CONCRETE CENTRAL SAFETY BARRIERS IN CONSTRAINED ROAD ENVIRONMENT

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Supervisor:

Professor Ron Ayers (USQ)

Prepared By:

Katherine Holzner

Student Number: 0050085531

ABSTRACT

Road crashes are a continuing source of personal grief and economic loss in most societies. In NSW between October 2008 and September 2013, head-on crashes made up 5.5% of all rural road rashes in NSW but contributed to 27% of all fatalities on those roads.

Head-on crashes tend to be concentrated at sites of substandard horizontal road geometry. Often, rectification of site geometry on constrained rural roads is beyond the limitations of Road Authorities. Installation of central barriers in narrow medians is a cost effective incremental solution but often comes at a sacrifice – reduction of sight distance, reduced recovery area and surface drainage implications.

This study assesses the implication of introducing a concrete central safety barrier (CCSB) into an already substandard, complex road environment by assessing the before-and-after performance of nine concrete central safety barrier sites.

The literature review compared the different types of central safety barriers including concrete (cast in-situ and pre-cast), guardrail and wire rope. When compared to wire rope and guardrail, concrete barriers are more suited to highly constrained road environments, having negligible deflection, being suitable for horizontal radius less than 200m and remaining operational post collision (reduced maintenance and worker exposure). The compromise with the system is increased crash severity, highest potential implications on surface drainage and sight.

Although the severity index of concrete barriers is seemingly the highest of all barrier systems, the results typically agreed with general performance of all barriers: non-injury (tow-away) crashes increase in place of injury crashes and injury crashes increase in place of fatal crashes. Fatal crashes were almost entirely eliminated.

CCSB were found to be an effective solution at eliminating head-on crashes at all nine sites investigated. The installation also had an improvement of general road safety at seven of the nine sites analysed. It is believed that the poor performance of the two remaining sites was likely attributed to poor co-ordination of horizontal and vertical geometry at one site and worsening of surface drainage conditions at the other.

The total average reduction in fatalities across all sites was 111% and factored severity costs in all accidents reduced by 200%.

Six of the nine sites had pre-cast concrete central barrier systems. Currently there is no current acceptance for the use of precast concrete barriers as a permanent installation. All six pre-cast sites had an overall positive impact on road safety, it is recommended this system be tested for acceptance as an RMS approved barrier system.

Stopping sight distance (SSD) is the distance required to enable a driver to perceive, react and break to a stop before reaching a hazard on the road ahead. SSD is frequently viewed as an overriding parameter which directly relates to road safety within the road design community. The literature review revealed that the SSD model was based on a number of 85^{th} percentiles combined with a small hazard being on the roadway. This has created quite a conservative design parameter which is often difficult to achieve, especially in constrained environments. The model may also stretch the limits of human abilities.

The significant reduction of SSD at the sites, ranging from achieving 33-100% of the required SSD value, did not directly result in significant increase in crash severity. There was no distinct relationship between the degree of SSD reduction and increase in crashes.

A less conservative, more realistic model such as 'SSD over barriers' is more suited to the constrained road environment. This model sights to a vehicle brake light or top of car and requires the provision of a 2.5m lane for manoeuvring around the object. However, as most sites failed to meet this model, no link between meeting 'SSD over barrier' and the reduction in crash severity was observed.

Consequential poor pavement drainage at one site was likely to have attributed to a significant increase in wet pavement crashes. This is likely related to the cast in-situ concrete barrier which had only small drainage slots. The slots were not likely to relieve adequate pavement flows and may have led to aquaplaning.

A site on the Princes Highway at East Lynne has been selected to apply the results and conclusions drawn from this study.

