Contract Report

Crashes on the Way to and From Coal Mines in NSW

by Nick Mabbott, Debbie Cornwell, Bob Lloyd and Anna Koszelak

for Coal Services Health & Safety Trust

RC5016 April 2005

ARRB Transport Research

Crashes on the Way to and From Coal Mines in NSW

for Coal Services

	Reviewed
Project Leader	Nick Mabbott
Quality Manager	Rod Hood

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Technical Summary

The general perception of the state of fatigue-related crashes in transit home from mining workplaces in the Hunter Valley, Newcastle Coalfields and Wollongong areas of New South Wales (NSW) is that it is occurring, although the prevalence is somewhat unknown. It was proposed that the following research questions be asked within the study:

1. What is the prevalence of coal mine workers having road crashes on the way to or way home from coal mines in the Hunter Valley, Newcastle Coalfields and Wollongong areas?
2. What proportion of these crashes has fatigue as a contributing factor?
3. Are there any differences in crashes for people who work in underground mining versus open cut mining?
4. Does the length of shift or time of day have an influence on any of these crashes?
5. Are there similarities between crashes on the way to and from coal mines in NSW as opposed to QLD?

Two sets of data were collected. The first was travel injury data matched with health data, supplied by Coal Services. A second data set was obtained through questionnaire to 18 mines. The data pertains to incidents and near misses that occurred within the last twelve months. Both crash data and incident data results are shown together where possible to highlight both the crashes and the near misses that have occurred on the way to and from coal mines in New South Wales. The basic findings are shown in the following table.

Crash/incident causal factor	Crash	Incident on way to work	Incident on way home
1. Fell asleep	6 (2.7)	15 (9.8)	28 (21.9)
2. Lost control due to inattention	27 (12.3)	6 (3.9)	5 (3.9)
3. Lost control due to conditions	28 (12.8)	5 (3.3)	4 (3.1)
4. Hit another vehicle from behind	12 (5.5)	0 (0)	0 (0)
5. Failed to give way	17 (7.8)	5 (3.3)	3 (2.3)
6. Other driver on wrong side of road	23 (10.5)	15 (9.8)	13 (10.2)
7. Other driver lost control	0 (0)	3 (2.0)	4 (3.1)
8. Hit or swerved to miss an animal	37 (16.9)	87 (56.9)	63 (49.2)
9. Other driver hit you from behind	35 (16.0)	5 (3.3)	1 (0.8)
10. Other driver failed to give way	34 (15.5)	12 (7.8)	7 (5.5)
Total	**219 (100)**	**153 (100)**	**128 (100)**

At January 2005, approximately 9,760 coal miners worked in New South Wales. A total of 219 vehicle crashes were recorded in the 7.5 year period of data supplied. Of these four were fatal. Therefore, there were 215 injury crashes, or 28.6 crashes per year. This represents a prevalence of approximately 0.3% of NSW coal miners being injured in a motor vehicle crash per year on the way to or from work. The four fatal crashes give a rate of 0.53 fatals per year. This represents 0.005% of the coal mining population of NSW being fatally injured in a motor vehicle crash per year on the way to or from work.

Costs of motor vehicle crashes to society include at least the following: Loss of future income, medical costs, damage costs, pain and suffering, emergency services, etcetera. A fatal non-urban crash in NSW is estimated to cost society $1,726,700 whilst an injury crash is estimated to cost $124,300 per crash. **The total cost to the coal NSW mining community per year is approximately $4,470,131 in June 2002 dollar terms.**

This research has highlighted the fact that around 29.2 coal miners in NSW will crash and be injured and 0.5 drivers will be killed on the way to or from work in any one year. This number is likely to increase as the mean age increases and the BMI of individuals increase. Further, the cost to the NSW coal mining community per year is approximately $4,470,131 in June 2002 dollar terms.

There are several benefits that can be gained through the implementation of this project. The most important is the knowledge concerning what are the factors that contribute most to coal miners crashing on their way to or from work. The information arising from the results of this project has provided a strong platform for which to base strategies to reduce the prevalence of coal miners suffering road trauma.

The body of text discusses justification for the recommendations provided. The following recommendations are made in an effort to reduce the trauma associated with travel crashes on the way to and from coal mines in NSW.

Recommendation 1: That a working party be established to investigate and initiate any recommendations from this report.

Recommendation 2: All NSW coal mines should undertake to ensure that all staff can adequately manage the current roster designs that are in place.

Recommendation 3: All NSW coal mines should undertake fatigue management training of all staff and management.

Recommendation 4: A health program for NSW coal miners is put in place, either through the mines or the NSW Government.

Recommendation 5: All mines should investigate opportunities for utilising buses as an alternative means of transport. If not practicable, car pooling should be encouraged.

Recommendation 6: Further investigation of traffic volumes and movements is conducted through the working party.

Recommendation 7: The working party initiates road safety audits to investigate the delineation of roads in the Hunter Valley Region.

Recommendation 8: That the working party investigates the costs associated with treating the two edges and the centre line of the New England Highway, between Singleton and Musswellbrook, with audio-tactile edgeline (raised).

Recommendation 9: That the working party discuss costs associated with mitigation of animals in the road reserve and recommend countermeasures to Government.

Recommendation 10: That the working party assess the outcomes of any treatments using similar performance indicators as used within this study.

Transport Research

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1 Introduction

At the 2002 Queensland Mining Industry Health and Safety Conference in Townsville, Nick Mabbott of ARRB Group (Formerly ARRB Transport Research) authored a role -play of a fatigue-related crash on the way home from a roster of shift work at a mine in the Bowen Basin. The idea was to highlight some of the major issues and contributing factors to fatigue crashes. It has had the desired effect of being a catalyst to increased attention from mine sites, education and research personnel, Police and other interested parties. This in mind, there are still few indicators of the prevalence of such crashes. Perceptions of the prevalence are generally derived from anecdotal evidence.

The general perception of the state of fatigue -related crashes in transit home from mining workplaces in the Hunter Valley, Newcastle Coalfields and Wollongong areas of New South Wales (NSW) is that it is occurring, although the prevalence is somewhat unknown. Discussions with personnel from the Roads and Traffic Authority (RTA) NSW and NSW Police Service indicated a desire to address the situation.

This research addresses the Coal Services Health and Safety Trust's research priority on fatigue and stress.

It was proposed that the following research questions be asked within the study:

1) What is the prevalence of coal mine workers having road crashes on the way to or way home from coal mines in the Hunter Valley, Newcastle Coalfields and Wollongong areas?
2) What proportion of these crashes has fatigue as a contributing factor?
3) Are there any differences in crashes for people who work in underground mining versus open cut mining?
4) Does the length of shift or time of day have an influence on any of these crashes?
5) Can we compare the prevalence of crashes on the way to or from coal mines between NSW and Qld operations?

From the research question outcomes, recommendations for a suitable countermeasure strategy would be put forward. The strategy would be based upon the major contributing factors found within the study, and the feasibility of such a strategy having an effect on controlling or reducing crashes on the way to and from work.

2 Literature Review

Long shifts and shift work incorporated with the need to drive to/from work to home has the potential for negative outcomes for the workforce. The amount of sleep the workers obtain, the length and time of day/night of the shift worked, the type of work performed and the time needed for travel will all impact on the fatigue levels and consequently the safety of the worker.

2.1 Shiftwork

Shift work has been defined as two or more groups of workers who replace each other in a specific work schedule (Hossain, et al 2004) in which at least 50% of the work is conducted outside of the hours 0800 to 1700 (Hedges & Sekscenski 1977).

Kurumatani et al (1994) looked at the effects of three frequently rotating shifts on the sleep and family life of nurses working shiftwork. It was found that the different shift combinations influenced their daily activities. These shiftworkers spent significantly more time on free-time activities on the day when they worked the nightshift followed by the evening shift than they did on the day when they worked any other shift combination. They offset sleep deprivation by either sleeping two to four hours later in the morning after working the evening shift and on days off, or by sleeping during the day before and after night shift. Results showed a strong positive correlation between total sleep time (including day sleep) and the length of interval between two consecutive shifts. The results suggested that more than 16 hours between work shifts is required to allow more than seven hours of total sleep time.

Hossain et al (2004) conducted a study of shiftworkers at an underground mine looking at sleep and performance in daytime and nighttime extended hours shifts. Workers originally worked an eight hour shift that consisted of a biweekly backward rotating schedule of nights, evenings and days.

A new forward-rotating 10-hour shift was introduced that consisted of four consecutive day shifts, two days off, three nights, and three days off. The roster times were also changed from 2300 hrs – 0700 hrs (nightshift), 1500 hrs - 2300 hrs (evening) and 0700 hrs – 1500 hrs (dayshift), to 0700 hrs – 1700 hrs (dayshift) and 1700 hrs to 0300 hrs (nightshift).

The purpose of the study was to evaluate the short and long term impact of a shift schedule change on sleep and performance. The results showed improved subjective and objective measures of sleep and performance in the new 10-hour nightshift schedule. They found the 10-hour nightshift worker subjectively reported more refreshing sleep, fewer performance impairments and driving difficulties than 8-hour nightshift workers. Objectives measures of sleep and performance on the 10-hour nightshift revealed very similar results to the 10-hour dayshift. The results suggest that a nightshift that does not include the entire night period may have significant benefits to the shift worker.

2.2 Circadian Rhythms

People who work nights, who perform shift work or work excessive periods can be subject to disrupted circadian rhythms. This is because these people’s work schedules are at odds with powerful sleep-regulating cues such as sunlight, and consequently they often become drowsy during work, and they may suffer insomnia or other problems when they try to sleep.

Furthermore, the body also experiences what is known as the ‘post lunch dip’ which is a decrease in body functions and alertness that occurs between 1200 and 1600 hours. Functions such as temperature, hormone secretion, lung capacity and blood pressure all decrease during this time. The post lunch dip can cause drowsiness during this time of lowered functioning, more so if a sufficient night sleep has not been obtained the night before.

Circadian rhythms are recurring changes in physical and cerebral characteristics that occur during the course of a day (Medical College of Wisconsin, 2003). These are controlled by the body’s biological "clock" known as the *suprachiasmatic nucleus* or *SCN*. The SCN is located in a part of the brain called the *hypothalamus*, just above the point where the optic nerves cross. Light that reaches photoreceptors in the *retina* creates signals that travel along the optic nerve to the SCN, acting as a time keeper.

