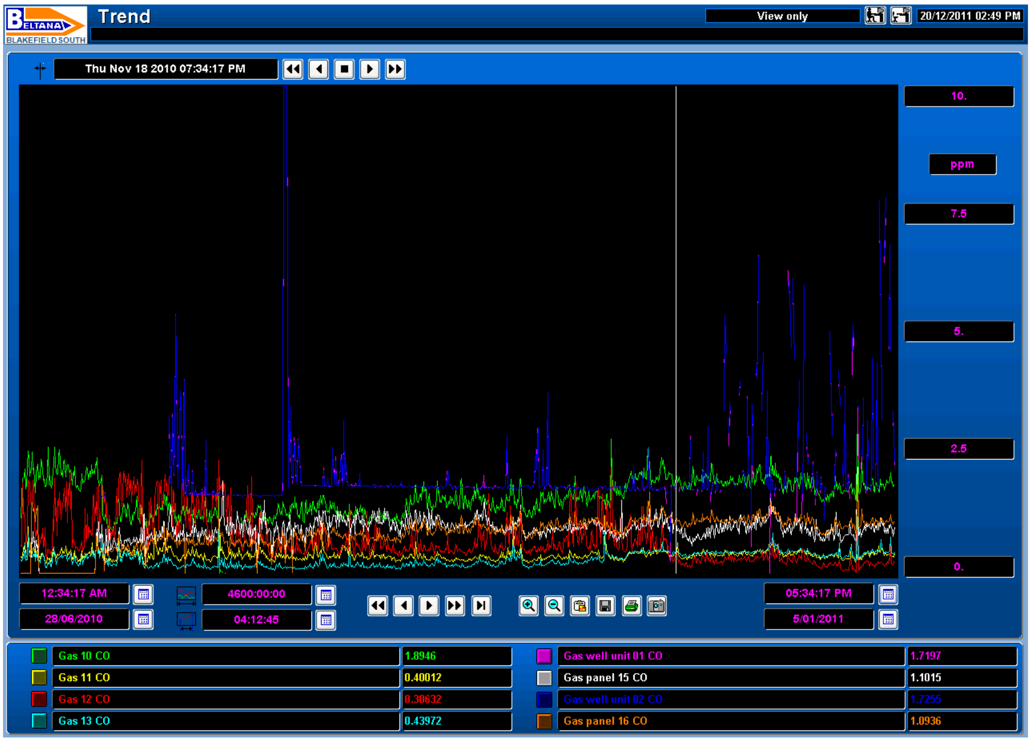

Figure 3.7 CO in the returns plus gas wells for the life of LW panel

The indications of "high" CO levels in the range of 7 to10ppm from gas drainage wells recorded by the Citect gas monitoring system could come from a number of sources.

- Vehicular traffic working hard sporadically in the Main Gate that ventilated across the face and around the goaf to the TG could have been the cause.

- Also slow oxidation of coal in the goaf will cause some low level CO. As the goaf forming roof fell air would have pushed into the face area and across CO sensors. These wind blasts would have altered the normal air gas concentration near the sensor for a short period (an inrush possibly followed by a suck back).

It also possible that the LW face retreat had been slow for occasional periods allowing goaf atmosphere to build up a slightly higher CO as it sat. Occasional periods of 7 to 10 ppm of CO as measured in the gas drainage wells are not a good indicator for spontaneous combustion as any trend for CO indicating spontaneous combustion should show a consistently rising CO lever against time.

4. COMPARISON OF DATA FROM VARIOUS SOURCES

The section compare and discuss data from Citect, deputies reports, gas samples, monthly ventilation reports, and the gas drainage data.

The following table show comparisons between methane readings taken by Deputies and recorded in deputies' shift statutory reports and the shift average, maximum and minimum monitoring methane readings based on recorded data by Citect mine control and monitoring system.

Table 4.1 Comparison of methane readings at LW TG by Shift Deputies and Citect

DATE	SHIFT	Deputy Report	Citect TG %CH_4			Citect TG %CH_4 RAW		
		TG % CH_4	AVG	Max	Min	AVG	Max	Min
1/12/10	NS	1.25%	0.07	0.17	0.01	0.23	0.35	0.13
	DS	1%	0.02	0.07	0.00	0.16	0.22	0.12
	AS	1.08%	0.11	2.37	0.09	0.13	0.17	0.12
2/12/10	NS	0.80%	0.10	0.11	0.09	0.13	0.14	0.12
	DS	0.80%	0.11	0.20	0.08	0.15	0.28	0.11
	AS	1.58%	0.13	0.24	0.09	0.17	0.35	0.10
3/12/10	NS	1.2 -1.06	0.13	0.22	0.05	0.16	0.30	0.09
	DS	1.2 diluting to 0.4	0.18	0.30	0.12	0.25	0.44	0.16
	AS	1.8	0.20	0.35	0.15	0.26	0.46	0.18
4/12/10	NS	2.34	0.18	0.21	0.17	0.23	0.27	0.21
	DS	>5 ch4 2ppm CO	0.18	0.23	0.11	0.22	0.33	0.12
	AS	*n/a*	0.17	0.25	0.13	0.22	0.35	0.19
5/12/10	NS	0.32	0.14	0.15	0.13	0.20	0.21	0.18
	DS	>5 ch4 2ppm CO	0.15	0.27	0.10	0.22	0.40	0.13
	AS	*n/a*	0.16	2.25	0.02	0.23	2.56	0.04
6/12/10	NS	0	0.12	0.21	0.09	0.19	0.31	0.15
	DS	0.6	0.11	0.20	0.05	0.18	0.30	0.12
	AS	0.5	0.12	0.29	0.05	0.20	0.44	0.12
7/12/10	NS	0.4	0.10	0.18	0.07	0.16	0.27	0.12
	DS	0.2	0.10	0.12	0.07	0.17	0.19	0.12
	AS	0.4	0.10	0.16	0.07	0.17	0.24	0.12
8/12/10	NS	0.3	0.09	0.17	0.05	0.15	0.28	0.10
	DS	0.4	0.11	0.19	0.07	0.17	0.28	0.12
	AS	0.4	0.11	0.22	0.07	0.17	0.34	0.12
9/12/10	NS	0.6	0.09	0.17	0.05	0.16	0.27	0.12
	DS	0.8	0.12	0.18	0.07	0.21	0.31	0.14
	AS	0.4	0.10	0.21	0.06	0.17	0.34	0.12
10/12/10	NS	0.4 - 0.26	0.10	0.17	0.07	0.17	0.29	0.13
	DS	0.6	0.13	0.25	0.09	0.22	0.38	0.15