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/ENG4112 Research Project

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Katherine Holzner

0050085531

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GLOSSARY

2+1	Restorative road treatment developed and implemented extensively in Sweden consisting of a 13-14m road formation with two lanes in one direction and one lane in the other, narrow median with wire rope safety barriers and narrow shoulders. The single and double lanes alternate from side to side every few kilometres to permit overtaking.
Aquaplaning	A condition occurring on a wet road when the tyres of a moving vehicle lose contact with the road surface and ride on a film of water.
Brownfields	Alterations to an already existing construction.
Constrained road environment	Characterised by social and environmental constraints (e.g. Undulating – hilly terrain, significant adjacent land use boundaries, services, low traffic volumes, on or near structure, ecological, heritage etc.). Also suggests a curved alignment.
Centrifugal force	Apparent force which is a component of the inertial force which tends to draw a rotating body away from its centre of rotation.
F	Crash resulting in occupant fatality
Factored severity costs (FSC)	Calculated costs based on the number of people involved, the associated severity/ies of the crash and Willingness to

	Pay Approach costs in $2012-2013 (TfNSW, 2013)
Greenfields	A construction on previously undeveloped land.
I	Crash resulting in occupant injury
Impact angle	The minimum angle at which a vehicle at speed leaves the road
Incidence	Occurrence of a crash including one or more vehicles and associated persons involved.
NI	Crash resulting in no injuries (non-injury/tow away)
Nearside	The side of a vehicle closest to the kerb on the left-hand side of the road when the vehicle is travelling in the normal direction of travel.
Offside	The side of a vehicle furthest away from the kerb on the left side of the road when the vehicle is travelling in the normal direction of travel (i.e. it corresponds to the driver's side of the vehicle).
National Cooperative Highway Research Program (NCHRP)	Research board created in 1962 to conduct research of acute problem areas that affect highway planning, design, construction, operation and maintenance for the United States of America.
Risk	The combination of severity and likelihood

Roads and Maritime Services (RMS)	New South Wales road authority, formerly Roads and Traffic Authority (RTA) until 2011
Safe system	A road safety approach which holds that roads, vehicles and speeds should be designed to reduce the risk of crashes and to protect people when a crash occurs
Severity index (SI)	A way of describing the consequences of a crash for analytical purposes.
Shy line	The shy line is an additional offset provided to minimise this behaviour. The shy line, measured from the edge of the traffic lane, provides adequate offset so the object will not be perceived at an obstacle.
Terminal	An initiative proposed by the Swedish government in 1998, with the aim reducing road fatalities to zero. A device designed to treat the end of a road safety barrier. The terminal may function by decelerating a vehicle to a safe stop within a relatively short distance, or permit controlled penetration of the vehicle behind the device, or contain and redirect the vehicle, or a combination of these performance characteristics.
Vision Zero	A road safety approach which holds that no foreseeable accident should be more severe than the tolerance of the human in order not to receive an injury that causes long term health loss.

1 INTRODUCTION

Road crashes are a continuing source of personal grief and economic loss in most societies. In particular, road fatalities are concentrated at sites of head-on crashes. In NSW between October 2008 and September 2013, head-on crashes made up 5.5% of all rural road rashes in NSW but contributed to 27% of all fatalities on those roads.

The need to minimise these crashes is understandably a core aim of roads authorities. Often these crashes are attributed to tight horizontal and vertical geometry, out of context road geometry and driver behaviours such as speed and fatigue. Often full realignment at sites of high crash rates is not practical. Lower volume rural highways in socially and/or environmentally sensitive areas do not often attract significant funding. It is in locations where such issues come into play that central barriers are predominantly employed.

Despite this intention for increased safety, however, there are accompanying safety drawbacks, including:

- Introduction of a fixed hazard adjacent to travel lanes
- Potential reduction of sight distance around curves
- Trapping of fauna
- Potential surface drainage issues – leading to aquaplaning

These drawbacks are being assessed by comparing pre- and post-construction crash data at particular rural highway sites in NSW.

This project is relevant to the incremental upgrade of existing roads which were characterised by:

- Rural
- High speed
- Single carriageway highways
- High accident rates, particularly head-on
- High level of constraint (environment, heritage, topographic, geotechnical, geometric, cost, scope, traffic volumes, services etc.)

The findings may also be of relevance in Greenfields design of roads in constrained road environment.