Signals from the SCN travel to several brain regions, including the *pineal gland*, which responds to light-induced signals by switching off production of the hormone melatonin. The body’s level of melatonin normally increases after darkness falls, making people feel drowsy. The SCN also governs functions that are synchronized with the sleep/wake cycle, including body temperature, hormone secretion, urine production, and changes in blood pressure.

2.3 Driving Tired

Falling asleep at the wheel has long been considered the major issue of driving tir ed. However, unsafe levels of performance have been monitored long before sleep onset occurs (Mackie &

Miller, 1978). Thus a reasonable definition of driver fatigue would be: *A loss of alertness that may or may not end up in sleep* (Mabbott, et al. 1999: p. 3). One of the major problems with defining fatigue crashes is the lack of physical evidence at the scene (Hartley & Mabbott, 1998). The author's state:

> The absence of a definitive sign is compounded by inadequate crash reporting, lack of awareness of ow n fatigue levels by the drivers involved in the crashes, and a lack of consistency in the reporting of, or the interpretation of, crashes. Research into the incidence of fatigue crashes, therefore, involves some assumptions, such as drivers can accurately report their state of fatigue, or that particular types of crashes are caused by fatigue (P.2).

This being the case, several factors of each crash must be taken into account in determining what constitutes the contribution of fatigue to the crash. Many att empts have been made to analyse large amounts of data using proxy measures such as: 'run off road', 'no avoidance manoeuvre' 'wrong side of road without overtaking manoeuvre' and 'speed not a factor'. Such attempts have arrived at a prevalence of fatigue c rashes of up to 33% of all rural crashes (Hartley, 2004). Most authors would state that this is an underestimate and improved methods of determining fatigue crashes are constantly sought.

One major factor that influences the way in which fatigue related c rashes are analysed, is in the confidential characteristics of the people involved in such crashes. The Road Traffic Authority (RTA) NSW collects crash data from Police reports that contain personal identification details. Such details must be removed befo re supplying the data to research agencies, under the Privacy Act. The removal of such information does not allow linking the data back to workplaces and thus, a connection between work periods and the time of the crash is not made available. However, Coal Services have a database known as the 'Periodic Injury database', whereby workers compensation claims through work travel are recorded within the database. This has been utilised as one of the main sources of information for this project.

3 Methodology

The following section sets out the methodology utilised to obtain the required project outcomes.

3.1 Apparatus

Information in the form of posters, flyers and other advertising materials was sent to all coal mines in the relevant areas. The material was to seek any people that have been involved in a crash on the way to or from work, to fill out a questionnaire provided. The questionnaire was to be utilised to gather information that could be used to link the person to the relevant crash/crashes in the RTA and Police databases. Other information sought would be rosters and shift lengths at the time of the crash, time of day and other factors that relate to sleep, health and other issues that impact upon fatigue and performance.

Response rates for the questionnaire were very low due to a medical questionnaire having been recently sent to all mines. As a consequence the few responses received were of little use. Due to the fact that the original questionnaire failed in its ability to obtain information from miners, a second, shorter questionnaire was developed. The questionnaire focussed upon any near misses or crashes that occurred from 1 August 2003 to the time of filling out the questionnaire (mid 2004). This was aimed at adding to the Periodic Journey Accident information supplied by Coal

Services, as the data was limited to end July 2003. People who had not had any crashes or near misses were also asked to respond in order to get an idea of the prevalence of the incident rate.

Questionnaires were developed to ascertain at least the following information:

1) Personal details
- Age
- Gender
- Height and weight

2) Work details
- Mine name
- Location of the mine
- Open or underground mine

3) Incidents/crashes
- Fell asleep
- Lost control due to inattention
- Lost control due to conditions
- Hit another vehicle from behind
- Failed to give way
- Other driver on wrong side of road
- Other driver lost control
- Hit or swerved to miss animal
- Other driver hit you from behind
- Other driver failed to give way
- What time did the incident/crash occur?
- On what road and location?

4) Comments on what could help make the trip safer.

1,000 questionnaires were delivered to the following mines:

1	Metropolitan mine;	10	Mount Arthur;
2	West Cliff mine;	11	Drayton (Anglo coal);
3	Cooranbong;	12	Cumnock South;
4	Warkworth;	13	Narama (Ravensworth);
5	Nambo open cut;	14	Liddell;
6	United underground mine;	15	Mount Owen;
7	Hunter Valley Operations;	16	Rix Creek;
8	Bengalla;	17	Bulga;
9	Beltana	18	South Bulga underground.

It should be noted that responses to the questionnaire were voluntary.

3.2 Method

Methods for identifying crashes on the way to and from coal mines were undertaken in two ways. The first was from data on crashes that had occurred and the second on incident data.

Files for fatal crashes were originally to be accessed through the Australian Transport Safety Bureau (ATSB). It is important to note that fatal crashes would be insignificant in number to make any strong assertions as to whether any trends in any direction are present. A representative of ATSB noted that the database does not have records for the last three or so years so it was suggested that it was not worth investigating. The record for any of the fatal crashes would also be within the Coal Services database. Therefore utilising the ATSB database would only add duplication to the records. This avenue was not undertaken for these reasons.

Coal services have a database with Periodic Journey Data on crashes occurring on the way to or from work. This data gives a reasonable amount of information regarding the crash time, the start time of their work, the approximate location, and a brief causation of the crash as (usually) described by the injured worker. Coal Services also have a database on health, which takes into account the height, weight, age and other useful personal information. The Periodic Journey Data was extracted for a seven and a half year period, covering 1/1/95 to 31/7/03. Corresponding health data was extracted from the health database for later matching by miner number. Both datasets then had all personal identifying features removed for privacy reasons. The two data sets were emailed to the author for matching and analyses.

From the information in the database and responses from the questionnaire, determinations of the possibility of fatigue as a causal factor would be drawn, and answers to the research questions would be sought. This also entailed scrutinising information from within the Police records (COPS database) that are generally additional to what is held within state road authority databases.

4 Data Collection and Manipulation

Two sets of data were collected. The first was injury data matched with health data, supplied by Coal Services. As all of the injuries of interest were caused by a motor vehicle crash, the data will be referred to from this point forward as **crash data**. A second data set was obtained through questionnaire to 18 mines (see page 4). The data pertains to incidents and near misses which will be referred to from this point forward as **incident data**. Both crash data and incident data results will be shown together where possible to highlight both the crashes and the near misses that have occurred on the way to and from coal mines in New South Wales.

4.1 Crash Data

Data from a total of 372 registered periodic travel injuries (crash data) were supplied by Coal Services. A total of 342 of the injuries were able to be linked to health data so that other information was available. Data was investigated in an attempt to determine the cause of the injury. A description of the incident that led to the injury was given in most cases; however, some of the vehicular crashes had important information missing. For example, an injured worker may have filled out the description as "*vehicle accident on the way to work*". This did not allow the researchers to establish what caused the crash.

A total of 71 crash records were sent to the Northern, Southern and Western regions of the NSW Police for further investigation. Of these, 23 were from the Western or the Southern Region and 49 were from the Northern Region. Police attempted to match the data for crashes supplied to them with the crash reports in their database to determine the cause of the crash. They were able to match 38 of the 71 crashes (53.5%), thus supplying a crash cause.

The causes of the injuries were assigned into 11 categories, designed to capture factors relating to who caused the crash and what the basic driving error was. Crash causes were rated by three behavioural scientists into the following categories:

Table 1: Rated crash causal factors

RATED CRASH CAUSE	FACTORS
1. Fell asleep	Driver stating that he/she fell asleep while driving
2. Lost control due to inattention	Driver stating that he/she ran off road or similar without conditions causing such to occur
3. Lost control due to conditions	Driver stating that he/she lost control due to road or weather conditions
4. Hit another vehicle from behind	Driver stating that he/she hit another vehicle from behind
5. Failed to give way	Driver stating that he/she didn't notice the other driver and/or failed to give way
6. Other driver on wrong side of road	Driver stating that he/she either hit or swerved to avoid oncoming vehicle on wrong side of road
7. Other driver lost control	Driver stating that other driver had lost control of their vehicle
8. Hit or swerved to miss an animal	Driver stating that he/she either hit an animal or swerved to avoid one
9. Other driver hit you from behind	Driver stating that he/she was hit from behind
10. Other driver failed to give way	Driver stating that another driver failed to give way causing an avoidance manoeuvre and/or crash
11. No clear cause or not a crash	Driver did not make a clear statement of crash causation or injury not due to motor vehicle crash

Inter-rater agreement for the cause of crash was 96.3%. The three raters then discussed the few remaining items until agreement was met on all items.

Out of the 372 injuries within the crash database, 153 were either not a motor vehicle crash (MVC) or a direct cause could not be attributed to the crash. Examples of non-MV crashes include: stung by bee; insect in eye; foreign matter in eye; bumped head on boot lid; tripped over on driveway, etcetera. A total of 219 injury crashes remained and have been used for all of the following analyses. Additional health data was supplied to allow the researchers to run analyses on the general age and body mass index (BMI) of coal miners in NSW. This included the age, weight and height of mine employees from medicals, de-identified for privacy reasons.

4.2 Incident Data

A total of 1,000 questionnaires were distributed to 18 mines from Wollongong to the Hunter Valley. Of these, 231 completed questionnaires were returned. As multiple responses were allowed, 289 incidents were shown. The questionnaire responses were able to be graded according to the causes as shown for crashes (see 1- 11 above).

5 Results and Discussion

The first set of findings within this report will address the research questions posed. They are:

1. What is the prevalence of coal mine workers having road crashes on the way to or way home from coal mines in the Hunter Valley, Newcastle Coalfields and Wollongong areas?
2. What proportion of these crashes has fatigue as a contributing factor?
3. Are there any differences in crashes for people who work in underground mining versus open cut mining?
4. Does the length of shift or time of day have an influence on any of these crashes?
5. Can we compare the prevalence of crashes on the way to or from coal mines between NSW and Qld operations?

Additional findings are shown where appropriate.