	AS	0.5	0.12	0.21	0.08	0.21	0.34	0.15
11/12/10	NS	*n/a*	0.11	2.05	0.01	0.18	2.29	0.03
	DS	0.5	0.11	0.20	0.06	0.19	0.29	0.13
	AS	0.5	0.10	0.21	0.06	0.17	0.32	0.13
12/12/10	NS	0.5	0.06	0.07	0.03	0.14	0.15	0.13
	DS	0.6	0.07	0.18	0.03	0.15	0.29	0.11
	AS	0.55	0.11	0.27	0.04	0.20	0.43	0.12
13/12/10	NS	0.5	0.07	0.18	0.03	0.13	0.26	0.08
	DS	0.5	0.10	0.20	0.06	0.18	0.31	0.11
	AS	1.2 dil to 0.2	0.09	0.22	0.04	0.17	0.33	0.11
14/21/10	NS	0.7	0.02	0.05	0.01	0.11	0.13	0.08
	DS	0.5	0.02	0.06	0.00	0.10	0.15	0.07
	AS	0.7	0.05	0.10	0.03	0.13	0.19	0.10
15/12/10	NS	2.6	0.07	0.13	0.03	0.14	0.21	0.10
	DS	4.6 dil to 0.9	0.06	0.12	0.03	0.14	0.23	0.10
	AS	1.2 (diluted)	0.04	0.07	0.02	0.13	0.15	0.10
16/12/10	NS	0.5	0.06	0.11	0.02	0.15	0.21	0.10
	DS	2.6	0.08	0.21	0.02	0.16	0.33	0.11
	AS	1.6	0.15	0.27	0.06	0.25	0.43	0.13
17/12/10	NS	0.12 - 1.5 (CO 4ppm)	0.08	0.43	0.00	0.17	0.68	0.10
	DS	0.6 - 0.8 (CO 4ppm)	0.04	0.05	0.02	0.09	0.12	0.08
	AS	1.1	0.01	0.06	0.00	0.08	0.11	0.06
18/12/10	NS	0.34	0.01	0.02	0.00	0.08	0.12	0.06
	DS	0.6	0.02	0.06	0.00	0.11	0.16	0.08
	AS	*n/a*	0.04	2.50	0.00	0.10	2.47	0.03
19/12/10	NS	0.13	0.03	0.04	0.01	0.08	0.10	0.08
	DS	0.1	0.06	0.12	0.03	0.11	0.20	0.08
	AS	*n/a*	0.04	0.06	0.03	0.09	0.11	0.08
20/12/10	NS	None	0.03	0.04	0.01	0.08	0.10	0.07
	DS	0.2	0.02	0.04	0.01	0.07	0.08	0.05
	AS	0.12	0.01	0.02	0.01	0.07	0.07	0.05
21/12/10	NS	Detected no.	0.01	0.02	0.00	0.07	0.07	0.06
	DS	0.13	0.01	0.02	0.00	0.07	0.08	0.05
	AS	0.2	0.00	0.02	0.00	0.05	0.08	0.03
22/12/10	NS	*n/a*	0.00	0.02	0.00	0.03	0.05	0.03
	DS	0.4	0.01	0.09	0.00	0.05	0.18	0.03
	AS	0.4	0.02	0.06	0.00	0.06	0.13	0.03
23/12/10	NS	*n/a*	0.02	0.06	0.00	0.05	0.11	0.02
	DS	0.16	0.02	0.06	0.01	0.06	0.11	0.03
	AS	0.4	0.05	0.10	0.03	0.09	0.17	0.06
24/12/10	NS	*n/a*	0.07	0.14	0.03	0.11	0.24	0.06
	DS	0.21	0.07	0.12	0.05	0.12	0.19	0.09
	AS	*n/a*	0.00	0.00	0.00	0.00	0.00	0.00

25/12/10	NS	No	0.00	0.00	0.00	0.00	0.00	0.00
	DS	No	0.00	0.00	0.00	0.00	0.00	0.00
	AS	No	0.00	0.00	0.00	0.00	0.00	0.00
26/12/10	NS	No	0.00	0.00	0.00	0.00	0.00	0.00
	DS	No	0.00	0.00	0.00	0.00	0.00	0.00
	AS	No	0.00	0.00	0.00	0.00	0.00	0.00
27/12/10	NS	No	0.00	0.00	0.00	0.00	0.00	0.00
	DS	No	0.00	0.00	0.00	0.00	0.00	0.00
	AS	No	0.00	0.00	0.00	0.00	0.00	0.00
28/12/10	NS	No	0.00	0.00	0.00	0.00	0.00	0.00
	DS	No	0.00	0.00	0.00	0.00	0.00	0.00
	AS	No	0.11	2.84	0.03	0.08	2.07	0.04
29/12/10	NS	0.4	0.06	0.10	0.03	0.04	0.08	0.02
	DS	0.4	0.08	0.20	0.03	0.08	0.24	0.02
	AS	0.4	0.09	0.22	0.05	0.10	0.26	0.05
30/12/10	NS	0.4	0.08	0.16	0.05	0.06	0.16	0.03
	DS	0.4	0.09	0.14	0.05	0.08	0.17	0.03
	AS	0.4	0.07	0.14	0.02	0.11	0.22	0.05
31/01/10	NS	0.4	0.08	0.14	0.05	0.13	0.20	0.10
	DS	0.6	0.08	0.14	0.00	0.14	0.23	0.09
	AS	0.75	0.11	0.24	0.05	0.17	0.36	0.11
1/01/11	AS/NS	0.2	0.05	0.08	0.03	0.10	0.13	0.08
	DS	1.9 dil 0.5	0.09	0.18	0.03	0.15	0.28	0.08
	AS	*n/a*	0.11	0.20	0.07	0.15	0.27	0.11
2/01/11	NS	0.12	0.06	0.08	0.05	0.11	0.12	0.09
	DS	2.08 dil 0.6	0.10	0.29	0.05	0.15	0.42	0.08
	AS	*n/a*	0.05	0.12	0.03	0.07	0.21	0.04
3/01/11	NS	0.6 -1.8 of goaf edge	0.10	0.20	0.05	0.12	0.25	0.06
	DS	1.9	0.09	0.17	0.00	0.11	0.30	0.03
	AS	2.6	0.20	0.70	0.07	0.29	0.96	0.10
4/01/11	NS	2	0.26	0.51	0.14	0.35	0.83	0.16
	DS	1.5	0.20	0.43	0.10	0.27	0.61	0.13
	AS	2.5	0.32	0.81	0.14	0.41	1.01	0.16
5/01/11	NS	3.1 dil to 0.6	0.22	0.36	0.13	0.28	0.47	0.16
	DS	1.2	0.20	2.22	0.14	0.23	2.17	0.18
	AS	2.6 4ppm CO	0.14	0.18	0.10	0.18	0.24	0.10

It can be concluded the CH_4 information from Citect and the Deputies at first reading do not directly and exactly parallel or resemble each other. However to have an understanding and be able to draw a comparison between the readings it must be understood how these sample readings are taken.

The Deputies readings are taken at one of the most gassy points within the LW section, the LW TG at the last Chock position. This point of sampling is likely to be affected by gas being released from the face as it is cut, gas from the newly forming goaf, gas from overlying and underlying strata and ventilation air sweeping through the active goaf directly behind the chock line. Furthermore the point lies close to the fringe line defining explosible concentrations of gas within the goaf as discussed in Chapter 7. The fringe line is likely to move closer to or further away from the chock line as the goaf atmosphere is affected by gas release roof falls and other factors. The Deputies are sampling raw gas being emitted outbye or downstream from high gas concentration zones within the goaf.

Citect readings were from a point fixed on the LW TG installation. They are further away from the goaf and the "moving" goaf fringe line than the particular shift Deputy's chosen sampling point. They are in the LW face ventilation flow path and the measurement point allows good dilution.

The Deputy's reading is a real time reading taken at a specific moment within the shift. The Citect readings on the other hand are taken in sequence. The average for the shift is calculated from all readings recorded in sequence over the shift; the maximum and minimum taken from that sequence across the shift duration.

In summary while both the Deputy and Citect readings are taken from the LW TG they are not taken at the same exact location and are affected by varying ventilation and dilution considerations. They are indicators support whether CH_4 levels are in accepted safe ranges and relatively stable or alternatively changing and possibly moving out of ranges considered safe. They are a very important part of the safe running of the mine and support each other while undertaking analysis in different ways.

5. EVALUATION OF SPONTANEOUS COMBUSTION MANAGEMENT PLAN

This section includes discussions on the content of the mines Spontaneous Combustion Management Plan (SCMP) and the TARP levels or Triggers in the BSM's SCMP.
Potential Interconnection with Whybrow workings resulting in spontaneous combustion (heating in Whybrow workings, goafed roof coals (Whynot, Wambo, Redbank Creek seams), or Blakefield goaf) and spontaneous combustion during longwall extraction had been identified as one of high risk issues which could result in catastrophic operation interruption in Blakefield South Coal Mine Project, Ventilation system design risk assessment - Final Report December 2006 by Hawcroft Miller Swan Consultants Pty Ltd. These matters were considered in the design and feasibility study phase before detailed information from strata exposures were available. To minimise leakage from surface (negative longwall face pressure), leakage to Whybrow (positive longwall face pressure) and South Bulga workings are known to be connected to surface, the following controls were put in place or planned to be put in place.