1.1 Background

In the author's time as a road designer, there have been a number of sites within heavily constrained road environments that have experienced above average crash rates. As a result, these sites had increasingly bad publicity within the organisation, community and media. The typical setting of these sites consisted of two-way, rural highways, generally low traffic volumes, substandard horizontal alignment geometry, substandard shoulder and lane widths, high degree of constraint due to proximity to boundary, side slope, rail line, services etc.

Projects were initiated in order to combat cross centreline crashes. Due to the high level of constraint, truly rectifying the geometric problems by means of full realignment would result in prohibitively high costs. Roads having low traffic volumes and a lower order function are usually afforded low cost-benefit ration, thus making the costs associated with major works very difficult to justify and unlikely to gain funding.

Besides rectification of the geometry, the other discussed solutions included installation of a central safety barrier and localised widening or increased enforcement. Installation of a central safety barrier and localised widening was considered the most practical solution, although concerns were raised about the implications. The installation of the central safety barrier within a section exhibiting substandard geometry and minimum median width would result in a significant reduction of the available stopping sight distance, well below minimum (Austroads, 2010). Therefore, in many of these cases the central safety barrier was argued as a trade-off of one safety issue for another. On the other hand, if minimum sight distance was to be achieved, then the project may once again become impractical. Risk assessments found that installing central safety barrier had less risk than using the traditional model, despite the inherent loss of stopping sight distance.

Since installation, the barriers, even with the acknowledged risk, have had little or no publicity of crashes within the organisation or within the community/media. This knowledge has not been quantified with crash investigations post-installation.

This study aims to review real world sites across NSW in order to investigate the performance and implication of central safety barrier construction in constrained road environments. From this, the connection between the reduction in sight distance and crashes on high speed, rural highways has been evaluated. The impact of changed surface drainage conditions at the sites has also been investigated.

Although there is greater push to install flexible, wire rope systems within Australia, concrete safety barrier systems have their own advantages. One main advantage of concrete safety barriers is they can be installed on horizontal curve radii less than 200m. This makes concrete barriers more suitable to highly constrained sites which are characteristic on many rural NSW highways.

Concrete safety barriers have a greater and more obvious visual intrusion on drivers' sight. Concrete safety barriers also offer the minimum dynamic deflection of all safety barrier systems, thus allowing reduced offset to the travel lane. The combination of these characteristics means concrete safety barriers hinder sight distance more significantly than any other types of safety barrier system. Therefore concrete safety barriers offer more certainty when investigating the relationship between limited sight distance and road safety.

The purpose of this research was to inform and improve understanding of the implications associated with installation of a concrete central safety barrier (CCSB) in a mid-block, high speed rural road environment. This dissertation is aimed at increasing the awareness of these research outcomes for the practical use to design practitioners. This in turn will hopefully increase certainty and therefore delivery times when investigating treatments at these sites where the only other alternative is to 'do nothing'. This study is relevant to median barriers on single carriageway, Brownfield sites. As such, this study is being completed from a reactive perspective but is hoped to aid in understanding and decision making in proactive design treatment at Greenfields sites.

1.2 Project Objectives

The broad objectives of this project were to:

- Better understand the performance and appropriate application of central safety barriers

- Analyse CCSBs in service to objectively quantify performance based on crash statistics
- Interrogate and test the impact of reduced sight distance in attempt to understand any relationship to road safety
- Apply the findings to an existing site

1.2.1 Personal Objectives

- Analyse sections of Austroads Guide to Road Design in entirety
- Generate practical insight to the road engineering practice
- Improve safety for road users with a cost effective solution
- Fulfil the requirements of the Bachelor of Engineering (Civil)

2 LITERATURE REVIEW

The following predominantly online/electronic literature review intended to summarise and evaluate the national and international literature which investigated and discussed crashes, central safety barriers and sight distance.

A large proportion of the literature reviewed was focussed on flexible, wire rope safety barrier (WRSB) systems. This system has become very popular in the last 15-20 years. A lot of research has been conducted on its performance that is relevant to this study.

Although the rigid concrete barrier system and flexible barrier systems vary significantly in properties, it is thought that the papers and their findings are still relevant, particularly when evaluating management of cross centreline crashes. The literature review therefore intends to summarise, compare and evaluate literature for common types of central safety barrier types including flexible (WRSB), semi-rigid (steel guardrail) and rigid (concrete safety barriers).