5.1 Prevalence

5.1.1 Crashes

At January 2005, approximately 9,760 coal miners worked in New South Wales. A total of 219 vehicle crashes were recorded in the 7.5 year period of data supplied. Of these four were fatal. Therefore, there were 215 injury crashes, or 28.6 crashes per year. **This represents a prevalence of approximately 0.3% of NSW coal miners being injured in a motor vehicle crash per year on the way to or from work.** The four fatal crashes give a rate of 0.53 fatals per year. **This represents 0.005% of the coal mining population of NSW being fatally injured in a motor vehicle crash per year on the way to or from work.**

Compensation was supplied to most injured drivers within the crash database. This totalled more than $2 million dollars but is only a small portion of the cost to society. Costs to society include at least the following: Loss of future income, medical costs, damage costs, pain and suffering, emergency services, etcetera. Costs for non-urban crashes in NSW were evaluated in Thoresen, Roper, Lloyd and Michel (2004) Economic Evaluation of Road Investment Proposals; Unit Values for Road User Costs at June 2002. A fatal non-urban crash in NSW was estimated to cost society $1,726,700 whilst an injury crash was estimated to cost $124,300 per crash. This being the case, the annual cost per year to the NSW coal mining community is $915,151 (cost of fatal x 0.53 fatals), plus $3,554,980 (cost of injury x 28.6 injuries). **The total cost to the coal NSW mining community per year is approximately $4,470,131 in June 2002 dollar terms.**

5.1.2 Incidents

Respondents to the questionnaire were able to show if they have had, or not had, an incident or near miss on the way to or from work. This has allowed the researchers to obtain a ‘snapshot’ from the sample who supplied information. Table 2 below shows the number of workers who claimed that they had an incident either on the way to or way from coal mines in NSW.

Table 2: Responses from the incident questionnaire.

	Incident or near miss	Frequency	Percent
On the way to work	Yes	154	53.3
	No	127	43.9
	Missing	8	2.8
	Total	289	100
On the way home from work	Yes	126	43.6
	No	143	49.5
	Missing	20	6.9
	Total	289	100

The above table shows that 53.3% had an incident on the way to work whilst 43.6% had an incident on the way home in the past twelve months. **Therefore, approximately half of the surveyed respondents had either had an incident or near miss on the way to and/or from their workplace.**

5.2 Fatigue as a Contributing Factor

As previously noted, fatigue as a causal factor in motor vehicle crashes is reasonably hard to establish. Therefore, an investigative approach was taken to ensure that as many fatigue factors as possible, were examined.

Of the 219 injuries, caused by motor vehicle crashes, 64 crashes (29.2%) were not able to be categorised into ‘to’ or ‘from’ groups due to missing data for time of crash or start time of work. This left 155 that could be sorted into ‘to’ or ‘from’ crashes. A crash was determined to be on the way to work if it occurred within four hours prior to the work commencement time. It was determined to be on the way home from work if it occurred within four hours post work finish time. Of these 155 crashes, 47 (30.3%) were on the way to work while 108 (69.7%) were on the way home.

Taken together, 53.3% of incidents and 30.3% of crashes occurred on the way to work, while 43.6% of incidents and 69.7% of crashes occurred on the way home from work. It is interesting to note, that more incidents occur on the way to work but result in fewer crashes. In opposition, fewer incidents occur on the way home but result in more crashes. While it seems plausible to consider that perhaps the driver on the way to work has enhanced vigilance and is thus able to avoid crashes (as opposed to the driver on the way home), an accurate determination cannot be made as there will be a mix of drivers coming and going to and from work at the same time. This being the case, crashes and incidents were sorted into the 11 previously noted casual factors for further investigation. Category 11 represents an injury not caused by a motor vehicle crash or no causal factor was known and will be omitted from the table.

Table 3 below displays the number and percent of incidents that have occurred in the past twelve months and the number and percent of crashes that occurred over the 7.5 year crash data period.

Table 3: Causal Factors for Incidents and Crashes. Percentages in parentheses.

Crash/incident causal factor	Crash	Incident on way to work	Incident on way home
11. Fell asleep	6 (2.7)	15 (9.8)	28 (21.9)
12. Lost control due to inattention	27 (12.3)	6 (3.9)	5 (3.9)
13. Lost control due to conditions	28 (12.8)	5 (3.3)	4 (3.1)
14. Hit another vehicle from behind	12 (5.5)	0 (0)	0 (0)
15. Failed to give way	17 (7.8)	5 (3.3)	3 (2.3)
16. Other driver on wrong side of road	23 (10.5)	15 (9.8)	13 (10.2)
17. Other driver lost control	0 (0)	3 (2.0)	4 (3.1)
18. Hit or swerved to miss an animal	37 (16.9)	87 (56.9)	63 (49.2)
19. Other driver hit you from behind	35 (16.0)	5 (3.3)	1 (0.8)
20. Other driver failed to give way	34 (15.5)	12 (7.8)	7 (5.5)
Total	**219 (100)**	**153 (100)**	**128 (100)**

Although only 2.7% of the crashes were due to a driver actually falling asleep at the wheel, an additional 12.3% of the drivers had crashes from losing control due to inattention. The additional 5.5% of crashes caused by hitting another vehicle from behind, plus the 7.8% failing to give way could arguably be attributed to fatigue. It has been shown that drivers do not maintain headway speed or lane tracking adequately (Mackie & Miller, 1978) whilst driving tired. People going through bouts of tiredness can also suffer from 'empty field myopia' (Swann, 2000), whereby they can maintain the vehicle in the appropriate direction but may not address any other necessary driving tasks (such as giving way at intersections) that have normally arisen from visual searches. It is this inattention that occurs long before sleep onset that causes many motor vehicle crashes. In total, 28.3% of those who were injured in a motor vehicle crash likely did so because they were driving tired.

Importantly, 9.8% and 21.9% of respondents to the questionnaire stated that they had fallen asleep on the way to work and home respectively, from work in the previous 12 months. The National Sleep Foundation's (NSF) Sleep in America Poll (2002) released findings that showed 17% of adult drivers said they had actually fallen asleep at the wheel in the past year. A 1996 research report produced for the RTA NSW found that 27% of drivers going to or from work had had a fatigue related incident and 30% had had a fatigue related accident (Quadrant Research Services, 1996). From this it can be deduced that the population of coal miners within NSW is not largely different from the NSW driving population. However, the issue is exacerbated by the fact that a large workforce works within a relatively small region, with vehicular movements being the basic mode of travel. This increases the exposure of NSW coal miners to travel crashes.

Table 2 also shows that 9.8% and 10.2% of respondents had problems avoiding other vehicles on the wrong side of the road on the way to and from work. Arguably, there appears to be a constant mix of tired drivers driving both to and from work at the same times. This mix increases the opportunities for crashes due to tired drivers causing errors and other tired drivers having decreased reaction times and fewer opportunities to avoid impact.

A portion of the injured drivers in the database have been injured due to the errors and misjudgements of other drivers. When taking into account, ‘other driver on wrong side of road’, ‘other driver hit you from behind’ and ‘other driver failed to give way’, another 42% of the injuries were likely due to fatigue. This high figure could be the culmination of having to avoid a fatigued driver whilst also being in a fatigued state.

Further support that fatigue is contributing to the crashes, especially on the trip home from work, is seen in the crash data whereby:

- Drivers fell asleep and crashed four times more on the way home than they did on the way to work, however, it must be noted that the numbers were small;
- Drivers fell asleep without crashing almost twice as often on the way home as on the way to work;
- Drivers who crashed due to their own inattention (lost control – inattention & hit other vehicle from behind) did so one and a half times more on the way home than on the way to work;
- Drivers who were injured by driving into the rear of a vehicle did so three times more on the way home;
- Drivers injured by another driver hitting them from behind were involved twice as much on their way home from work, and
- Drivers injured by another driver failing to give way were involved almost three times as often on the way home.

These findings are consistent with other research, for example, Fell and Black (1997) found that 35% of incident involved respondents were driving their usual trip to or from work with 42 % of these being shift workers at the time of the incident. **It is clear that fatigue is a contributing factor in both the injury crashes that have occurred over the 7.5 year capture period and the incidents that have occurred in the past twelve months.**

5.3 Underground Mining versus Open Cut Mining?

The incident database was examined and it was found that there was a small and non-significant difference (X^2 (1) = .740; p >0.05) in the percentage of incidents in open cut and underground mines that occurred on the way to work (see Table 4 below). A total of 57.1% of incidents occurred from the open cut mines on the way to work and 42.9% occurred from the underground mines.

Table 4: Incidents on the way to work both open cut and underground mines.

Incident going to work		Open cut	Underground	Total
Yes	Count	88	66	154
	Expected Count	91.5	62.5	154.0
	% within Incident going to work	57.1%	42.9%	100.0%
No	Count	79	48	127
	Expected Count	75.5	51.5	127.0
	% within Incident going to work	62.2%	37.8%	100.0%
Total	Count	167	114	281

The incident database was also examined for a difference in the percentage of incidents in open cut and underground mines that occurred on the way home from work (see Table 5 below). A total of 65.1% of incidents occurred from the open cut mines on the way home from work and 34.9% occurred from the underground mines. This difference between the two was significant (X^2 (1) = 4.398; $p<0.05$). We can therefore conclude from our sample that significantly more incidents are occurring on the way home from open cut mines than underground mines.

Table 5: Incidents on the way home form work at underground and open cut mines

Incident coming from work		Open cut	Underground	Total
Yes	Count	82	44	126
	Expected Count	73.5	52.5	126.0
	% within incident coming from work	65.1%	34.9%	100.0%
No	Count	75	68	143
	Expected Count	83.5	59.5	143.0
	% within incident coming from work	52.4%	47.6%	100.0%
Total	Count	157	112	269

Further examination of these incidents revealed that open cut drivers are having more incidents that involve animals than underground (54.8% compared to 38.6%) drivers and slightly more fell asleep incidents (23.8% compared to 18.2%). However, the most notable difference is that underground drivers have more incidents that involve ‘other driver on wrong side of the road’ than open cut drivers (18.2% compared to 6%). It is unknown why these differences would occur. **More incidents are occurring on the way home from open cut mines than underground mines; however, it is unknown why this is occurring.**

The crash database was investigated to determine if more crashes occurred for drivers going to and from open cut versus underground mines. However, due to the small data sets, the numbers did not give any meaningful results. Thus they are not reported.

5.4 Length of shift or time of day - influence on crashes?

5.4.1 Length of Shift

Both sets of data did not contain sufficient information to analyse the effect of the lengths of shift on the crashes.