1. Force – exhaust (pressure balancing) ventilation system, designed such that the absolute pressure within the mine can be varied to balance, or slightly exceed, that on surface
2. Pressure balancing on longwall panel final seals
3. Seal Standards
4. Development & Longwall Management Plan
5. Tube Bundle Monitoring System
6. Seam Gas Emission
7. Mine Inspections System

It is understood that Tube Bundle Monitoring System was not installed during the extraction of LW1 prior to the 5 Jan 2011 incident. According to BSM's SCMP, the TARP is set at the following levels for active goaf.

BSM's SPONTANEOUS COMBUSTION TARP FOR ACTIVE GOAF OHSPRO3.5.08.015	
Normal	▪ General Body Return CO Make <20L/min or ▪ General Body Return CO < 15ppm or ▪ General Body Return H_2 < 10ppm or ▪ General Body Return CO/O_2 def < 0.3 or ▪ TG Goaf Gas Emissions <100ppm CO
Level 1 Trigger Levels	▪ General Body Return CO Make >20 L/min or ▪ General Body Return CO > 15ppm or ▪ General Body Return H_2 > 10ppm or ▪ General Body Return CO/O_2 def > 0.3 or ▪ TG Goaf Gas Emissions >100ppm CO or ▪ Unusual Smell, Heat, Sweating
Level 2 Trigger Levels	▪ General Body Return CO Make >30 L/min or

	▪ General Body Return CO > 25ppm or ▪ General Body Return H_2 > 15ppm or ▪ General Body Return CO/O_2 def > 0.4 or ▪ Accelerating gas trends or ▪ Confirmed Heating
Level 3 Trigger Levels	▪ Potentially explosive atmosphere detected or trending towards explosive range and ▪ Confirmed Heating or Fire capable of igniting atmosphere

It is concluded that the mine's Spontaneous Combustion Management Plan (SCMP) and the TARP levels or Triggers in the BSM's SCMP is conservative for the following reasons.

As discussed in Chapter 2 In the various figures both Gas 16 & 10 Stations' data indicate that CO levels are below 4ppm almost all the time and never recorded greater than 6ppm and then only for a very short period. Furthermore readings are very stable with no indication of a long term rising trend that may indicate onset of a heating. The relationships in Chapter 2 indicate that the Spontaneous Combustion indices of Graham's Ratio and CO/CO_2 indicate that after the goaf has settled from the initial formation period that the indices' numbers are very low.

Transcripts of interview from BSM Geologist [redacted] as set down in more detail in Chapter 7 highlight his professional opinions on propensity to spontaneous combustion from information focused on the conditions and behaviour of the 80m thick interburden strata immediately above the worked seam, the Blakefield South seam, up to the next seam of economic interest, the Wybrow seam. Further he also commented on his understanding of general propensity to spontaneous combustion of all coals in the surrounding measures, the Whittingham coal measures. He states that as far as he is aware they all have moderate propensity as defined in SIMTARS reports. He does not believe that the Blakefield South seam has a higher or lower propensity than the Wybrow or other seams above that have been mined in the past.

The appearance of physical indicators (such as heat, smell, etc) of spontaneous combustion needs to be taken seriously. The Maintenance Supervisor, [redacted] stated that immediately after the Wind blast "something that was really different was the smell….it smelt like gunpowder…..like cordite….after you shoot….it's got a real distinctive smell and I'll never forget that smell". The Deputy, [redacted], stated that as he moved along the LW face after the Wind blast an unrecognised smell was experienced close toward the TG and a bit of a rumbling sound was heard. He then entered the TG and witnessed combustion and flames coming from goaf material behind the chock line. There is no reason to believe that the "gunpowder or cordite" or "unrecognised smell" came from anything other than the goaf fire combustion process.

The reference to gunpowder or cordite likely means that there was a pungent "sulphide like" smell. Many coal seams contain small traces of the mineral pyrite (FeS_2) or the gas Sulphide Dioxide (SO_2) that when heated by the goaf fire could release a "sulphide like" smell unrelated to spontaneous combustion. Furthermore no other physical indicators of spontaneous combustion were mentioned in either the interview transcripts of these witnesses.

6. BSM's VENTSIM MODELLING

The 2D Ventsim model supplied by BSM has been converted into a 3D Ventsim model with all the "z" (height) coordinates at each branch junction (normally roadway intersection) in the model included based on the seam roof (Blakefield Seam) contours mine plan data obtained from mine. However, it should be noted that the 2D Ventsim model supplied by the mine is for the August 2010 mine situation; a time of five months prior to the incident in January 2011. The latest Ventsim model prior to the incident was requested and this five month old Ventsim model was made available as the latest model prior to the incident. Screen snapshots of the 3D Ventsim model are shown in the following figures.

Mines typically keep Ventsim models updated monthly after the statutory ventilation survey. It can only be assumed that the mine was not maintaining an up-to-date Ventsim model for the short term planning of their ventilation system. The mine does not appear to have the capability to do so possibly due to the complexity of the push and pull ventilation system used at BSM.

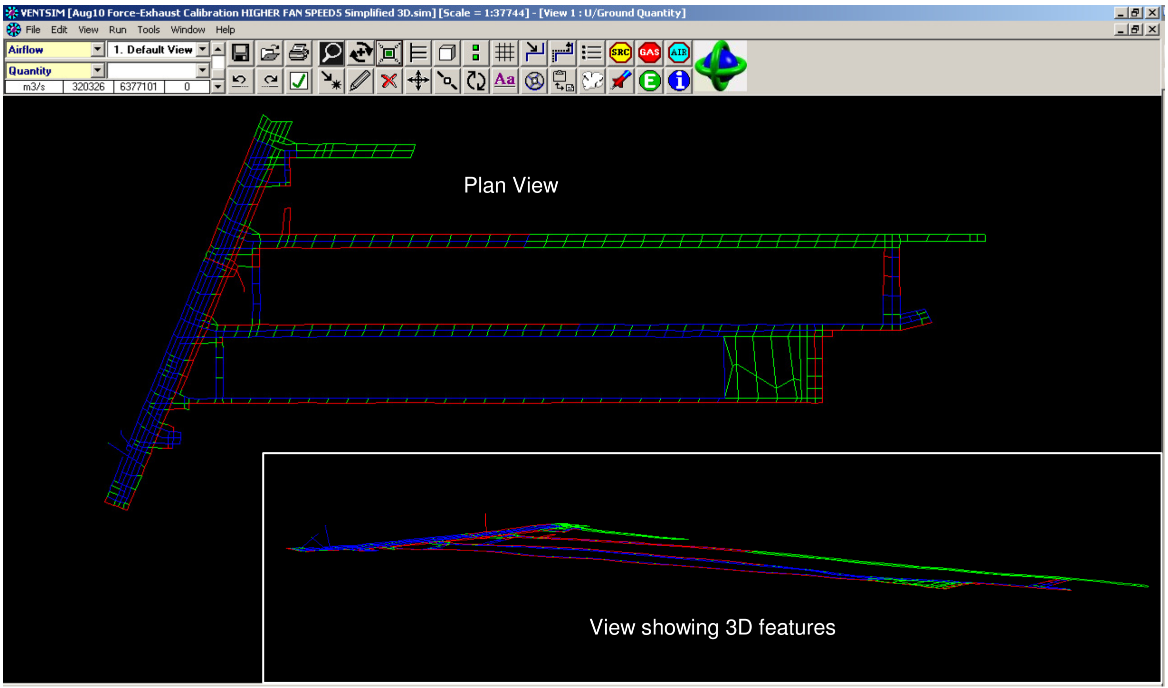

Figure 6.1 Screen snapshots of the 3D Ventsim converted based on 2D model supplied.

The model supplied also does not include the attributes of the actual forcing fans and exhaust fans operating at the time. Instead, fixed quantities had been incorporated in the model at the locations of the fans at the intake and exhaust shafts to simulate the total mine airflows. This means that the model is not able to reflect/predict the effects from all changes made to the ventilation system in the model. It only represents a static snapshot of a particular time phase. This supports the recent interview statement obtained by the Investigation Unit from the former BSM ventilation officer that it was not possible to maintain a valid ventilation model for the push/pull ventilation system used.

These circumstances indicate that BSM's mine ventilation management system needs improvement when compared with the standards of current Australian underground coal mine ventilation accepted practice.

