From: Adrian Barnett
To: Justine Stansen
Subject: RE: Hazelwood Mine Fire Inquiry
Date: Friday, 9 October 2015 8:42:17 PM
Attachments: image001.jpg
image002.jpg
Death.Analysis.5.pdf

Dear Justine

Please find attached my responses to Prof Armstrong's queries. Regards,

Adrian

From: Justine Stansen [m[redacted]
Sent: Friday, 9 October 2015 10:55 AM
To: Adrian Barnett
Subject: FW: Hazelwood Mine Fire Inquiry

Dear Adrian

Please see email below received from Professor Bruce Armstrong. I would be grateful if you could provide any comment on the matters raised below as soon as possible.

Kind regards

Justine Stansen
Principal Legal Advisor
Hazelwood Mine Fire Inquiry
[redacted]

From: Bruce Armstrong [[redacted]]
Sent: Thursday, 8 October 2015 10:47 PM
To: Justine Stansen
Cc: Monica Kelly
Subject: RE: Hazelwood Mine Fire Inquiry

Justine

Thank you for asking me to comment on Associate Professor Adrian Barnett's fourth report, which was attached as file Death.Analysis.3.pdf to an email he sent you on 25th September 2015. Barnett states that this fourth report was an expansion on his original (I assume immediately previous) analysis to answer [my] questions.

His further analysis responds effectively to these of my observations about the previous report:

"The greater increase in mortality in the period of the mine fire could be due, perhaps, to the more precise definition of the period of the fire or to effects of one or more of the variables newly added to Barnett's statistical model for this analysis (time trend in mortality, weekly variation in mortality and maximum daily temperature). Whether it was any of the latter could be tested by removing each in turn from Barnett's statistical model and observing the change in the mine fire result consequent on the removal."

His further results in Table 5 on page 11 show that the relative risk of death during the mine fire was sensitive to the (appropriate) inclusion of temperature in the model, and that this inclusion partly explains the higher relative risk of death during the mine fire that he observed in this model. I agree with him that adjustment for the effects of temperature is appropriate and thus that temperature should be in the model.

It does not appear to me that his further analysis has fully responded to these of my observations about the previous report:

"It is worth noting that Barnett's latest analysis shows an excess of deaths during the period of the mine fire in all four postcodes, Morwell included. In his second previous analysis there was an apparent deficit of deaths in Morwell (relative risk 0.8, 95% CI 0.55-1.28; Table 3 of the relevant report). Barnett does not describe how he arrived at the estimated number of extra deaths during the mine fire in the four postcodes."

Barnett now describes how the numbers of additional deaths due to the fire in each postcode were calculated. This explanation, however, is not clear to me. There are two variables in the expression that Barnett offers on page2, 4th line up from the bottom of the page:

1. The mean number of deaths per day for each postcode.
   The period over which this average has been calculated is not stated; It should be. As I see it, the period should (a) be relatively recent so that it can provide a reasonably unbiased estimate of the expected number of deaths in the four postcode areas over the period of the fire, (b) not include the observed deaths during the period of the mine fire and (c) be based on a period long enough to remove most of the effect of day to day variation in daily numbers on the calculated mean numbers. All these may be true, but it is not clear that they are.
2. Exp (a_{20}), the relative risk of death during the fire. As far as I can tell this is the relative risk across all four postcodes. If this is true, postcode specific relative risks have not been used when estimating the excess deaths and, therefore, previously apparent variation between postcodes in relative risk of death during the period of the mine fire is not taken into account when calculating the numbers of excess deaths. If this is correct, a deficit of deaths in Morwell during the period of the mine fire would be

obscured in this analysis.

Bruce

BRUCE ARMSTRONG
Emeritus Professor, School of Public Health
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CONTACT INFORMATION
[redacted]

From: Bruce Armstrong
Sent: Friday, 18 September 2015 10:18 PM
To: Justine Stansen ([redacted]
Cc: Monica Kelly
Subject: RE: Hazelwood Mine Fire Inquiry

Justine

I have now read Adrian Barnett's Analysis of daily death data during the Morwell mine fire (version of September 2015).