2.1 Crashes

Reducing fatal and casualty crashes is both an ethical and economic responsibility. This responsibility lies with governing Road Authorities.

2.1.1 Designing for safety

In research undertaken by Hankey et al (1999) and Medina, Wierwille & Hanowski (2004), human error was identified as the major contributing factor for up to 75% of all roadway crashes.

The concept of providing a safe road environment for road users is very prominent in Sweden. In 1998, the Swedish government set to drastically reduce road fatalities to zero. This initiative was called ‘Vision Zero’. The ideals of vision zero can be summarised by the following;

‘No foreseeable accident should be more severe than the tolerance of the human in order not to receive an injury that causes long term health loss”. (Tingvall, 1998)

“No loss of life is acceptable… It is based on the simple fact that we are human and make mistakes. The road system needs to keep us moving. But it must also be designed to protect us at every turn.” (VisionZero, 2014)

The NSW Work Health & Safety Act (2011) states, the organisation and associates whom design, construct and commissions the infrastructure have a duty of care to ensure the infrastructure is without risk to health and safety of the users, within reasonably practical limits.

In line with the WH&S Act 2011, the NSW Roads and Maritime Services (formerly Roads and Traffic Authority) adopted the Safe System approach, where possible

The Safe System approach is reproduced below:

“Safe system

The Safe System is a road safety approach which holds that roads, vehicles and speeds should be designed to reduce the risk of crashes and to protect people when a crash occurs…

The Safe System approach also recognises that road safety is a shared responsibility by those who:

- *Plan, construct and maintain the network.*
- *Use the network i.e. drivers, riders, pedestrians.*
- *Manufacture motor vehicles.*
- *Enforce road user behaviour.”* (NSW Centre for Road Safety, 2011)

All road crashes have an associated economic cost. In 2013, Transport for NSW produced the NSW Principles and Guidelines for Economic Analysis of Transport Investment and Initiatives. The document assigns costs to fatal, injury and property damage only. The exact basis of these costs was not specified within the TfNSW document or within the study which obtained the values.

These costs are shown in Table 1.

Table 1 – Reproduced fatality and injury costs, Willingness to Pay Approach, $2012-2013 (TfNSW, 2013)

Risk category	Value of risk reduction (cost per person in $2012-2013)
Fatal crash	$6,742,550
Injury crash	$154,166
Property damage only	$9,289

These costs are the preferred values for economic appraisals in NSW.

2.1.2 Cross Centreline Crashes

Central safety barriers are installed to mitigate crashes related to a cross-centreline manoeuvre – the primary related crash is the head-on collision.

As documented by McLean, Baldock and Kloeden (2002) in their study which investigated 236 crashes attended by an ambulance, other less obvious crash types related to cross-centreline movement include:

- run off road to right,
- run off road to left (overcorrection away from oncoming traffic)

Nilsson and Prior (2004), who assessed the impact of central WRSB before and after installation at a number of sites on the Pacific Highway, also documented cross-centreline crashes frequently resulted from:

- overtaking (head on and run off road to right)

The causes of cross-centreline crashes were well summarised by Tziotis, Styles and Turner (2010):

> *"The rural road environment is substantially different to the urban environment. Factors that may contribute to the occurrence and severity outcome of rural head-on crashes include:*

Road:

- *the geometry of curves*
- *condition and surfacing of edges and shoulders*
- *cross-section of the road – carriageway width, divided/undivided, width of median*
- *inconsistency in geometric design*
- *delineation of the road surface and curves*
- *sight distance*
- *overtaking opportunities.*

Driver:

- *declines in driving performance caused by fatigue, alcohol, drugs, or lack of attention*
- *high, often excessive speeds on rural roads*
- *driver experience in overtaking manoeuvres*
- *lack of seat belt wearing*
- *driver age and experience.*

Environmental conditions:

- *weather conditions*
- *time of day*
- *level of enforcement*
- *mix of vehicles on rural roads."*