To be able to undertake proper Ventgraph model and simulation for the January 2011 incident, the 3D Ventsim model is to be updated to the status of the ventilation network just prior to the incident using the relevant information available from monthly ventilation reports and plans. This task is currently being undertaken and the following figure shows a screen snapshot of the updated 3D Ventsim model at 5 January 2011 prior to the incident.

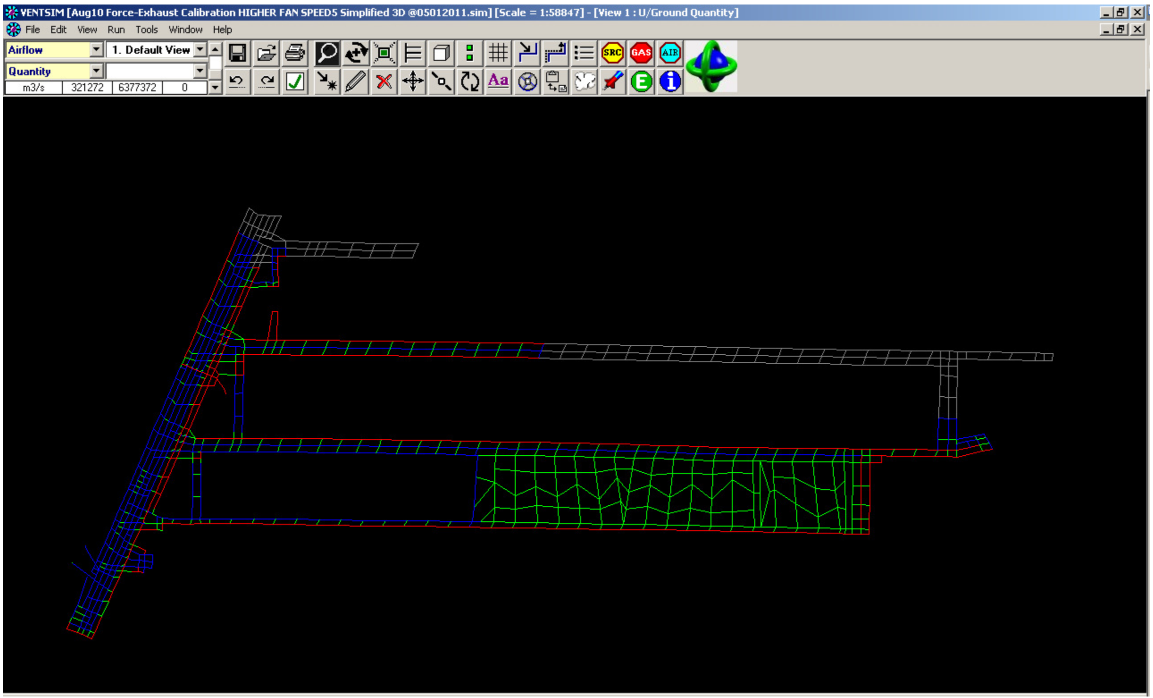

Figure 6.2 Screen snapshots of the updated 3D Ventsim model as at 5 January 2011.

7. EXPLOSIVE FRINGE

This section covers discussion and comments on explosive fringe that existed in the mine and its location relative to the line of chocks and possible ignition sources.

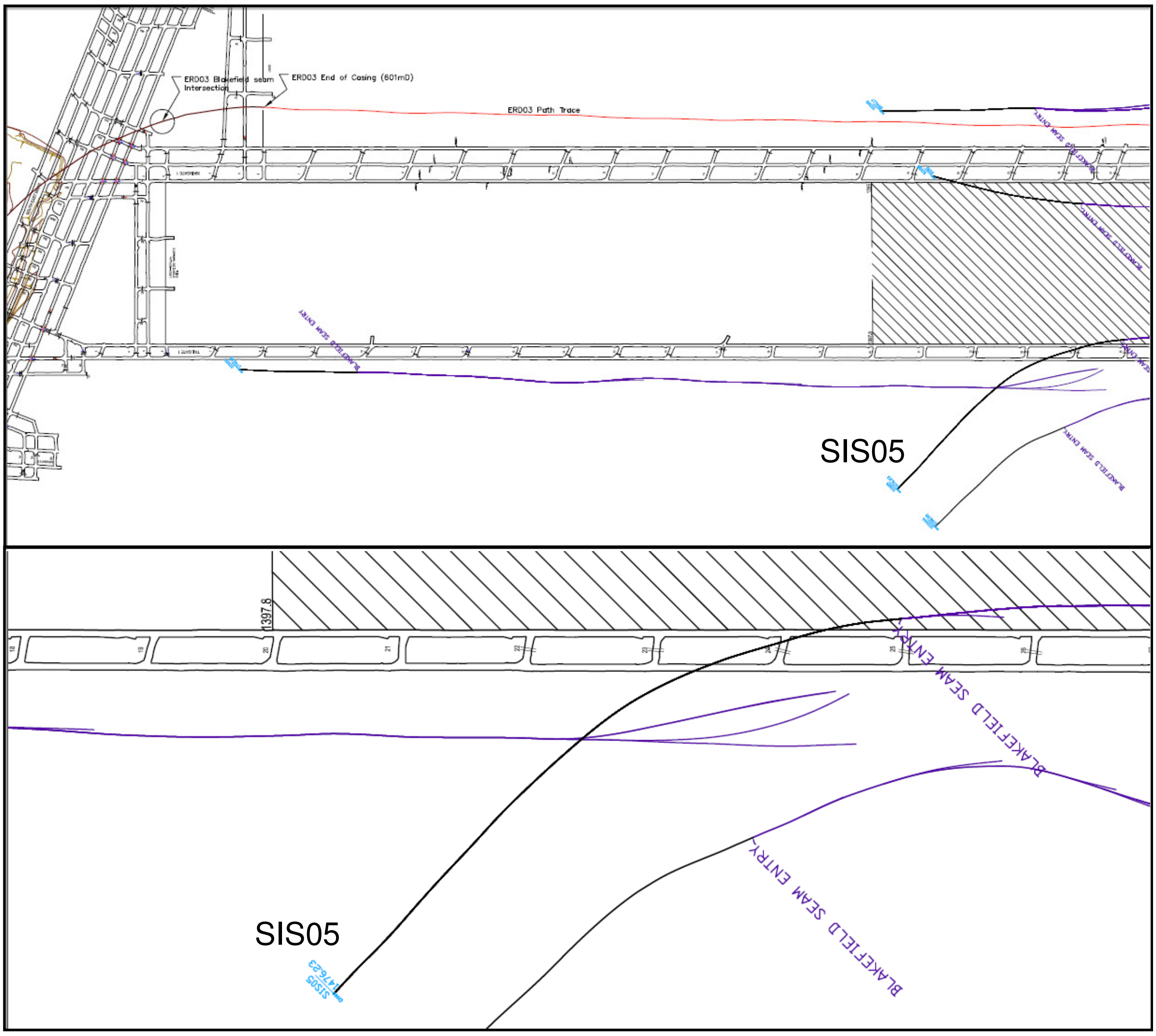

Figure 7.1 Extract from mine plan showing SIS 05 hole intercept LW TG at about 4 to 5 CTs inbye of the LW face line at the time of incident.

Figure 7.2 shows a plan and elevation view of the boreholes intersecting the upper and lower seams being worked in the vicinity of the TG on 5 January 2011. These demonstrate that there were a number of borehole connections between upper Wybrow and lower Blakefield South coal seams that could have held gassy atmospheres that possibly played a part in allowing CH_4 to pass from the upper seam to replenish CH_4 gas concentration levels immediately after dilution with ventilation as the longwall mined through a particular part of the coal seam being worked and goaf formation occurred.

The mine Deputy [redacted] on the LW face on the shift of the explosion commented that his shift gas inspection readings at the back of 158 Support and goaf edge showed gas readings of 2.6% CH_4, 4ppm CO and O_2 at 20.6%. Deputy [redacted] stated that the gas readings he took at the particular time were not considered to raise issues as he explained that quite regularly at the back of 158 Support CH_4 levels of 5% were observed and gas was diluted off to around 1% 5m into roadway.