5.4.2 Time of Day

Time of day that the crashes occurred was examined in the crash database and the incidents database. Results are presented below.

5.4.2.1 Crashes

The time of day of crashes was examined (see Figure 1 below). It was found that there was an early peak between 0600 and 0900 hours. The largest percentage of crashes occurred in the afternoon period with the peak being between 1400 and 1600 hours. Another smaller peak occurred between 2200 and 2300 hours. The early morning peak is likely to be a combination of workers traveling to and from work, as could be the case with the evening peak. The smaller afternoon peak corresponds to the ‘post lunch dip’ in the human circadian rhythm cycle and also coincides with travel to and from 8-hour shift periods, as they often start/finish mid afternoon.

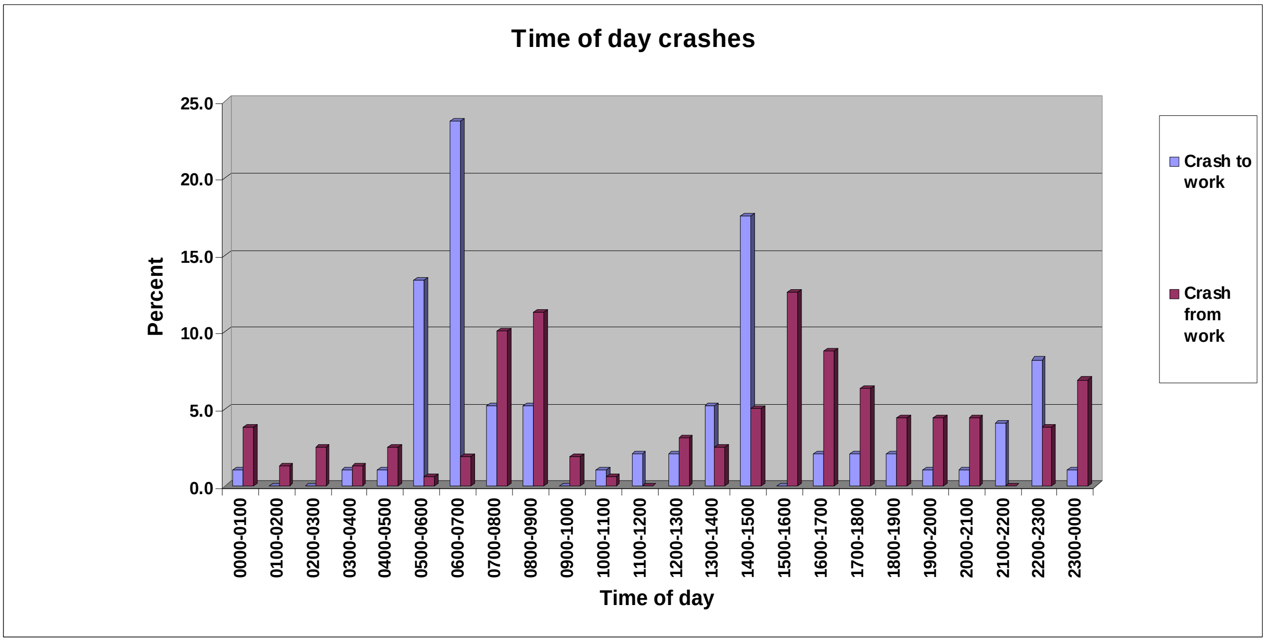

Figure 1: Time of day crashes

5.4.2.2 Incident Database

The time the incident occurred going to work was also examined in the incident database (see figure 2 below). It was found that there was a peak period in the early morning also; however in this data the peak time was considerably earlier than what was found in the crash database. In this data the early peak occurred between 0430 and 0630 when respondents were on their way to work. Data described later, on the numbers of incidents with kangaroos/wallabies in the incident data base may account for some of this very early peak. The afternoon peak disappeared and is possibly due to a change to 12-hour shifts over the last few years. The peak has shifted more towards a start/finish time of 1800 hours.

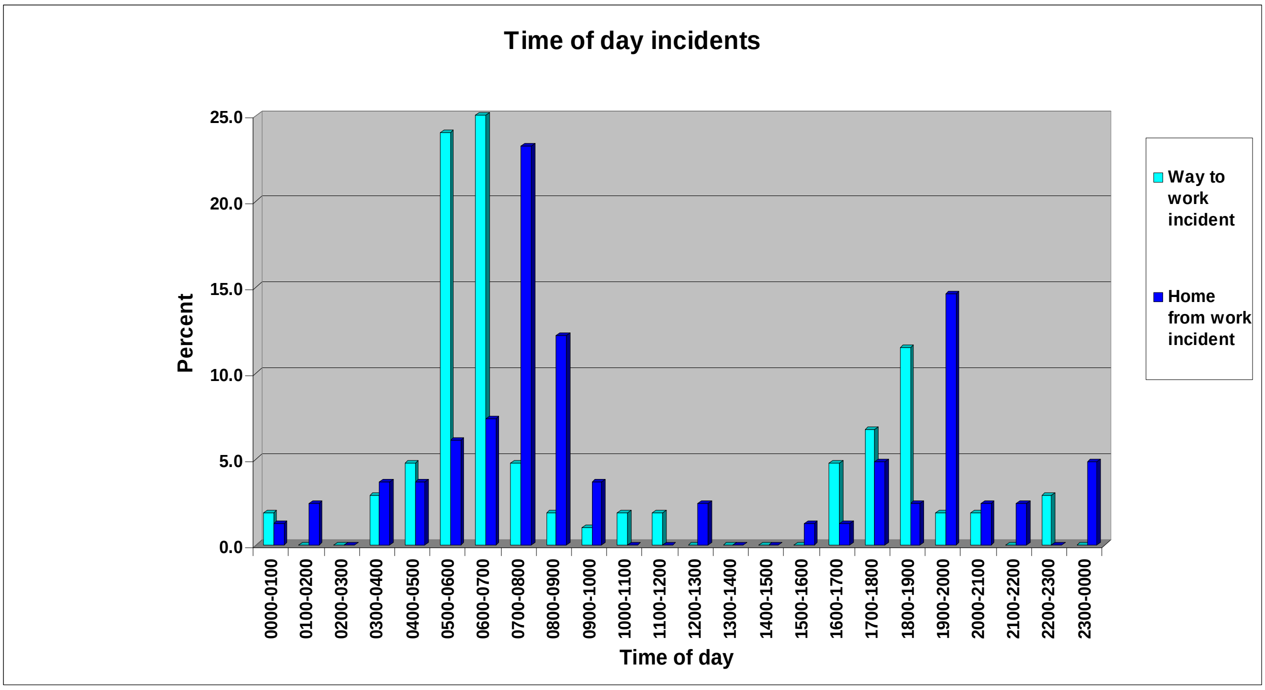

Figure 2: Time of day incidents.

It is evident that two distinct periods of time of day are influential on crashes and incidents on the way to and from coal mines in NSW. The first peak is between 0400 hrs and 0900 hrs, indicating workers arriving or leaving work commencing around 0600 hrs to 0700 hrs. The traffic flow in the Hunter Valley Region in particular would be high in volume and is likely to have many tired workers driving the routes. This is further complicated with movements of heavy vehicles and the dawn period associated with the movement of kangaroos and wallabies on the roads.

The second peak is between lunchtime and 2000 hrs, whereby a mix of drivers will be going to and from work, plus having additional heavy transport vehicles, tourists and wildlife in the traffic mix. This mix also occurs through the afternoon ‘post-lunch dip’ in the circadian rhythms of humans, whereby many drivers are likely to drive in a tired state especially if they have reduced nighttime sleep prior to the drive or work period.

5.5 Additional findings of significance

5.5.1 Age and Body Mass

Recent research has shown that some personal characteristics can influence the likelihood of a driver crashing or performing at a reduced capability whilst driving (Hanowski, Wierwille & Dingus, 2003; Mabbott & Lloyd, 2004). The personal demographics of the drivers were examined for age and body mass. The mean age for the drivers from the crash database was 39.62 years with the mean age for drivers from the incidents database being marginally older at 40.47 years.

Additional data was obtained through Coal Services Health Data on age, weight and height. It included data taken from 14,052 medicals spanning January 2002 to January 2005. This was to allow comparisons between the two datasets and the general mining population characteristics. The mean age for the total NSW Coal Mining Population from that data is 39.29 years and is no different from the two databases on crashes and incidents.

The body mass index (BMI) for individuals was also calculated to enable comparisons between data sets. The mean BMI for the total mining population of NSW Coal Miners was 28.22, which is overweight. A total of 76.8% of the miners in the health data were either overweight (46.4%) or obese (30.4%). This is a concern regarding the health issues associated with both being overweight and ageing. Being overweight or obese substantially raises the risk of illness from high blood pressure, high cholesterol, type 2 diabetes, heart disease and stroke, gallbladder disease, arthritis, sleep disturbances and problems breathing, and certain types of cancers (Healthy People 2010). The Australian Institute of Health and Welfare statistics show that 67% of adult men and 52% of women were overweight or obese in 2000. NSW coal miners are considerably higher.

It was found that drivers from the crash database had a BMI that increased with increasing age (r^2 (df=206) .274; $p:<0.01$) however, data from the incident database showed no correlation between age and BMI (r^2 (df=219) = .086 ns). Further, the total NSW coal mining group also had a high correlation between increasing age and increasing body mass index (r^2 (df=14050) .217; $p:<0.001$). This is likely to be common within society; however, is still a cause for concern as the mining population ages.

It was found that the mean BMI for drivers who’d had a crash was 27.5 which places them in the overweight category. The mean BMI for drivers who’d had an incident was very comparable at 27.7 which also places them in the overweight category. This is intuitive as the mean BMI is reflective of the NSW coal mining industry.

Table 6: Percent of drivers in each category.

BMI	Crashes	Incidents	Health
Acceptable	30.1	22.5	23.1
Overweight	47.6	51.8	46.5
Obese	17.5	21.2	23.2
Very obese	4.9	4.5	7.1
Total for overweight	70% overweight	77.5% overweight	76.8% overweight

Table 6 shows that drivers who were located in any of the overweight categories had a total of 70% of the crashes and 77.5% of the incidents. This is consistent with recent research conducted on obesity and crashes.