His analysis of deaths is, from a technical point of view, an improvement on his previous analyses because it uses daily death data (referenced to the postcode of residence) and Australian Bureau of Statistics population data. It also restricts the analysis to the four postcode areas of greatest interest – Churchill, Moe, Morwell and Traralgon. From this analysis he reports a relative risk of death from the days of the fire (9th February 2015 to 26th March 2014) of 1.32 (95% credible interval of 1.03 to 1.66; p value 0.01). He also estimates the number of additional deaths in the four postcode areas from the period of the fire to be 23, 1 in Churchill, 8 in Moe, 6 in Morwell and 8 in Traralgon.

These estimates take account of the time trend in mortality in these four postcodes from 2009 to 2014, the underlying differences in mortality in the four postcodes, the seasonal variation in mortality, the weekly variation in mortality and the maximum daily temperature. Therefore, on the face of it, the observed relative increase in mortality risk during the period of the mine fire was independent of these other variables.

These results are reasonably coherent with, but suggest a greater increase in mortality in the period of the mine fire than, the other mortality analyses. For example, the table below compares Adrian Barnett's latest result with my result for the period February to March 2014 (Table 2 of my report) based on the Flander et al 2015 analysis.

Years	February-June			February-March		
	Rate	95%	p-	Rate	95%	p-

	ratio	CI	value	ratio	CI	value	Notes
Deaths from all causes							
2014	1			1			
2009-2013[b]	0.90	0.80-1.00	0.04	0.83	0.68-1.02	0.08	As in Table 2 of my report
2009-2013				1.20	0.98-1.47	0.08	Inverted to be in the same form as Barnett's latest result
2009-2013				1.32	1.03-1.66	0.01	Barnett's latest result

The greater increase in mortality in the period of the mine fire could be due, perhaps, to the more precise definition of the period of the fire or to effects of one or more of the variables newly added to Barnett's statistical model for this analysis (time trend in mortality, weekly variation in mortality and maximum daily temperature). Whether it was any of the latter could be tested by removing each in turn from Barnett's statistical model and observing the change in the mine fire result consequent on the removal.

It is worth noting that Barnett's latest analysis shows an excess of deaths during the period of the mine fire in all four postcodes, Morwell included. In his second previous analysis there was an apparent deficit of deaths in Morwell (relative risk 0.8, 95% CI 0.55-1.28; Table 3 of the relevant report). Barnett does not describe how he arrived at the estimated number of extra deaths during the mine fire in the four postcodes.

Bruce

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From: Bruce Armstrong
Sent: Thursday, 17 September 2015 2:42 PM
To: 'Justine Stansen'
Subject: RE: Hazelwood Mine Fire Inquiry

Thanks Justine. I will be happy to give the Board my opinion. You should have it by Monday.

Bruce

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Emeritus Professor, School of Public Health
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[redacted]

From: Justine Stansen [redacted]
Sent: Thursday, 17 September 2015 11:29 AM
To: Bruce Armstrong
Subject: Hazelwood Mine Fire Inquiry

Dear Bruce

I trust you are well. We have received some further analysis undertaken by Associate Professor Adrian Barnett since the Hazelwood Inquiry hearings held earlier this month which is based on daily death data rather than monthly data. I was wondering whether you could consider the **attached** analysis and contact me to discuss your thoughts about it. The Board would be grateful for your additional input in relation to this issue.

I look forward to hearing from you.

Justine Stansen
Principal Legal Advisor
Hazelwood Mine Fire Inquiry
[redacted]

Analysis of daily death data during the Hazelwood mine fire

Purpose

The purpose of this document is to answer two queries from Professor Bruce Armstrong:

1. The mean number of deaths per day for each postcode. The period over which this average has been calculated is not stated; It should be. As I see it, the period should (a) be relatively recent so that it can provide a reasonably unbiased estimate of the expected number of deaths in the four postcode areas over the period of the fire, (b) not include the observed deaths during the period of the mine fire and (c) be based on a period long enough to remove most of the effect of day to day variation in daily numbers on the calculated mean numbers. All these may be true, but it is not clear that they are.
2. Exp(α_{20}), the relative risk of death during the fire. As far as I can tell this is the relative risk across all four postcodes. If this is true, postcode specific relative risks have not been used when estimating the excess deaths and, therefore, previously apparent variation between postcodes in relative risk of death during the period of the mine fire is not taken into account when calculating the numbers of excess deaths. If this is correct, a deficit of deaths in Morwell during the period of the mine fire would be obscured in this analysis.