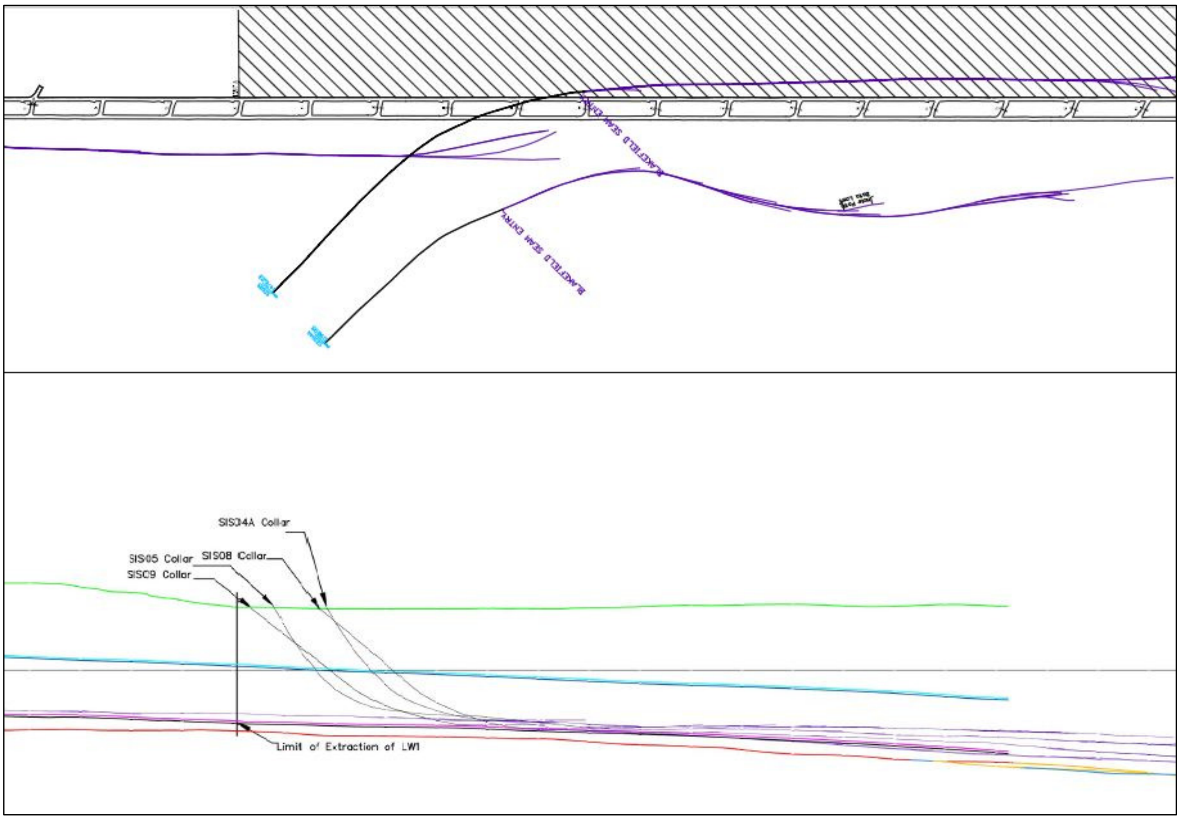

Figure 7.2 Plan and Elevation view of the boreholes intersecting the upper and lower seams being worked in the vicinity of the TG on 5 January 2011.

Further and as set down in Chapter 4 of this report the Shift Deputy across each of the three shifts daily undertook and recorded manual portable gas sensor CH_4 readings standing at the TG every shift. These readings varied widely from shift to shift and day to day. Also different Deputies would have stood at slightly varying positions adjacent to the last LW chock 158 while taking the readings with hand held gas electronic monitors. Selected tabulated date shows a number of instances of high (>2%) or potentially explosive range readings (>5%) in the period from 1 December 2010 leading up to the 5 January 2011 incident as shown in Table 7.1.

Active goafs in gassy seams have a complex pattern of CH_4 concentrations in three dimensions across the width, along the length and at different vertical positions through the recently extracted goaf void. Air in the middle of a formed goaf may have 50 to 80% CH_4 concentration. At the back of the goaf and adjacent to the back bleeder headings this concentration is likely of lesser value as some ventilation air mixes with the CH_4.

With the mine ventilation system in place at Blakefield South colliery the air flowing along the LW MG headings was being drawn (pushed/pulled) across the LW face. In general some face ventilation air travels behind the chock line. Various studies sampling goaf atmosphere through recently constructed MG seals back a few CTs behind the chocks demonstrate that CH_4 concentrations increase as less face air reaches into the goaf with distance. The goaf is packing down as it takes weight and becoming less permeable.

Table 7.1 Selected TG Deputy Shift CH_4 Readings

DATE	SHIFT	TG CH_4
04/12/2010	DAY	>5.0
05/12/2010	DAY	>5.0
15/12/2010	DAY	4.6
02/01/2011	DAY	2.08
03/01/2011	AFTERNOON	2.6
04/01/2011	AFTERNOON	2.5
05/01/2011	NIGHT	3.1
05/02/2011	AFTERNOON	2.6

In summary sampling of the face ventilation air travelling directly behind the chock line shows a progressive increase in CH_4 concentration away from the face. The face air where the shearer cuts coal by NSW legislative regulation should have CH_4 concentration at no more than 1.25% as at that point the machine methanometer cuts power to the machine. Back from the chock line and at some point that may be very short, only a few metres or considerably more (depending on rock behaviour, ventilation quantity, seam extraction thickness and other parameters) a CH_4 concentration of 5%, the lower explosive limit, will be met; further back into the goaf the upper explosive limit of 15% will be met and normally readings even further back will be greater than this and non explosible being above the rich limit of explosibility. Lines of CH_4 concentration which are approximately parallel can be drawn running across the goaf from MG to TG to illustrate this concept.

Within the goaf and back from the chock line the term explosible fringe line is used to describe the point when the contour of CH_4 concentration of 5%, the lower explosive limit, is met. Various empirical and computational fluid dynamics studies have found that the explosible fringe line is generally a greater distance back from the line of chocks at the LW MG end but becomes closer to the chocks towards the TG end as the ventilation air is drawn around the “corner” into the TG.

The CH_4 concentrations of levels for specific dates and shifts leading up to the time of the incident set down in Table 7.1 show variations at the TG measurement location adopted by mine management. This can be interpreted that over time the gas explosible fringe line is moving in and out from the measurement point. The data in this table shows that at times the TG was in air of high CH_4 concentration but not explosible and at others at yet higher CH_4 concentrations in excess of the minimum explosible limit. Or put another way the explosible fringe line moved and at times intersected the line of chock supports.

It can be seen from interpreting information from Table 7.1 and Figures 7.1 and 7.2 that at times the CH_4 concentration in the goaf on the goaf TG side behind Chock 158 and behind the chock line had CH_4 concentrations in excess of the minimum explosible limit with levels within the explosible range of 5 to 15%. This CH_4 originated from gas within the coal seam itself, gas that permeated into the forming goaf from surrounding strata and gas that flowed in strata cracks and through intersecting boreholes from the upper seam.

Transcripts from BSM Geologist [redacted] recorded during an interview were made available. The information focuses on the conditions and behaviour of the 80m thick interburden strata immediately above the worked seam, the Blakefield South seam, up to the next seam of economic interest, the Wybrow seam. [redacted] makes the point that there is no fracture system or connection between the Wybrow and the Blakefield South seams. He also states that in the 80m of interburden above the Blakefield South seam there is complex sedimentary geology; he implies that immediately above the Blakefield South seam there are some siltstones that break up easily and fragment when mining occurs below. He says the goaf behind the LW in these areas is a lot tighter in these areas and this is typical of LW 1 where it is currently being mined. Further up in the sequence the sediments and sandstones tend to be quite strong. They tend to bridge and stay as a massive unit. Further up again the interbed claystones and sediments up to the Wybrow seam at their height above the Blakefield South seam and in forming the LW goaf tend to lay down in terms of subsidence over the goaf. He concludes by agreeing that there is no major fracturing system formed during the subsidence phases that are a part of goaf formation.