Research conducted in Seattle, Washington (Kleiner, 2002), investigated more than 26,000 people who had been involved in car crashes. It was found that heavier people are at far more risk than lighter people. People weighing between 100 and 119 kilograms are almost two-and-a-half times as likely to die in a crash as people weighing less than 60 kilograms. More importantly, the same was found when the researchers looked at body mass index (BMI). The study found that people with a BMI of 35 to 39 are more than twice as likely to die in a crash compared with people with BMIs of about 20.

5.5.2 Centreline crossings and run off road

Many of the incidents and crashes investigated involved running off the road or being run off the road by a driver on the wrong side of the road. These factors were evident in 23.8% of the crashes and 27.8% of incidents. It should be noted that these were not due to animals on the road as they are treated separately. Many of these crashes and incidents will be caused by drivers driving in a state of reduced capacity, and most likely due to the effects of fatigue.

5.5.3 Hitting and swerving to avoid kangaroos and wallabies

Examination of the incident database found that around 50% of incidents involved either hitting or swerving to miss kangaroos/wallabies. The crash database revealed that 16.9% of crashes were due to the same. This contributes to a large portion of the crashes and an even larger proportion of incidents. As issues with native fauna are not within the general scope of this report, a supplementary report can be found at Appendix 1. The report outlines the issues associated with animals on the road, road crashes caused by such and possible treatments to deal with the problem. The most suitable countermeasures taken from the supplementary report will be included in this report's 'countermeasure' section.

5.6 Comparison between NSW and QLD study results

Similar research to this project was undertaken by Dr. Lee Di Milia and Professor Peter Smith in Queensland and reported in February 2004. The report, *The Underlying Causes and Incidence of Driver Fatigue in a Shiftwork and Non-Shiftwork Population* investigated driver fatigue as an issue for miners travelling to and from work in Queensland. The research consisted of three separate studies providing data on driver fatigue in short and long distance driving, and driving patterns for shift workers on days off. The research included data for 'drive in – drive out' (DIDO) workers who often drove long distances to work then stayed at accommodation for the roster period, as well as people who drove short distances to work.

The major findings from the Queensland research that could be used comparatively with this current research follow (QLD research in italics).

1) *Mean age for all workers was 40 years old (page 30).*

NSW – The mean age of all NSW coal miners who appeared in the crash database, responded to the incident questionnaire or had completed a medical examination over the past three years, was between 39 and 40 years.

2) *Falling asleep at the wheel was reported in 13% of shift workers when driving to night shift and 43% when driving home from night shift (Page 25). Further, 13% of workers driving to day shift fell asleep over the past 12 months (Page 31). Workers reported higher sleepiness levels and higher impairment levels when driving home from night shift work than day workers (page 32).*

NSW – 2.7% of the crash injured drivers fell asleep at the wheel causing the crash, most on the drive home from work. A further 9.8% of surveyed miners fell asleep on the way to work and 21.9% fell asleep on the way home from work.

3) *Ten drivers reported involvement in a small number of incidents on driving to work in the previous 12 months. Twenty four drivers reported incidents on driving home from work in the previous 12 months….common to all groups were running onto the shoulder or off the road and crossing the centre line (page 26).*

NSW – 12.3% of the crash injured drivers had crashed due to losing control from inattention. This included running off the road and over the centreline. Further, 10.5% of crash injured drivers, 9.8% of incidents on the way to work and 10.2% of the incidents on the way home from work, were due to another vehicle (usually opposing direction) crossing the centreline.

4) *…results suggested that driving too early in the day, driving long distances and working long daily shifts contribute to increased driver fatigue ratings and recorded incidents (page 28).*

NSW – A high number of crashes and incidents occurred early in the morning between 0400 hours and 0900 hours. However, a further high peak of crashes appeared between lunchtime and 2000 hours. This was more likely to be influenced by miners driving to and from 8-10 hour shifts through the post-lunch circadian low point. The more recent incidents over the past year indicate that 12-hour shift patterns are moving the afternoon incidents to a later time slot. It should be noted that 12-hour shifts are the norm in Queensland so afternoon accidents were not noted.

5) *23% of DIDO's reported falling asleep on the long drive home (page 35). Some of the DIDO workers left home at 0300 hours to drive directly to the working shift (up to 230 km), while others left as early as 0200 hours the day before and drove up to 1300 km (Page 33, 34). Interviewed drivers were driving long distances after a number of consecutive night shifts (up to 12 consecutive shifts) and some drove up to 600 km without a break from driving (Page 38).*

NSW – Unable to ascertain how long some of the drives were. It is likely that there is a mix of destinations to local townships within 50 kilometres and drives as far as from the Hunter Valley to Sydney and surrounding areas. Some survey respondents mentioned that having a break or nap before driving would be useful, as would having buses to carry high numbers of miners.

Although there were differences between the methodologies of the two research projects, there is clearly enough evidence to support that coal miners are suffering the effects of driver fatigue on the way to work and more so on the way home. This has led to many crashes and a high level of incidents in both New South Wales and Queensland.

The Queensland study has shown that long drives, early starts and long shifts promote fatigued driving states. The New South Wales study indicates that driver fatigue appears to have been present when 8-10 hour shifts were in place, and also now that 12 hour shifts are the norm. In both cases, countermeasures can be put in place to reduce the prevalence of incidents and crashes on the way to and from work. The following section focuses upon countermeasures specifically aimed at reducing incidents and crashes on the way to and from coal mines in NSW. However, many of the countermeasures could also be directed at the Queensland coal miners.

6 Countermeasures

This research has highlighted the fact that around 29.2 coal miners in NSW will crash and be injured and 0.5 drivers will be killed on the way to or from work in any one year. This number is likely to increase as the mean age increases and the BMI of individuals increase. Further, the cost to the NSW coal mining community is approximately $4,470,131 in June 2002 dollar terms. The following sections will highlight the types of crashes and incidents and provide possible countermeasures to reduce the prevalence of such.

First and foremost, however, is the fact that many research reports are produced each year and tend to be read and filed without further thought to what might be realised through use of the document. Oftentimes, it is because there is no direct conduit between the receiver of the report and those who might implement any strategies or processes to put into action any recommendations from the report. To this extent, it is highly recommended that a working party be established to investigate and initiate the feasibility of any recommendations from this report.

The working party should initially focus upon the Hunter Valley Region, as a high number of crashes and incidents are reported within the region. If successful, the working party could then direct its focus upon other regions on a priority basis. It is highly likely that many of the learnings and treatments could be applied across different regions and at reduced costs. The working party should consist of at least the following people:

- Working party leader,
- Mine representatives,
- Police,
- Local Government engineers,
- Roads and Traffic Authority representatives.

The working party would require a source of funding and would make recommendations to Government on resources and funding for road safety improvements and health strategies.

Recommendation 1: That a working party be established to investigate and initiate the feasibility of any recommendations from this report.

6.1 Fatigue as a contributing factor

It is clear that fatigue is a contributing factor to a large portion of the travel crashes and driving incidents for NSW coal miners. This research has not been able to identify if the length of working shift or any particular roster is a contributing factor. A common feeling in NSW coal mining is that 12-hour shifts produce more fatigue than 8-hour shifts. However, the data shows crashes at times of the day that are conducive with 8-hour start and finish times. Therefore, all countermeasures discussed will focus on what can be attained without making changes to shift lengths. In viewing the recommendations it is important to remember that the traffic mix at any one time will consist of alert and tired drivers travelling to and from coal mines, the general local public, heavy vehicles (especially on the New England Highway) and tourists visiting the region.

6.1.1 Changes to work patterns

It is possible that making changes to roster designs may have an influence on the outcome performance of miners travelling to or from work. All mines should undertake to ensure that all staff can adequately manage the current roster designs that are in place. The information may best be captured by questionnaires to staff or a series of ‘toolbox’ meetings with groups of staff. Information should also be captured on the length and timing of breaks supplied to staff.

Recommendation 2: All NSW coal mines should undertake to ensure that all staff can adequately manage the current roster designs that are in place.

6.1.2 Education on fatigue management

Personal experience with fatigue management training is that those who have been trained are more likely to discuss fatigue issues and retain vital information on their management of fatigue and performance. In the right environment, they are also more likely to discuss fatigue issues with supervisors and management. This is likely to lead to increases in both safety and productivity. It is recommended that to ensure adequate retention of training is assured, have short training sessions and provide materials and reminders on a constant basis. The training should include information on at least the following:

Proactive:

- Health,
- Diet,
- Exercise,
- Alcohol and drugs,
- Extra-curricular activity and its impact on work performance,
- Breaks and rest periods,
- Sleep conditions.

Reactive:

- Illnesses and how to manage outcomes of performance
- How to recognise tiredness,
- How best to manage tiredness when it occurs,
- Napping strategies,
- Strategies to get to and from work if tired without driving.

Recommendation 3: All NSW coal mines should undertake fatigue management training of all staff and management.

6.1.3 Health programs

It was mentioned earlier that the NSW coal mining population has 76.8% of its people overweight. This issue is compounded by the ageing population and the fact that miners are increasing their body mass index with increasing age. Health management programs should be implemented either alone or in conjunction with the above-mentioned fatigue management programs.

Recommendation 4: A health program for NSW coal miners is put in place, either through the mines or the NSW Government.

6.1.4 Alternative transport and pooling

Buses to workplaces provide a means of safely transporting large numbers of workers to and from work with the benefits of reducing the numbers of vehicles on the road (thus reducing exposure and conflict) and allowing tired miners to relax and rest. The costs associated with buses will be well offset by the reduction in injury and crash costs, reduced running costs for vehicles, and a possible increase in productivity through reduced driving stress and extra time to relax. Car pooling will provide similar benefits to those described above but to a lesser extent. Nonetheless, it is a much better option than all miners driving to and from mines.

Recommendation 5: All mines should investigate opportunities for utilising buses as an alternative means of transport. If not practicable, car pooling should be encouraged.

6.1.5 Traffic volumes and movements

A separate investigation could be conducted to measure traffic flows in the Hunter Valley to determine if the high morning peak could be better controlled. This may be possible through changes to some shift commencement times, buses and car pooling, improved traffic flows on roads and more overtaking opportunities for passing heavy vehicles. The investigation could be utilised to determine if countermeasures could be put in place.

Recommendation 6: Further investigation of traffic volumes and movements is conducted through the working party.