Summary response

1. I tried a few alternative methods for calculating the mean number of deaths based on Professor Armstrong's suggestions. The estimated number of deaths during the fire were similar regardless of which mean was used.
2. A model using postcode specific relative risks was not as good a fit to the data as a model with a common relative risk. Hence the previous results using a common relative risk should be preferred. However, even for a model with a varying risk across postcodes, there is an increased relative risk of death during the fire in Morwell.

More detailed analyses that address the two queries are given in the sections below.

1. The mean number of deaths per day for each postcode

The estimated additional number of deaths during the fire in each postcode were calculated using:

$$45 \times \overline{d}_i \times [\exp(\alpha_{20}) - 1],$$

where $\overline{d}_i$ is the mean number of daily deaths in postcode i and $\exp(\alpha_{20})$ is the relative risk of death during the fire. The daily estimate is multiplied by 45 days to give an estimate for the period of the fire.

Prof Armstrong queried the time period used to calculate the mean number of deaths ($\overline{d}_i$). This was based on the entire period of available data, from 1 January 2009 to 31 December 2014 and hence includes the period of the fire. My reasoning for using the entire period was that the influence of the fire would be relatively small given the large sample size.

However, I agree with Prof Armstrong's reasoning that the baseline mean should exclude the period of the fire, I therefore show some alternative calculations below.

Table 1: Mean number of additional deaths during the fire and 95% credible intervals using alternative versions of the baseline mean number of deaths in each postcode ($\overline{d}_i$).

Postcode	Period used to calculate the baseline mean	Baseline mean	Mean	Lower	Upper
3825	All data	0.56	8.2	0.9	16.5
3825	Period of fire in previous years (2009–2013)	0.48	7.1	0.7	14.3
3825	Period of fire in previous two years (2012–2013)	0.52	7.5	0.8	15.2
3840	All data	0.40	5.8	0.6	11.7
3840	Period of fire in previous years (2009–2013)	0.41	6.0	0.6	12.1
3840	Period of fire in previous two years (2012–2013)	0.40	5.8	0.6	11.7
3842	All data	0.08	1.1	0.1	2.2
3842	Period of fire in previous years (2009–2013)	0.08	1.1	0.1	2.3
3842	Period of fire in previous two years (2012–2013)	0.06	0.9	0.1	1.9
3844	All data	0.52	7.6	0.8	15.5
3844	Period of fire in previous years (2009–2013)	0.49	7.2	0.7	14.6
3844	Period of fire in previous two years (2012–2013)	0.45	6.6	0.7	13.3
Total	All data	1.56	22.7	2.4	46.0
Total	Period of fire in previous years (2009–2013)	1.47	21.4	2.2	43.3
Total	Period of fire in previous two years (2012–2013)	1.43	20.9	2.2	42.2

The results in Table 1 show that the alternative calculations for the baseline mean have only a minor impact on the estimated additional number of deaths. The 'period of the fire' is 9 February to 26 March.

2. Postcode specific relative risks

Prof Armstrong is correct in stating that $\exp(\alpha_{20})$ is the relative risk common to all four postcodes. My reasoning for using a common relative risk is that the previous analysis found little evidence for a postcode-specific effect (Table 4 in December 2014 analysis [1]). However, we can revisit this issue given that we are now examining daily data.

Given the time constraints of providing these analyses I could not use a Bayesian approach as these take time to run. Instead I used a standard statistical approach, and I show the similarity of the Bayesian and standard models below. The major differences between the two approaches are: i) how they estimate the model parameters, and ii) the interpretation of the parameters. Both approaches used the same model structure (e.g., same variables to control for daily temperature).