[redacted] also commented on his understanding of general propensity to spontaneous combustion of all coals in the surrounding measures, the Whittingham coal measures. He states that as far as he is aware they all have moderate propensity as defined in SIMTARS reports. He does not believe that the Blakefield South seam has a higher or lower propensity than the Wybrow or other seams above that have been mined in the past.

Some possible ignition sources (or textbook ignition sources) that could have ignited gas at concentrations within the explosible range in the vicinity of the flames witnessed in the goaf include the following:

1. Goaf or TG roof falls resulting in frictional ignition,
2. Shearer frictional ignitions,
3. AFC caused frictional ignition,
4. Smoking accessories,
5. Electrical ignitions eg lightening,
6. Electrical apparatus.

There have been some public discussions that the ignition cause may have been lightening transmitted down a steel lined borehole.

8. REVIEW OF EYE WITNESS ACCOUNTS

Discussions on deputy's eye witness account and how it relates to other evidence provided in the brief are included in this section. Two records of interview were provided by the Investigation Unit for review. These are

- Record of Interview conducted by Mr Tim Flowers, Inspector of the Investigation Unit with [redacted], LW Crew Deputy on 1 February 2011.
- Record of Interview conducted by Mr Tim Flowers, Inspector of the Investigation Unit with [redacted], Maintenance supervisor on 8 February 2011

According to the records of interview as supported by both Deputy [redacted] and Maintenance supervisor [redacted], the afternoon shift on 5 Jan 2011 was planned to continue undertaking the maintenance work uncompleted during day shift. LW deputy, [redacted] did his inspection of face conditions including TG and general conditions of the goaf. In his verbal statements at interview he stated that everything looked quite good and nothing abnormal face wise. Up at the TG everything was as usual. LW TG position was right on the intersection of 20 CT and link locks supports were in normal places but being at a CT intersection extra supports were "all over the place". Link locks were usually installed in 6m spacing, just off centre of the TG roadway. But six extra supports were placed in the mouth of the CT. Gas inspections at the back of 158 Support (the last chock) and goaf edge showed gas readings of 2.6% CH_4, 4ppm CO and O_2 at 20.6%. [redacted] stated that the gas reading levels he took at the particular time and before the incident were no issue as he explained that quite regularly at the back of 158 Support that CH_4 levels of 5% were observed and gas was "diluted off" to around 1% 5m into roadway.

He also stated that surprisingly the goaf had fallen right up to the back of 158 Support in TG roadway to the link lock beside 158 Support. Roof conditions in the goaf were good. Inspection was also undertaken outbye in the TG A Hdg and only slight floor heave observed about 5m outbye from face line. He stated that this minimal floor heave might be due to LW face standing that day and face line run at the CT.

Three crew members were working up on the isolated AFC just before the gas explosion incident. The AFC was electrically isolated and the LW still had power in the form of hydraulics and face lights. All other power was isolated at the MG.

A major pressure fluctuation or huge windblast was experienced at the time of the incident (7:36pm 5 Jan 2011) with windblast direction against mine ventilation flow direction (i.e. from TG to MG) rather than the normal direction on the LW face of air flowing from MG to TG. The Deputy, [redacted], who was at the MG end of the face stated that the windblast did not blow him or the other four crew members near him over. Within seconds of the blow a big "suck back" was experienced. He noted that the suck back was stronger than the blow but there were no distinct sounds heard at the MG.

Immediately after the incident the Deputy used the DAC to contact the only crew member working up the face, [redacted], who responded immediately. The Deputy left to quickly move to [redacted]. One or more of the LW miners also at the MG followed the Deputy as he started to move up the LW face. The Deputy met [redacted] about a third of way along the face from the MG. [redacted] verbal account records that he stated that he had been standing working at Chock position 130 at the time of the incident and had been knocked over by the windblast. Figure 8.1 shows LW Maintenance Supervisor, [redacted], hand drawing indicating his position on LW face at Chock 130 at time of incident.

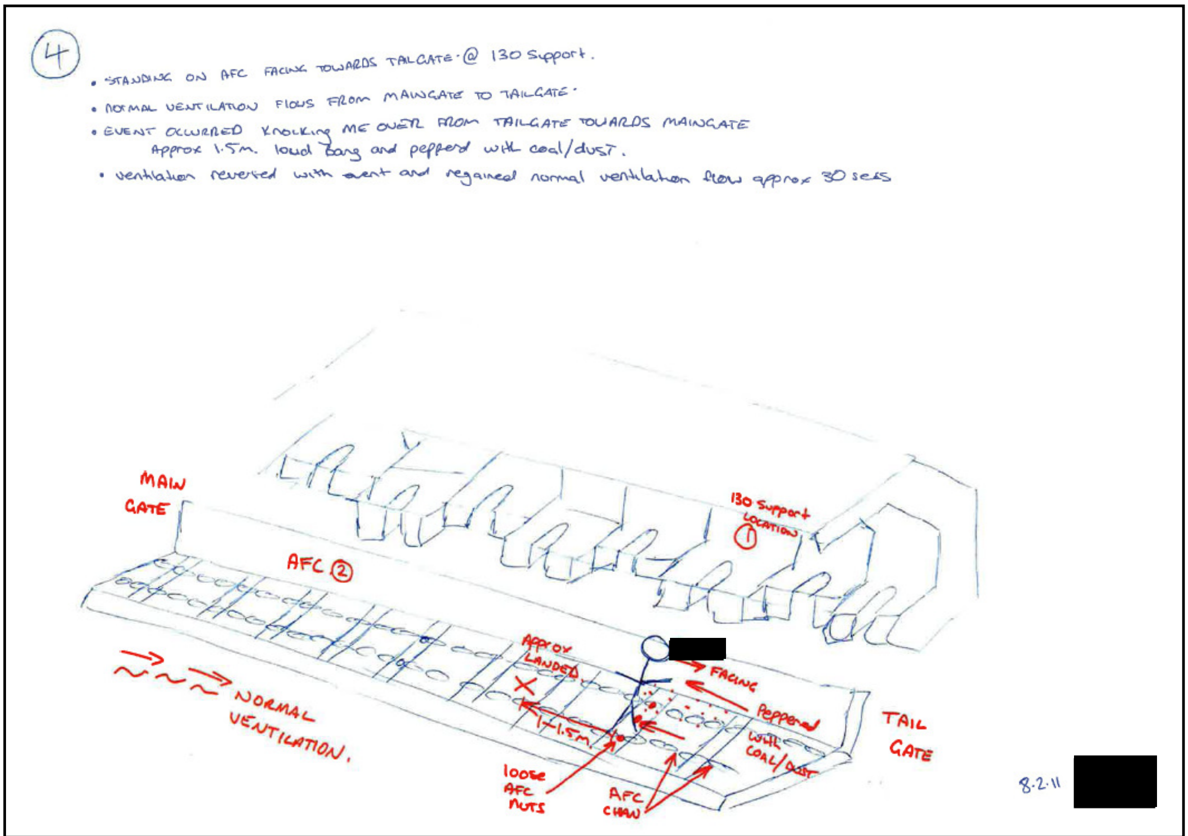

Figure 8.2 LW Maintenance Supervisor, [redacted], hand drawing indicating his position on LW face at Chock 130 at time of incident.

The Deputy's statement says that [redacted] was somewhat agitated when they met on the face. The Deputy then continued travelling toward the TG to find out what had caused the windblast.

The independent verbal statements of both [redacted] and [redacted] as to changes in face air flow behaviour support each other. [redacted] recorded comments on the state of face ventilation at the time of being knocked down. He said it was not like a wind blast or any goaf fall he had ever experienced. He said normally they start off and you feel pressure change and then it's like a slow gradual build up of air but this was a "sudden and really fast pulp and then a bang". The ventilation took 30 seconds to change back to its original direction; the change back of air direction occurred slowly.