6.2 Line crossings and running off the road

Maintaining tracking of lanes is an issue that becomes harder to do the more tired a driver gets. Instances of drifting into other lanes, off the road or onto the wrong side of the road are common for tired drivers and feature highly in the crash and incident databases. For example, drivers either crashing or having to avoid other vehicles on the wrong side of the road account for around 10% of all crashes and incidents travelling to and from the workplace in NSW coal mines. A further 12% involve crashes to do with losing control of the vehicle. Many of these are ‘run off road’.

There are two ways of reducing the occurrence of this issue. The first is to ensure more alert drivers are on the road. This can be achieved through education and better management of health and fatigue, as previously stated. The second requires engineering treatments to roads. The two basic treatments are:

- Better delineation of roads – Edge lines, marker posts, reflective cats eyes,
- Tactile/audible edge line & middle line treatment.

6.2.1 Delineation of roads

Delineation must provide guidance to drivers and clear, definitive indications of traffic lanes and direction (Poole, 2004). The delineation of roads includes line markings on road shoulders, centre lines, reflective marker posts and centre markers (cat’s eyes), signage and other visible means of directing traffic. Delineation treatments are primarily designed to reduce and/or eliminate single vehicle ‘run-off’ crashes and, to a lesser extent, multi-vehicle ‘head-on’ and ‘side-swipe’ crashes. Their application should be seen as part of a programme to create a ‘friendlier’ environment for drivers, especially where external factors constrain the space available for drivers to utilise.

Given that the primary purpose of delineation treatments is to provide road users with an accurate ‘picture’ of the road ahead, it is not surprising road crashes can occur when this does not happen. Road safety audits are used to determine aspects of roads that may contribute to reduced safety. They are also used to arrive at a countermeasure to correct the poor design or flaw in the roadway or intersection. The ARRB ‘Road Safety Risk Manager’ is a tool that enables engineers and planners to determine the value per dollar invested for such treatments. The tool has been used by many Australian State Road Authorities to rank treatments according to value for money. It is recommended that the working party investigate the delineation of roads in the Hunter Valley Region to determine the state of roadway delineation.

Recommendation 7: The working party initiates road safety audits to investigate the delineation of roads in the Hunter Valley Region.

6.2.2 Audio-tactile edge and middle line treatment

Audio-tactile lines (also known as longitudinal rumble strips, profile line markings/lines, audible line markings) are continuous or intermittent grooves or raised profiles in the road surface that run parallel to the direction of traffic flow, usually along the edgeline, shoulder and/or the centre. The purpose of the treatment is to provide an audio-tactile stimulus to fatigued drivers in order to warn them that they have left the roadway and hence need to correct their steering to return to the road. Therefore, they help to prevent run-off-the-road crashes, as well as head-on and side swipe crashes. This is particularly relevant on rural highways where drivers often become fatigued when travelling long distances, and also become dazed by the constant speed, lack of other traffic and the monotony of landscape. They might also travel at high speed to minimise the travel time.

Audio-tactile lines can be of four main types: milled, rolled, formed and raised. The various types will produce differing amounts of noise and vibration.

- Milled rumble strips are the most common types found in the U.S., installed on either new or existing asphalt. They are made by a machine, which cuts a smooth uniform groove into the surface.
- Rolled rumble strips must be installed when the asphalt is being compacted, when grooves are pressed into the hot asphalt surface by a roller.
- Formed, or corrugated, rumble strips are grooves installed during the finishing process.
- Raised rumble strips are strips of material that adheres to new or existing surfaces. Materials used include asphalt bars, ceramic raised pavement markers and thermoplastic materials. Corkle & Marti (2001) in a report for the Minnesota Research Board state that these rumble strips have the advantage of being able to have glass beads added to them (except for asphaltic rumble strips) giving reflectivity at night.

Chip sealed roads are unsuitable sites for rumble strips formed using any grooving techniques, as they would damage the surface (Dravitzki, Logan and Munster, 1998). Only raised types would be effective. All rumble strips types can be used on asphaltic surfaces. In Australia and the UK, these lines tend to consist of thermoplastic line marking, and are typically applied as a line marking with protruding ribs of the same material at regular intervals.

Audio-tactile edgelines were first used in Australia on the Sydney to Newcastle Freeway (F3) in 1990, and their usage has been increasing since (Poole 2004). The majority of available data on crash rates in Australia have been acquired on relatively limited applications between 1 and 10 km in length of audio-tactile edgelines. Run-off-the-road accident reductions of up to 49% have been observed (Dravitzki et al. 1998).

Despite the increasing number of applications, it seems that there is relatively little published information on the cost-effectiveness of audio-tactile edgelines. In a study carried out by the Roads and Traffic Authority, Bhatnagar (2001) provides a comparative assessment based upon crashes and traffic volumes. It is recommended that because of the high initial cost associated with audio-tactile edge lines they should only be applied where a minimum traffic volume of 10, 000 AADT exists and a long term remedial solution is needed.

6.2.2.1 Shoulder treatments

A comprehensive research study carried out by the Virginia Department of Transportation (Chen et al. 2003) has shown that the milled continuous audio-tactile shoulder line is a low-cost, high-benefit, feasible measure of reducing the frequency of run-off-the-road crashes. The research indicated a reduction in run-off-the-road crashes of 32%. Evaluations carried out by the

California Department of Transportation and Federal Highway Administration has also reported a reduction in run-off-the-road crashes of 20-72% (Chaudoin and Nelson 1985, Ligon et al. 1985, Corkle et al. 2001). In the UK, the County Surveyors' Society (1989) reported a reduction of 76% in run-off-the-road accidents in three years following the installation of shoulder strips.

6.2.2.2 Centreline treatments

At least four out of sixteen US States that have placed rumble strips in two and four lane undivided roadways have reported substantial reductions in crossover crashes. For example, the Colorado Department of Transport has reported a 24% reduction in crossover crashes over a 44-month study period (Poole 2004).

Persaud, Retting & Lyon (2004) reported on data they analysed 210 miles of undivided, two lane rural roads across seven Canadian states, before and after treatment with centreline rumble strips. Their results indicated significant crash reductions for all injury crashes combined, as well as for frontal and opposing-direction sideswipe injury crashes.

A study carried out by the Kansas Centreline Rumble Strip Evaluation Team found that a continuous 300mm wide audio-tactile centreline produced the best results in terms of optimum noise, steering wheel vibration and driver vehicle positioning (Russell 2003).

Transit New Zealand has developed guidelines for the use of audio-tactile lines on both edge and centre lines. The basic recommendations include the following (Munster et al. 1998):

- The use of profiled thermoplastic line marking, as opposed to changing the pavement surface with indentations or raised pavement ribs
- Application where there is a high incidence of run-off-the-road or loss-of-control crashes
- Use where there is limited recovery space and/or hazardous terrain
- Use in fog-prone areas

6.2.2.3 Potential Adverse Effects

The benefits resulting from shoulder rumble strips could potentially be offset by accident migration from treated to untreated locations. In order to counteract this, continuous installations over extended highway sections may be necessary to maximise the benefits (Harwood 1995). To this end, Queensland Transport recommends the line to be applied for a distance of 10 km, and Vicroads for a minimum of 1 km application (Munster et al. 1998).

Noise is considered to be of potential concern; however vehicle encounters with the audio-tactile line are relatively infrequent (Harwood 1995, Garder 1995). Also, this would be dependent on the location of treated road sections in relation to residential areas (Garder 1995). Moses (1993) states that this treatment should be restricted to further than 200 m away from a residence.

Use of audio-tactile lines over extended highway sections should also be carefully considered on bicycle routes. This is a concern primarily on non-freeway facilities as bicycles are normally prohibited on freeways. A study carried out by Garder (1995) indicated that not a single rider actually reported any loss of control when riding over the audio-tactile line, however, they found the treatment annoying. Also, the area between the treatment and the outside of the shoulder is often covered with debris. The combination of the two factors above may result in cyclists riding on the roadway to avoid the treatment and debris rather than in the shoulder. A number of solutions are available to counteract this issue (Corkle et al. 2001, Bachman 2001).

Drainage issues are another concern. However, introducing drainage gaps at regular intervals along the line, particularly where surface ponding is likely to be an issue, should minimise the negative impact (Munster et al. 1998).

There are clear benefits in providing audible tactile edge line and centre line treatments for sections of the New England Highway and possibly sections of other major roads in the Hunter Valley.

Recommendation 8: That the working party investigate the costs associated with treating the two edges and the centre line of the New England Highway, between Singleton and Musswellbrook, with audio-tactile edgelines.

6.3 Kangaroos and wallabies

Crashes and incidents caused by kangaroos and wallabies on the roadway are plentiful in the coal mining areas of NSW. For this reason, kangaroos and wallaby treatments are discussed in detail in the supplementary report attached. The recommended treatments for the mitigation of these animals on the roadway include:

- Signage
- Education
- Odour treatments
- Fences
- Culling
- Treatment of roadside vegetation

Recommendation 9: That the working party discuss costs associated with mitigation of animals in the road reserve and recommend countermeasures to Government.

6.4 Summary of countermeasures

The countermeasures shown within this report have the capacity to reduce road trauma due to travel crashes of NSW coal miners. The dissemination of this report and discussion of the possible countermeasures are a useful starting point and will hopefully promulgate actions to reduce travel crash injuries. The outcomes should be measured so that the countermeasures can then be applied to other jurisdictions. Therefore, key performance indicators similar to those used within this report should be captured and measured post-implementation of any road treatments or programs of human behaviour change.

Recommendation 10: That the working party assess the outcomes of any treatments using similar performance indicators as within this study.

7 Recommendations

There are several benefits that can be gained through the implementation of this project. The most important is the knowledge concerning what are the factors that contribute most to coal miners crashing on their way to or from work. The information arising from the results of this project has provided a strong platform for which to base strategies to reduce the prevalence of coal miners suffering road trauma.

The following recommendations are made in an effort to reduce the trauma associated with travel crashes on the way to and from coal mines in NSW.

Recommendation 1: That a working party be established to investigate and initiate any recommendations from this report.

Recommendation 2: All NSW coal mines should undertake to ensure that all staff can adequately manage the current roster designs that are in place.

Recommendation 3: All NSW coal mines should undertake fatigue management training of all staff and management.

Recommendation 4: A health program for NSW coal miners is put in place, either through the mines or the NSW Government.

Recommendation 5: All mines should investigate opportunities for utilising buses as an alternative means of transport. If not practicable, car pooling should be encouraged.