The estimates in Figure 1 are very similar for both the means and 95% intervals. The only noticeable difference is for the intercept, where the Bayesian credible interval is narrower

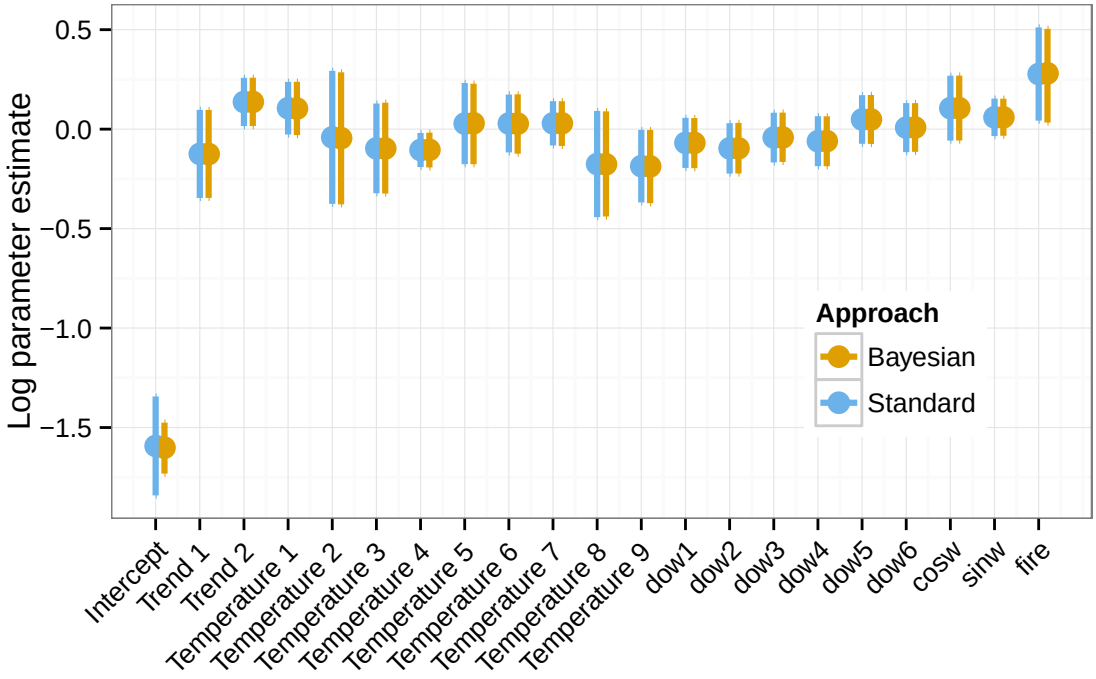

Figure 1: Comparison of parameter estimates using a standard statistical and Bayesian approach. The dots show the mean and the vertical lines are the 95% confidence/credible intervals.

than the standard confidence interval.

Table 2: Akaike information criterion (AIC) and degrees of freedom (df) comparing the two models using a standard statistical approach. The lower the AIC the better the model.

Relative risk of fire	df	AIC
Common across postcodes	22	13301
Varying across postcodes	24	13305

To compare the model fit we can use the Akaike Information Criterion (AIC) [2] as shown in Table 2. The fit was somewhat worse for the model with the varying relative risk, therefore the model with a common risk should be preferred. The degrees of freedom is essentially the number of model parameters, so the model with a varying relative risk had two extra parameters. The varying model was more complex, but did not give a better fit to the data.

The relative risks assuming a varying model are shown in Table 3. The lowest risk was in 3825 (Moe) and the highest in 3842 (Churchill), but the range in relative risks was relatively narrow and all mean risks were increased (i.e., greater than 1).

Table 3: Estimates of the mean relative risk assuming a common and varying effect of the fire across the four postcodes.

Model	Postcode	Mean relative risk
Common effect of fire		1.32
Varying effect of fire	3825	1.29
Varying effect of fire	3840	1.31
Varying effect of fire	3842	1.38
Varying effect of fire	3844	1.35

References

[1] Adrian Barnett. An updated analysis of death data during the morwell mine fire. Technical report, Queensland University of Technology, `http://eprints.qut.edu.au/81685/`, 2 2015.

[2] K.P. Burnham and D.R. Anderson. *Model Selection and Inference: A Practical Information-Theoretic Approach*. Springer New York, 2013.