[redacted] when asked said he had not noted any change in smell before or up to time of being knocked over. He noted when he was at Chock 130 a cloud of dust and he was peppered by dust. He recorded in the verbal interview that "something that was really different was the smell….it smelt like gunpowder…..like cordite….after you shoot….it's got a real distinctive smell and I'll never forget that smell". [redacted] stated that he was aware of the mine's spontaneous combustion management plan and expected to note signs of "...sweating of, of steel, heat, haze and......" if this existed. He did not recall any of these effects at the time of the incident.

The Deputy stated that an unrecognised smell was experienced as he moved close toward the TG and a bit of a rumbling sound was heard. Just before he tried to step out from under 158 Support he saw flames coming back towards him from the goaf edge and from down the roadway as shown in the following drawing included in the record of interview provided.

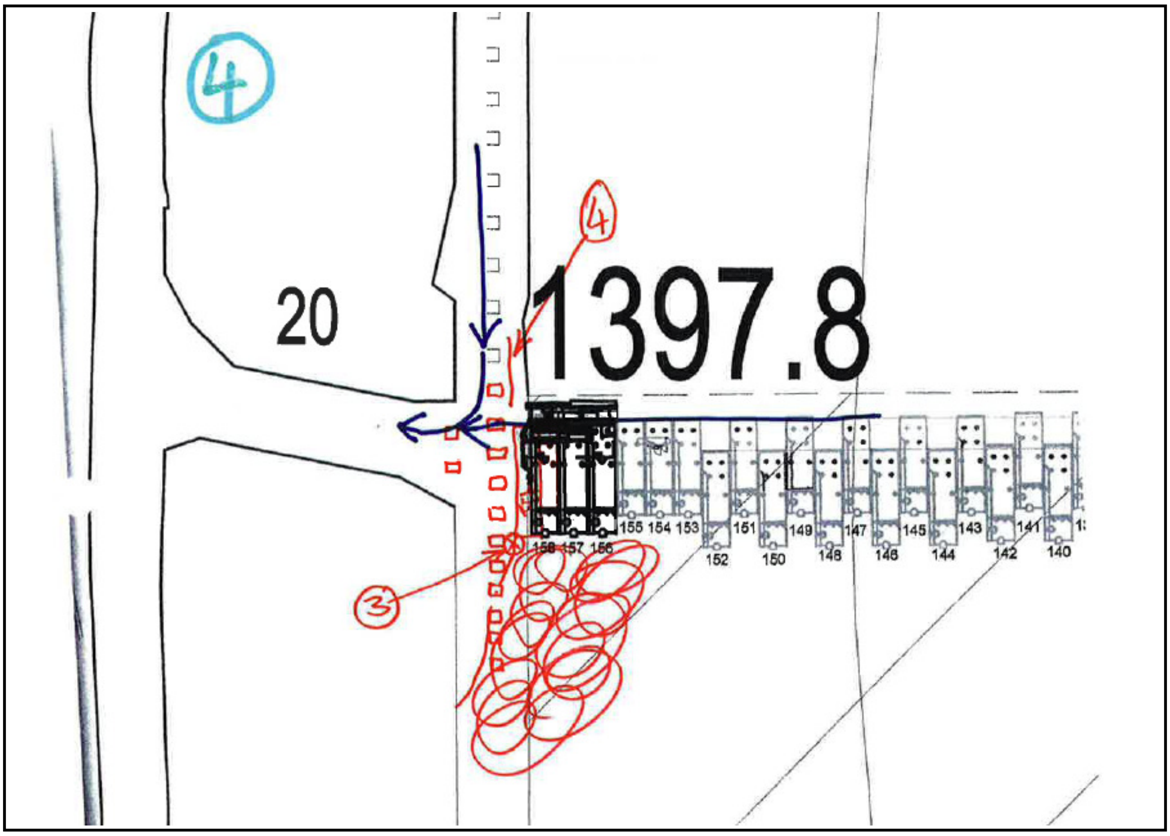

Figure 8.2 LW Crew Deputy, [redacted] hand drawing indicating the locations of the flames he saw at TG end of LW.

He stated that LW face was "double chocked" which is a policy on the LW for more than two hours downtime to close the face up to maintain the face and roof conditions. Every second chock was advanced with alternatively every second one back; this formed a staggered walkway along the LW face.

Comparisons of information on LW location, situation, shift activities and gas levels provided in the records of interview of [redacted] and [redacted] and information and data from other sources (Citect monitoring system, deputy statuary reports and mine ventilation plan) show that descriptions and accounts provided in the records of interview were consistence with other sources. Minimum LW Shearer movements during the afternoon shift on 5 January 2011 were observed from Citect data with LW Shearer position stationary at 19.4m from MG end of LW face from 2:30pm to 7:30pm. Citect data showed that Shearer position in relation to LW MG had changed three times,

- from 19.4m to 17.8m at 3:22pm and then back to 19.4m at 3:33pm.
- from 19.4m to 17.8m at 6:54pm and then back to 19.4m at 6:55pm.
- from 19.4m to 18.4m at 7:31pm and then to 15.5m at 7:32pm. It should be noted that the incident occurred shortly after at 7:36pm.

These Shearer (or AFC) movements were to position AFC for maintenance work to be undertaken as described in the records of interview.

Gas levels at LW TG recorded in the Deputy statuary report for 5 January 2011 are consistence with the gas levels measured on 5 January 2010 and described by [redacted] during the interview. His opinion or comment on the gas levels generally observed at LW TG or goaf edge around 158 Support is also in agreement with the LW TG gas levels recorded at deputy statuary reports as shown in Table 4.1 in Section 4 of this report.

Comments on the Colour of Flame Described by [redacted]

[redacted] comments from his interview were as follows: The flame was described by [redacted] as "4 to 5 to 6, maybe 8 metres long, coming out of the goaf; big bright orange, reddy orange long flames fanning out of the goaf when he put his head out of the rubber flips made from conveyor belt hung on the 158 support to have a look of the status of goaf. He was looking backwards from the Tailgate inbye. [redacted] was asked about the position of the flame and answered that the flame he saw was not quite at roof level; he said a foot, or foot and a half from roof level, down. These comments are extracted from Page 16 and also Page 77 Q519 of [redacted] Records of Interview.

What was being seen by [redacted] was a fire consuming natural gas (methane and other gases) trapped in and being emitted or flowing through the goaf and secondarily coal in the goaf from roof, floor and some wastage. Some gas may have been being emitted from boreholes. Thus the fire is a function of combustion from these two sources.

Experimental science has demonstrated that perfect (oxygen/fuel mixing ratio) burning of pure methane will produce a blue flame (as seen with a well adjusted science laboratory Bunsen burner flame). However, when mixed with condensates and imperfect oxygen/fuel mixing ratios incomplete combustion processes will produce yellow, orange, green, purple or red colours in the flame. The colder part of a diffusion (incomplete combustion) flame will be red, transitioning to orange, yellow and white as the temperature increases as evidenced by changes in the blackbody radiation spectrum. For a given flame's region, the closer to white on this scale, the hotter that section of the flame is. The condensates could be Benzene, Toluene, Tar, Oil, Dust, Rust, Gas Odorants or PCBs. These are volatile and the colours burst out and jump about. The coloured condensates bursting in the flame are some of the chemicals in the gas.

It should be noted that if the flame isn't blue something mixed with the methane is burning. Flame colour depends on several factors, the most important typically being blackbody radiation and spectral band emission, with both spectral line emission and spectral line absorption playing smaller roles. In the most common type of flame, hydrocarbon flames, the most important factor determining colour is oxygen supply and the extent of fuel-oxygen pre-mixing, which determines the rate of combustion and thus the temperature and reaction paths, thereby producing different colour hues.

In a laboratory under normal gravity conditions and with a closed oxygen valve, a Bunsen burner burns with yellow flame (also called a safety flame) at around 1,000 °C. This is due to incandescence of very fine soot particles that are produced in the flame. With increasing oxygen supply, less blackbody-radiating soot is produced due to a more complete combustion and the reaction creates enough energy to excite and ionize gas molecules in the flame, leading to a blue appearance. The spectrum of a premixed (complete combustion) butane flame on the right in the figure below shows that the blue colour arises specifically due to emission of excited molecular radicals in the flame, which emit most of their light well below ~565 nanometers in the blue and green regions of the visible spectrum.