Recommendation 6: Further investigation of traffic volumes and movements be conducted through the working party.

Recommendation 7: The working party initiate road safety audits to investigate the delineation of roads in the Hunter Valley Region.

Recommendation 8: That the working party investigate the costs associated with treating the two edges and the centre line of the New England Highway, between Singleton and Musswellbrook, with audio-tactile edgelines.

Recommendation 9: That the working party discuss costs associated with mitigation of animals in the road reserve and recommend countermeasures to Government.

Recommendation 10: That the working party assess the outcomes of any treatments using similar performance indicators as within this study.

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9 Kangaroo and wallabies supplementary report

NSW Wildlife Information and Rescue Service (WIRES) estimate that 7000 native animals are killed every day on NSW roads (Canberra Times (2004a). The kangaroo is the most frequently hit animal, according to the NRMA Insurance Claims Research 2000-2002. However, surprisingly few officially published data on road kills of kangaroos is available.

Kangaroo/vehicle collisions raise economic and social issues, including human injuries and fatalities, loss of biodiversity, passenger distress, motor vehicle damage and high insurance premiums (The University of New South Wales, 2003). Only 1% of all accidents in NSW involving death or injury are attributed to collisions with animals and human fatalities from animal/vehicle collisions are rare (ACT Kangaroo Advisory Committee 1997). However, kangaroos do pose a great risk to humans due to their size, and there is also concern that the number of collisions is increasing. NRMA estimate the cost of animal/vehicle collision cost to be in excess of A$10 million (approx. A$3000/vehicle) (Cooper 1998, NRMA Insurance 2002 and 2004). Kangaroos may also become injured, or die as a result of accidents (ACT Kangaroo Advisory Committee 1997).

Three broad factors affect kangaroo/vehicle collisions:

1. *Road and design attributes*

   These include the following issues:
   - Ephemeral puddles formed after rains are used by western grey kangaroos as a temporary water resource (Coulson 1993).
   - Structures over road may force animals from verges onto roads (Bender 2001).
   - High speed roads. Vehicle speed is generally higher on bitumen roads than unsealed roads (Bender 2001).
   - High traffic volumes (Bender 2001).
   - Open space adjacent to roads supporting a resident kangaroo population (ACT Kangaroo Advisory Committee 1997).
   - Roads bisect natural movement corridors (ACT Kangaroo Advisory Committee 1997).
   - Funnelling effect of some roads, especially major roads with central concrete and vegetation barriers (ACT Kangaroo Advisory Committee 1997).

2. *Behaviour of animal*

   This includes the following issues:
   - Movements related to dispersal, breeding, etc. Can result in road crossings (Bender 2001, Lintermans & Cunningham 1997).
   - Moon phase – they appear to cross roads most on either side of a full moon (ACT Kangaroo Advisory Committee 1997, Bender 2001).
   - Dry conditions may result in kangaroos moving to road edges and closer to urban centres which have the road edges enhanced by drainage, irrigation and mowing (Bender 2001).
   - Seasonal movements (Bender 2001, ACT Kangaroo Advisory Committee 1997).
   - Kangaroos are mainly nocturnal – feed at dawn and dusk. This makes them hard to see and headlights dazzle them.
   - Excessive kangaroo numbers contribute to pressures to move from areas of high density (ACT Kangaroo Advisory Committee 1997).

3. *Behaviour of driver*

   This includes the following:
   - Affected by seasonal patterns including rain. (Bender 2001).
   - High traffic speed (Case 1978).

- Driver inattention (ACT Kangaroo Advisory Committee 1997).
- Driver inexperience (Bender 2001).
- Lack of awareness of or ignorance of “hotspots” (ACT Kangaroo Advisory Committee 1997).

The Kangaroo/wallaby-Vehicle collision mitigation measures, costs, advantages, disadvantages and effectiveness are shown in the table below.

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
Australian Research				
Methods minimising vehicle damage				
Impact bars, such as bull bars and nudge bars fitted to vehicles (e.g. Bender 2001, ACT Kangaroo Advisory Committee 1997).)	Relatively cheap compared with fencing and reflectors (ACT Kangaroo Advisory Committee 1997).	• Successful in minimising damage to vehicle (Jones 1994)	• Increased damage to other vehicles in minor accidents (Jones 1994) • Pedestrians thrown onto road from greater height (Jones 1994) • Rigid bar structure may affect crash pulse and airbag sensor (Tomas 1994, Jones 1994) • Protects front of vehicle only (ACT Kangaroo Advisory Committee 1997).	Medium practicality (ACT Kangaroo Advisory Committee 1997).
Improving collision strength of vehicles, eg Robo Roo and Robo Roo 2 have been developed by Holden to simulate impacts (Autoweb 2000).				
Methods of avoiding collisions				
Barrier fencing along roads which transverse kangaroo habitat (e.g. Bender 2001, ACT Kangaroo Advisory Committee 1997)	Very high construction and maintenance costs, eg. erection of a 2.4 high chain mesh enclosure fence at Tidnibilla Nature Reserve, ACT in 1997 cost $32/lineal metre.	• Would prevent the majority of kangaroos entering road corridor, especially if fence effective against juvenile male kangaroos (ACT Kangaroo Advisory Committee 1997).	• Would prohibit natural movement of kangaroos along wildlife corridors • May trap animals within road corridor (ACT Kangaroo Advisory Committee 1997).	• May be effective in some specific “hotspots” when these are more precisely identified, but ongoing maintenance cost will be an issue • Low practicality (ACT Kangaroo Advisory Committee 1997).

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
Fauna underpasses and ramps (e.g.Bender 2001, Jones 2000, Magnus et al. 2004)	• Large underpasses are costly • Best done during road upgrade or construction rather than a retrofitting activity (Magnus et al. 2004)		• There may be some reluctance for kangaroos to use underpasses due to potential predators (e.g. Canberra Times 2004b). • Note that in order to design effective underpasses, the following features need to be considered: placement, size, light, moisture, temperature, noise, substrate, approach characteristics, fencing, human disturbance and interactions among species (Jackson & Griffin 2000). In addition, need to consider roadside planting, internal features, detritus/silt traps, maintenance program, the use of bridges and median strips (RTA 1997).	• A 9 month trial conducted by the Australian Museum Business Services for the RTA in 1997 found fauna underpasses effective for wallabies (Roads and Traffic Authority NSW 1997), trial 18-month project conducted by the Australian Museum Business Services for the RTA in 2001-2002 found the fauna underpasses effective for kangaroos (Road and Traffic Authority NSW 2002a) • A trial to be carried out by Main Roads QLD, with results published in 2004 in Volume 2 of the Fauna Sensitive Road Design Series (Jones 2000)
Wildlife road signs, rumble strips and or/lighting in potential conflict areas, or "hotspots" (e.g. Bender 2001, ACT Kangaroo Advisory Committee 1997).)	Permanent signs relatively cheap compared with other options (ACT Kangaroo Advisory Committee 1997). The cost seems to be approx. $600-900 per sign in Tasmania (Magnus et al. 2004).	• Point out potential risk of accident with kangaroos to public (ACT Kangaroo Advisory Committee 1997).	• Current signs tend to provide no information about what the risk is, or what the driver is supposed to do – signs can be mistaken for areas for viewing wildlife (Magnus et al. 2004). • A whole variety of signs used throughout Australia at present – it may be more beneficial to provide a general wildlife warning sign (Magnus et al. 2004). • Lack of guidelines where the signs should be installed	• Unclear effectiveness of permanent signs. Could consider seasonal signs, but may be impractical due to extra work involved (ACT Kangaroo Advisory Committee 1997, Magnus 2004). • Deemed low to medium practicality (ACT Kangaroo Advisory Committee 1997).

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
			– note the map of "hotspots" is currently being complied in the UNSW state-wide research project (Magnus et al. 2004).	
Warning reflectors fitted to posts along roads, eg Swareflex, Strieter-Lite. They deflect vehicle headlights into adjacent road reserve, creating an "optical fence" (e.g. Bender 2001, ACT Kangaroo Advisory Committee 1997).	High installation maintenance, and possible vandalism/theft costs (ACT Kangaroo Advisory Committee 1997, Magnus et al. 2004)	• Unobtrusive structures (ACT Kangaroo Advisory Committee 1997). • The advantage over conventional fencing is that it does not interfere with the normal movement of animals around their habitat (WIRES/ IFAW 2004).	• Operate only after dark (Bender 2001) • Likely to be more effective when used on roadways with low traffic volume (Bender 2001) • Only effective on animals that are not on the verge or road itself (Magnus et al. 2004)	• Efficacy unclear, but widely used overseas (Bender 2001). • Deemed impractical unless demonstrated to be fully effective (ACT Kangaroo Advisory Committee 1997). • A trial carried out by Main Roads QLD in 2003 revealed that reflectors didn't appear to be effective (Scott 2003) • The UNSW state-wide research project has reported that red kangaroos have shown a 16% increase in vigilance response to Strieter-Lite reflectors, and 11% response to Swareflex reflectors (Ramp & Croft 2002).
Ultrasonic devices fitted to motor vehicles– passive whistles (wind-driven), and active (electronic) (e.g. Bender 2001, ACT Kangaroo Advisory Committee 1997)	Low purchase and installation costs (ACT Kangaroo Advisory Committee 1997).	• Popular with general public as manufacturers claim they don't hurt the animal • Non-irritant to humans (Bender 2001)	• May adversely affect other wildlife species and domestic animals (ACT Kangaroo Advisory Committee 1997).	• Efficacy unclear. Deemed impractical unless demonstrated to be fully effective (ACT Kangaroo Advisory Committee 1997). • Passive whistle (Hobi ultrasonic animal alert) tested in a 2004 study by the Cooperative Research Centre for Sustainable Tourism (CRCST), Tasmania have shown no evidence of efficacy (Magnus et al. 2004). • Sophisticated study carried out in 2001

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
				on the only active device available in Australia (Shu Roo) by the University of Melbourne for MRMA, RACV, RTA and Transport SA strongly argues against its efficacy (Bender 2001)
Chemosensory i.e. taste and/or odour repellents, eg spraying road sides with synthetic dog urine (e.g. Ramp, & Croft 2002).			• Possibility of habituation if used extensively (Magnus et al. 2004) • May cause kangaroo population decline (Magnus et al. 2004)	• A one-year study was conducted by the Australian Catholic University in 2001-2002 for the RTA to investigate the usefulness of chemical repellents in rural NSW. Results are unknown at present (Road and Traffic Authority NSW 2002a) • Encouraging results in the UNSW state-wide research project: Parma wallabies showed a strong aversive response and red-necked pademelons showed attraction response (Ramp & Croft 2002). • Reduced time spent on or near roads of deer in Germany, and of caribou in Canada. Concern is that the study methods may have not been objective and had low ecological validity. (Gibson 2001).