The geometry of curves is particularly of interest as is it common knowledge within the road design field that horizontal geometry is the most significant dictator of driver speed. This notion is reflected in the operating speed model presented in Austroads (2010):

> *"The speed adopted on an open road is affected more by the driver's perception of the horizontal alignment of the road than by any other single design feature. For this reason, whenever curves are used to change the direction of travel or to suit the topography, the radii must be large enough*

> *to permit travel speeds commensurate with those expected on adjoining straights or along the whole of the section being designed. Generally, the adopted alignment should be as direct as possible, with curve radii as large as practicable."*

This knowledge is enhanced by NSW CrashLink data which demonstrates that fatal head-on crashes on rural highways tend to be concentrated at substandard horizontal curvature.

Often horizontal geometry on rural highways is substandard without any vertical grade correction. In NSW it is not uncommon to have sites which have steep downgrade approaches which would make the already substandard horizontal radius an even lower standard as per Austroads (2010):

> *"On steep downgrades there is a greater chance of some drivers tending to overdrive horizontal curves. Therefore, the minimum curve radius from Section 7.6.1 should be increased by 10% for each 1% increase in grade over 3%..."*

Head-on Collisions

Head-on crashes are characteristically severe. Between October 2008 and September 2013, head-on crashes made up 5.5% of total rural road crashes in NSW but contributed to 27% of all fatalities. A head-on crash was the leading cause of death on rural roads in the same timeframe.

"The most damaging and deadly crashes are those that involve vehicles colliding head on" (WSDOT, 2006). The severity of this type of accident is due to the transfer of energy. Little energy is dissipated in any other directions except between the two vehicles.

In regard to head on collision, the Swedish Vision Zero philosophy indicates vehicle occupants should not be exposed to speeds greater than 70km/h when heavy vehicles are combined with light vehicles, for example (Austroads Guide to Road Safety Part 8, 2009):

> *"This also applies to roadside hazards; where these cannot be removed or the vehicle traffic separated, lower travel speeds should be considered. In some European countries, such as Norway, single carriageway roads with no central barrier, where there is the potential for head-on collisions, have speed limits of 70 km/h."*

In the National road safety action plan for 2007 and 2008, the Australian Transport Council (2006) reported the chances for surviving a head-on collision decreased significantly when travelling at 70km/h. In Australia, it is common for rural roads to be undivided and signposted at 100km/h.

Central safety barriers have a high success rate in essentially eliminating head on and overtaking accidents.

Run-off Road to Right

These accidents occur when the errant car drifts across the centreline and does not contact another vehicle. The vehicle then continues into a hazard. The severity of this accident type is dependent on the object hit and the speed of travel. This accident type allows for the most recovery time of all cross-centreline crashes. Although, as presented in AASHTO (2011), accidents were still observed when up to 61m of (median) recovery was available.

Run-off Road to Left

These crashes occur when the errant vehicles cross the centreline, overcorrect and travel off the carriageway into a hazard. Adequate shoulders, recoverable batter slopes or appropriate safety barriers will reduce the risk of these crashes.

Overtaking Related Collision

Nilsson & Prior (2004) found that 50% of all fatal accidents were attributed to overtaking at these sections of the Pacific Highway they investigated. Overtaking crashes also contributed to 40% of all injuries in the same high risk sections of the Pacific Highway. This finding supports the need for central safety barriers to prohibit overtaking at sites where the manoeuvre may not be appropriate i.e. where the geometry does not support the overtaking manoeuvre. With the introduction of a central safety barrier, crashes initiated by cross-centreline overtaking manoeuvres are eliminated.

2.1.3 Combatting Cross Centreline Crashes

In discussions between the Swedish Road and Transport Institute and Nilsson and Prior in 2009, it was found that of the overall 50% reduction in fatalities attributed to the 2+1 treatment, the central safety barrier treatment alone was responsible for about 45% of the fatality reduction. The remaining 5% fatality reduction was attributed to the shoulder barriers and other side area upgrades.

The Swedish VTI (Swedish Government Road and Transportation Research Institute) issued their final report on the effects of the 2+1 roads with mid-barriers in 2009. The statistics showed that on the 1800km of treatment, the number of fatalities were reduced by 79% for mid-block sites.