The colder part of a diffusion (incomplete combustion) flame will be red, transitioning to orange, yellow, and white as the temperature increases as evidenced by changes in the blackbody radiation spectrum. For a given flame's region, the closer to white on this scale, the hotter that section of the flame is. The transitions are often apparent in fires, in which the colour emitted closest to the fuel is white, with an orange section above it, and reddish flames the highest of all. A blue-coloured flame only emerges when the amount of soot decreases and the blue emissions from excited molecular radicals become dominant, though the blue can often be seen near the base of candles where airborne soot is less concentrated.

Different flame types of a Bunsen burner depend on oxygen supply as shown in the following figure. On the left a rich fuel with no premixed oxygen produces a yellow sooty diffusion flame; on the right a lean fully oxygen premixed flame produces no soot and the flame colour is produced by molecular radicals, especially CH and C_2 band emission. The purple colour is an artifact of the photographic process.

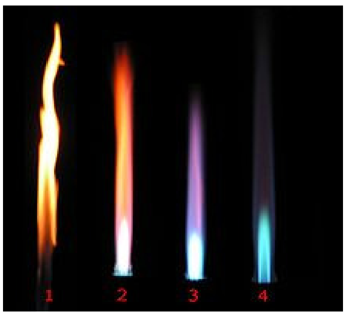

Figure 8.3 Various types of flame from a Bunsen burner

One important aspect is that a flame's colour does not necessarily determine a temperature comparison because black-body radiation is not the only thing that produces or determines the colour seen; therefore it is only an estimation of temperature. Other factors that determine its temperature are:

- Adiabatic flame; i.e., no loss of heat to the atmosphere (may differ in certain parts).
- Atmospheric pressure
- Percentage oxygen content of the atmosphere.
- The fuel being burned (i.e., depends on how quickly the process occurs; how violent the combustion is.)
- Any oxidation of the fuel.
- Temperature of atmosphere links to adiabatic flame temperature (i.e., heat will transfer to a cooler atmosphere more quickly).
- How stoichiometric the combustion process is (a 1:1 stoichiometricity) assuming no dissociation will have the highest flame temperature and excess air/oxygen will lower it and likewise not enough air/oxygen.

In fires (particularly house fires), the cooler flames are often red and produce the most smoke. Here the red colour compared to typical yellow colour of the flames suggests that the temperature is lower. This is because there is a lack of oxygen in the room and therefore there is incomplete combustion and the flame temperature is low, often at just 600-850 °C. This means that a lot of carbon monoxide is formed (which is a flammable gas if hot enough) and when this occurs carbon monoxide combusts and temporary temperatures of up to 2,000 °C can occur.

Material burned	**Flame temperature (°C)**
Charcoal fire	750–1,200
Methane (natural gas)	900–1,500
Propane blowtorch	1,200–1,700
Candle flame	~1,100 (majority), hot spots may be 1300–1400

As coals are heated either from adjacent hot air or gases burning nearby certain gases are driven out and appear at characteristic temperatures as referred to as the fire ladder. Coal heating from spontaneous combustion may produce similar conditions. The hierarchy and order of appearance varies from different coals and coal geological provinces. The first gas given off is CO_2. Next is CO then the products of low temperature oxidation CH_4, H_2, C_2H_4, C_2H_6. The order may vary from coal type to coal type. Finally as the coal reaches higher temperatures pyrolysis products of the coal will appear and the combustion process moves into a self generating stage.

Therefore, [redacted] observations indicate that a goaf fire burning gases and solid coal was occurring on the edge of the broken material forming the goaf and possible further inside the goaf. He was seeing a progression from the colder part of a diffusion (incomplete combustion) flame which is red, transitioning to orange, yellow, and white as the temperature increased as evidenced by changes in the blackbody radiation spectrum. In terms of the "fire triangle" oxygen was abundant from the mine ventilation airways surrounding the goaf, fuel was coal and seam gases and an ignition source existed (there have been some suggestions that this may have been lightening that directly ignited gas mixtures of concentration in the explosive range fringe as would have been found along the goaf edges and behind the longwall chock shield supports)

It is of interest that the UBB West Virginia mine had a major LW face gas event that fuelled a fire in 1997 that was witnessed by mine employees on the LW face in much the same way that the BSM fire was seen.

The 1997 UBB event involved gas ignitions. Eyewitness reports indicated two or more ignitions occurred beginning in the goaf and subsequently entering the LW face region. The incident occurred with a mine roof fall behind the shields. An ignition occurred in the goaf area where the roof had just fallen. The shield operator was standing facing the goaf and was first to see the ignition. He testified that he saw a red glow in the goaf that was becoming brighter. He pointed toward the glow, and then started running toward the LW MG. The other shearer operators also saw the ignition come from behind the shields and then continue up the face line from the TG. Both shearer operators ran toward the MG and reported “something blew up.” It is believed that the gas was ignited by sparks created when the sandstone mine roof struck the longwall shields after an unusually high roof fall.

The foreman and another worker went to the tail to check the area after making sure everyone was headed out toward the MG. The foreman stated he also observed the ignition. Both of these men detected 0.6% CH_4 and enough CO was present to activate the alarm of the foreman’s multi gas detector. The detector was set to alarm at 50 ppm CO. They detected a smell like “old works”. These two men witnessed a second ignition, which appeared like a “yellowish” flash, while they were examining near the TG. A third event occurred as they were walking past shield 36 toward the MG. They described this final event as “bucking of the air.”

The parallels between the 2011 BSM and the 1997 UBB incidents are striking. Both occurred at the TG of the goaf and had witnesses identifying a red glow after gas ignition in the goaf. Both mentioned subsequent bright orange or yellow flashes or flames. Both mentioned various “smells”. Both give no indication of the cause of ignition being related in any way to spontaneous combustion.

9. RECOMMENDATIONS

The following are recommendations that would be beneficial to the investigation of the BSM incident as well as to the industry and the on-going operation of BSM.

(i) Maintenance of an Up to Date and calibrated Ventilation Network Model to gain better understanding of the behaviour of the complex push and pull ventilation system implemented at BSM.

(ii) Tube Bundle Gas Analysis System is standard in Australian mines and should be installed at BSM. This is particularly so for gassy mines.

(iii) Further work using Ventgraph Fire Simulation Model
It is recommended that further work for the investigation of the incident at BSM to be undertaken includes the following.
- Validate the updated Ventsim model as at 5 January 2011 before the incident.
- Convert the validated and updated Ventsim model into a Ventgraph fire simulation model
- Analysis of the Gas and Shearer position data at various monitoring locations to work out gas makes for production and non-production phases for the LW panel and during the stoppages of main fans.
- Apply the gas make information to the Ventgraph model simulation and develop scenarios for possible causes of the incident.
- Validate simulated results of scenarios for possible causes of the incident with the actual Citect gas monitoring data recorded.

(iv) Undertake Ventgraph modelling with an ignition assumed to originate where a borehole intersects the worked seam in the TG about 4 CT back or inbye the LW face. In this modelling assume that ignition is caused by lightening and model to parallel the observations and re-actions of the LW shift Deputy and the Maintenance Supervisor from the moment of lightening strike recorded on the surface above the borehole position.

(v) The US April 2010 fatal mine ignition leading to a gas explosion that lifted dust and propagated a dust explosion in the Upper Big Branch (UBB) West Virginia Massey Coal mine bears a very close comparison to the BSM incident (except that the BSM incident fortunately did not propagate to a dust explosion). The January 2006 Sago fatal mine explosion in West Virginia is believed to have been caused by lightening. Review the publically available reports from these very closely studied disasters and particularly the federal Mine Safety and Health Administrations reports. Compare the technical explosion ignition and gas explosion aspects of UBB and Sago with BSM to see if any important aspects have been overlooked.

(vi) It is anticipated that the above mentioned tasks will require 140 to 180 hours to validate the updated Ventsim model, conduct Ventgraph modelling, undertake possible scenarios simulations, report findings from the Ventgraph modelling and review technical evaluations and MSHA reports from the Sago and UBB disasters.