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
Driver education through means including the following: 1)Sophisticated television campaigns 2) Raising awareness through public distribution of products and billing information, etc (ACT Kangaroo Advisory Committee 1997).	1) Significant up-front costs for research, selection of appropriate medium, preparation and distribution of material. 2) Lower cost in the long term compared with other options (ACT Kangaroo Advisory Committee 1997).			• Considered an effective means of changing human behaviour • Deemed high practicality (ACT Kangaroo Advisory Committee 1997).
Culling kangaroos on public land adjacent to major roads (ACT Kangaroo Advisory Committee 1997).	High cost as on-going program required (ACT Kangaroo Advisory Committee 1997).	• Would temporarily remove one element of conflict (ACT Kangaroo Advisory Committee 1997).	• Public safety issues on most public land within the urban area would prohibit culling with high powered rifles. Other means of culling eg poisoning are not appropriate (ACT Kangaroo Advisory Committee 1997).	Low practicality (ACT Kangaroo Advisory Committee 1997).
Leaving dead kangaroos on side of road (ACT Kangaroo Advisory Committee 1997).	Low cost, although ranger attendance still necessary from animal welfare perspective (ACT Kangaroo Advisory Committee 1997).		• May feed pest species such as foxes and wild dogs • Unsightly, may cause distress to some members of community and tourists • Some risk to driver safety (ACT Kangaroo Advisory Committee 1997).	• Some evidence from work on deer road kills and driver behaviour in North America that leaving carcasses on site may act as a warning or speed deterrent to drivers (ACT Kangaroo Advisory Committee 1997). • Deemed medium to high practicality (ACT Kangaroo Advisory Committee 1997).

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
Slowing down traffic through traffic calming (e.g. slow points) or perceptual speed reduction treatments (Jones 2000)	Fairly high for traffic calming measures, low for perceptual markings	• Perceptual speed reduction treatments are non-obtrusive – no additional hazard on road		• The traffic calming measure in the form of slow point was considered to be the primary measure contributing to the recovery of eastern quoll and Tasmanian devil population in Tasmania in 2000. The effect on kangaroos is unknown (Jones 2000). • However, slow points were shown to reduce driving speed by 20kph in the above study (Jones 2000)
Table drain management – involves reducing food and water resources for kangaroos (Magnus et al. 2004)	Biodegradable herbicide cost $110/hectare in Tasmania (Magnus et al. 2004)		• Threatened plant and community issues (Magnus et al. 2004)	• Measure should be considered where wildlife appears to be attracted to road by food. Several means of table drain management are available (Magnus et al. 2004) • Note vegetation should not be slashed or mown as creates new growth and may attract more kangaroos (Magnus et al. 2004)
Making the road surface lighter in colour (Magnus et al. 2004)		• Wildlife may feel more exposed on road due to their increased visibility (Magnus et al. 2004) • Drivers may see animal sooner against the light coloured surface (Magnus et al. 2004)	• Selection of stone relates to durability and degree of polishing – need to select appropriate stone (Magnus et al. 2004) • Light coloured aggregate not considered desirable due to its high visibility (Magnus et al. 2004)	• Effectiveness unknown (Magnus et al. 2004)
Use of car horns (e.g. Magnus et al. 2004).	Nil			• A study carried out by the CRCST in Tasmania indicates that sounding the horn

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
				appeared to have a positive response in cases where there is enough time for the driver to do that (Magnus et al. 2004).
Roadside lighting installation (e.g. Magnus et al. 2004)	• Very high installation and maintenance costs (quote for 1.2km of road using 26 lights was $44 251 in Tasmania) (Magnus et al. 2004)	• Wildlife may be discouraged from loitering on road (Magnus et al. 2004) • Increases driver awareness and driver visibility (Magnus et al. 2004)		• Effectiveness unknown – it may be tested using existing data and survey methods (Magnus et al. 2004)
Use of driving lights on vehicles (e.g. Ramp & Croft 2002, Magnus et al. 2004).	• Nil			• The UNSW research also indicated that red kangaroos and red-necked wallabies were also observed to exhibit a vigilance response to simulated car light without motion or sound for 50% of cases (Ramp & Croft 2002) • Another document (a study carried out by the CRCST in Tasmania) indicates that the use of driving lights appear to result in fewer animals being hit (Magnus et al. 2004).
Additional Overseas Research – mainly related to deer - vehicle collisions				
Improved wildlife signage: • lighted/ animated signs • active signs (activated only when deer detected		• increased effect of warning signs		• One study by Pojar et al. (1975) found some effect of lighted/ animated signs on vehicle speeds but no reduction in deer collisions • A small study of active signs by Gordon et al. (2001) found some speed reductions, but no

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
near the road) (Hedlund et al. 2004) • signs stating the number of animal/ vehicle collisions within the next mile the previous year				deer collision data was collected.
Roadside clearing (Hedlund et al. 2004)	Maintenance costs (Hedlund et al. 2004)	• Animals are more visible to driver • Attractiveness to animal somewhat reduced (Hedlund et al. 2004) • Other advantages beyond collision control, eg. safety and aesthetic benefits		• A number of studies recommend roadside clearing for deer collision control (e.g. Putman 1997, Bruindeink & Hazebroek 1996)
Infrared animal detection fitted to vehicles (Hedlund et al. 2004, Transportation Research Board 2004).			Would take many years to fit into the majority of vehicle fleet (Hedlund et al. 2004).	Effects appear to be not yet evaluated
Speed limits (Hedlund et al. 2004)			• Extra speed enforcement necessary • Lower speed limits may not necessarily result in lower travel speeds (especially if not enforced) (Hedlund et al. 2004)	• One study (Bertwistle 1999) has shown *increased* crashes with sheep and elk where speed limits were decreased – hence suggests measure ineffective • May be beneficial in specific locations with high population or migration routes (Hedlund et al. 2004)

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
At-grade crosswalks (Hedlund et al. 2004, Danielson & Hubbard 1998)	Lower cost than underpasses (Danielson & Hubbard 1998)			In the only study to date, Lehnert and Bissonette (1997) have shown collisions to decrease by about 40%, although there was small sample size.
Intercept feeding (feeding stations) (Hedlund et al. 2004, Danielson & Hubbard 1998)	Continuing costs		• May make animals dependant on the food provided • May attract more animals to roadside (Wood & Wolfe 1988)	One study carried out concluded that intercept feeding may only be useful in very specific situations (Wood & Wolfe 1988)
Animal mirrors (round conventional mirrors reflecting headlights off the highway) (Danielson & Hubbard 1998)			• Animals may become accustomed to the reflected light over time (Danielson & Hubbard 1998)	Two studies found mirrors effective for only a year after installation, with accident rates returning o pre-treatment levels in the second year of study (Queal 1967 and Beauchamp 1970).
Animal hazing (Danielson & Hubbard 1998)				No evaluation studies appear to be available
IRD Wildlife Warning System (Canadian Pilot project - approaching vehicles trigger a sensor that in turn warns the animals by the use of sound and light) (Saskatchewan Highways and Transportation 2002)	• Lower cost than fencing • Costs $35,000 per mile. Installation and maintenance costs are not listed. Both IRD and Saskatchewan Government Insurance are each providing $25,000 to fund the two year study (College of Natural Resources 2004).	• Animals should not grow used to warnings (Saskatchewan Highways and Transportation 2002) • No physical barriers hence normal migration patterns (Saskatchewan Highways and Transportation 2002) • Flexible system (College of Natural Resources 2004). • Possibility of adding on	• Adapting the system to local conditions and solving technical difficulties may take a lot of time (College of Natural Resources 2004). • Wildlife may not continue to respond to the sounds and lights if there is a significant time lag between the warning and presence of the vehicle near them (College of Natural Resources 2004). • Animals may become accustomed to the sounds and lights and ignore them, especially in areas of high traffic	Results not available at this time

Mitigation Measure	Cost of Measure	Advantages	Disadvantages	Effectiveness/ Expected Practicality
		extra devices later • Easy installation – no power or communicatio n required	volume where the system would be continuously operating (College of Natural Resources 2004). • If the warning system is found to be effective, it may interfere with normal wildlife movement through an area, reducing dispersal and genetic interchange (College of Natural Resources 2004). • Wildlife crossing areas may change over time. This would mean that, the sensors and warning units would need to be moved. Constant assessment of mortality figures is needed to monitor this (College of Natural Resources 2004). • No ecological solution to connectivity or mortality issues associated with roadways is provided (College of Natural Resources 2004).	

The following messages should be included in driver education:

3) Follow the basic road rules and regulations, including the following (e.g. Basey 2002, Smart Motorist 2004):
   - Don’t drink and drive
   - Don’t drive if you’re tired
   - Always wear seatbelts
   - Don’t speed
4) Avoid travel at the high risk times (dawn and dusk) (e.g. Road and Traffic Authority NSW 2002b).
5) Drive slowly and be alert, especially at dusk and dawn (e.g. Wildlife Information and Rescue Service 2004a). Appoint a passenger to be a kangaroo “spotter” (Environment ACT 2004).
6) Take extra care where road signs indicate wildlife (e.g. Wildlife Information and Rescue Service 2004a, Road and Traffic Authority NSW 2002b).

7) Don’t swerve to miss a kangaroo – just slow down (e.g. Road and Traffic Authority NSW 2002b).
8) Stop if you can do so safely and wait for the animal to cross – you never know what the animal is going to do next (e.g. Road and Traffic Authority NSW 2002b).
9) Remove dead animals off the road to avoid secondary crashes with the victim and/or scavengers feeding on the victim (Wildlife Information and Rescue Service 2004a).
10) Check dead animals for babies (Wildlife Information and Rescue Service 2004a).
11) If you have hit an animal, stop the car and see if you can help. If it is alive, keep it warm and in a quiet area. If it is dead, try to remove it off road and check for babies. Report to a wildlife rescue centre or veterinarian.

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