In many cases, barriers pose a lower risk than an undivided road when there is an existing and established accident history. In the literature reviewed which compared crashes before-and-after installation of central safety barriers, there was a significant reduction in severity of fatal and casualty crashes. Typically, property damage and low level injury increased. Central wire rope crash severity shifts reported by Carlsson (2009) and Nilsson and Prior (2004) have been summarised in Table 2.

Table 2 – Fatality and severe injury reduction cited from previous studies

Location	Study	Barrier Type	Fatality Reduction	Severe Injury Reduction	Increase Property Damage
Sweden	Carlsson, 2009	WRSB	76%	58%	NA
Australia, Pacific Hwy (forecast)	Nilsson & Prior, 2004	WRSB	35-50%	30-40%*	30%

The literature reviewed demonstrates that the use of central safety barriers is well justified to prevent high severity accidents from occurring.

2.1.4 Crashes related to central safety barriers

The typical crashes that could be associated with the installation of central safety barriers include:

- Crashes with safety barrier
- Side swipe – increased risk of side swipe on multilane roads wide narrow lanes due to vehicles shying from close barriers
- Encroachment collision
- Rear end collision – reduced sight distance
- Roll over

Crashes with safety barrier

Austroads Part 6 (2009) acknowledges that the removal of the hazard is preferred to applying a treatment to protect road users from it. In the case of constrained road environments, there is often little that can be done to eliminate the oncoming traffic or provide sufficient clear zone for recovery in the median.

As part of the outcome of controlling these accidents, collisions with the barriers occur instead (Blackman, 2011). With the introduction of a barrier comes the introduction of a permanent hazard adjacent offside travelling vehicles. With no barrier separation, errant vehicles may cross the centreline, having the opportunity to recover if there are no oncoming vehicles or other hazards. At stretches of road where there are low traffic volumes this recovery may be possible. But, with the introduction of a central safety barrier the same manoeuvre would result as an imminent collision with the barrier. Thus a higher accident rate is expected but the overall severity of the crash is significantly reduced. The Blackman (2011) paper brings up a reasonable and valid point:

> *"Thus, the measure of effectiveness of barriers is how much they reduce injuries that might have occurred in the absence of the barrier, rather than whether the barriers themselves cause injury. Unfortunately, it is impossible to measure accurately the injuries that no longer occur, so the emphasis is often on the injuries that occur in collisions with barriers"*

The Swedish Road and Transport Institution's half yearly report by Hollnagel (2004) states that:

> *"…accidents with severe outcome are prevented by the barrier but instead are turned into barrier collisions with limited injuries"*

Austroads (2009) Roadside Design, Safety and Barriers notes a good point,

> *"It is important to understand that whilst safety barrier is effective in shielding severe hazards, the barrier will be longer and closer to the road than the hazard it is shielding. Therefore, the barrier will have greater probability of being impacted and the number of crashes is likely to increase even through there is a net road safety gain because of reduced severity impacts."*

Thus, the barrier is designed to minimise force on the occupants of the vehicle during the collision with the central barrier. The barrier should redirect the vehicle, either to stop or to the offside lane in a controlled manner.

Side Swipe Collision

There is an increased risk of side swipe on multilane roads with narrow lanes due to vehicles shying from close barriers. The shy line effect is where drivers will tend to reduce speed, drive off-centre in the lane, or move into another lane when travelling adjacent a roadside object (such as safety barriers, retaining walls, bridge railings etc.).

Encroachment Collision

Encroachment is mainly an issue for WRSB systems as represented in the previous figures. The dynamic deflection may not be contained within the median. In the presence of an oncoming vehicle, this could lead to collision between the two vehicles. There is also risk that the barrier system hardware on WRSBs in particular and guardrail systems encroach into the travel lane post collision.

In a study of 11,457 median barrier collisions that occurred in Washington State between 1999 and 2004 (WSDOT, 2006), it was found that of all errant vehicles which hit a central median barrier, 1%, 4% and 5% went beyond the barrier for concrete, beam guardrail and wire rope barrier respectively.

Oregon, USA used high tension cable within a 2.4m narrow median, which gave 1.2m of dynamic deflection (Austroads, 2011). Although encroachment is still possible, the treatment was deemed a cost effective solution to mitigate head on collisions.

The severity index table presented in Austroads (2009) takes encroachment into account. The road engineer/practitioner is to make adjustment for encroachment in consideration of barrier system type and median width.

The RTA Road Design Guide (1996) severity index table, which supersedes Austroads (2009) does not include encroachment adjustment.

Multi-Vehicle Collision

In the same study it was found that occupants striking concrete or beam guardrail were more likely to be killed or severely injured when compared to wire rope barrier system. Interestingly, this was mainly attributed to redirecting the errant vehicle back into an adjacent vehicle, rather than from the initial collision with the barrier. Accordingly, the study summarised the distribution of single vehicle and multi vehicle crashes. This has been reproduced in Figure 1.

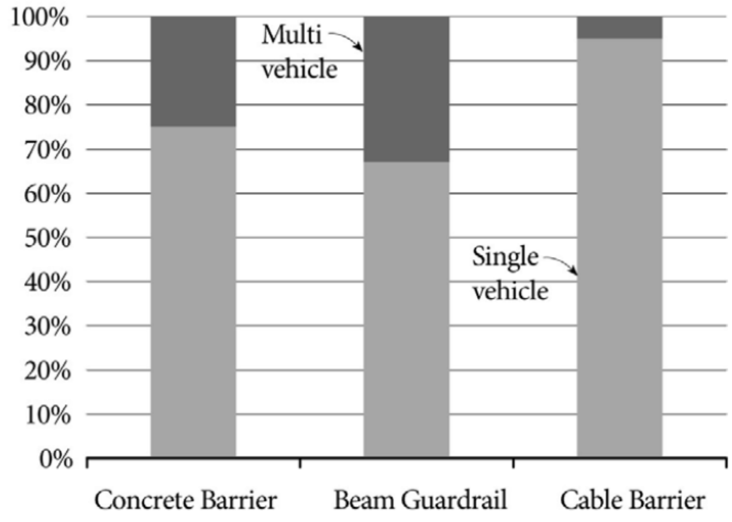

Figure 1 – Single and multi-vehicle collisions (WSDOT, 2006)

From this it can be deduced that collision with an adjacent vehicle after being redirected could have high severity. There is little documented regarding multi-vehicle collision post barrier redirection in Austroads guidelines (2009).

Table 3 – Reproduced excerpts of roadside hazard summary (Austroads, 2009)

Hazard	Comment
Other vehicles	Where the area of interest (as defined by clear zone widths) includes one or more opposing lanes of traffic, the danger of errant vehicles crossing the median and colliding with oncoming or stationary vehicles is high. This issue also applies to special facilities that are accommodated in a median or a separate reservation adjacent to the road. Such facilities may include: a high occupancy vehicle lane local traffic (e.g. frontage roads) traffic adjacent to the through traffic where there is a speed differential equal to or greater than 20 km/h transit corridors (e.g. busways, railways, light rail etc.) freight railways. These facilities may require a safety barrier to separate their operations from an adjacent road carriageway. For example, transit corridors or freight railways within or adjacent to intermediate or high speed roads are typically protected with an appropriate safety barrier unless a comprehensive risk assessment demonstrates that protection is not required. Consideration needs to be given to not only the risk to motorists but also to users of the transit corridor or the freight railway.
Road safety barriers	Road safety barriers should be regarded as hazards in that they are roadside objects which may be impacted by errant vehicles. They should only be used where they constitute a lesser hazard to road users than the hazard being shielded. There are increased risks associated with barriers when: • the vehicle crashes against an inappropriate barrier (e.g. barrier not suited to site constraints, improper dimensions, poor positioning or untreated terminations) • the vehicle crashes against improperly maintained road safety barriers • vehicles can move behind the road safety barrier • the distance between the barrier and the hazard is less than the working width of the barrier when impacted, allowing the vehicle to deform the barrier and contact the hazardous features • the height of the barrier is too low • the length of need is not adequate • the barrier is too short • the length of anchorage is too short • there is a short gap between two barriers • they are too high and limit sight distance • a gating end treatment is installed without a hazard-free run-out area • the barrier effectiveness is reduced due to terrain effects, kerbing, drains etc. • penetration of a lower test level barrier occurs when it is impacted by a vehicle that is larger than the test vehicle.

Hazard	Comment
	Motorcyclists are likely to be injured when hitting road safety barriers and barrier delineators.
	Road safety barrier terminals can be dangerous when: • the termination of the barrier is not properly anchored • the distance between the obstruction and the barrier terminal is too short • the transition between deformable and rigid barriers causes high deceleration • they do not meet performance class requirements.

2.2 Central Safety Barrier Systems

There are three main types of safety barriers adopted for median application. These include:

- Rigid (cast in-situ concrete – Type-F and single slope)
- Semi-rigid (precast concrete, beam guardrail)
- Flexible (wire rope)

The common barrier types are shown in Figure 2. Each type of barrier system is discussed in section 2.2.1.

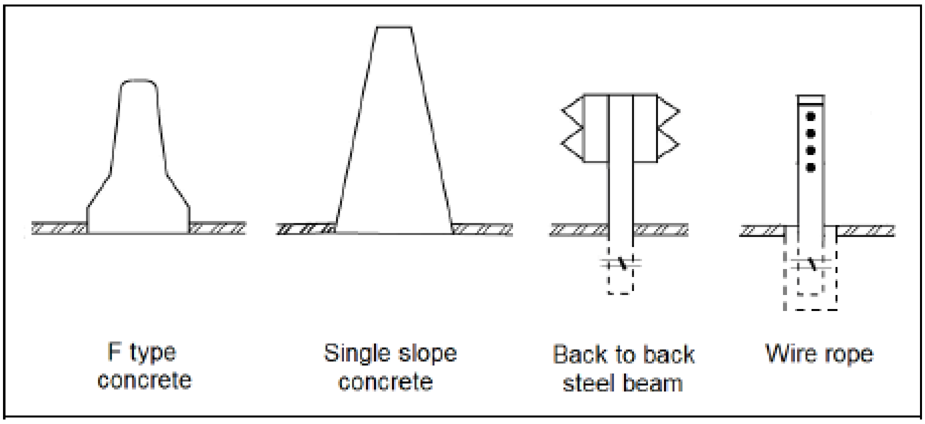

Figure 2 - Road safety barrier systems typically used in narrow medians reproduced from Austroads 2009

The typical properties safety barriers are measured by:

- Severity index
- Dynamic deflection
- Containment
- Physical measurements
- Cost
    - Principal
    - Ongoing

Barrier properties are discussed in section 2.2.2

The main issues associated with central barriers in narrow medians include:

- Fixed hazard in close proximity to travelling vehicles (section 2.1.4)
- Sight distance
- Shy line
- Drainage
- Maintenance access
- Emergency access
- Encroachment
- Rollover
- Motorbikes

The common issues related to central safety barriers in service are discussed in section 2.2.2.

The objective of safety barrier systems is to reduce risk, likelihood and severity, of incident. All safety barriers should have a severity index less than the hazard the barrier is shielding. Austroads (2006) state:

"A barrier should only be installed when the consequence of vehicle impact with the barrier are likely to be less severe than the consequences of impact with the feature being shielded."

The use of central safety barriers has been common for many decades. Median barriers are used to protect vehicle occupants from potentially severe collisions associated with crossing the centreline as described in section 2.1.2. Barrier performance in controlled conditions is frequently tested and well documented.

Assessment of central safety barrier performance in field conditions is not commonplace within the NSW roads authority – or from other Australian road and transport authorities. This lack of in-service evaluations of performance is documented in the NCHRP synthesis report 244 (1997) as also being uncommon amongst the US Departments of Transport. A number of studies have suggested that formal in-service evaluations be performed routinely in order to check laboratory testing compared to performance in the less controlled, real world conditions. These suggestions further validate this study. Assessing real world conditions provides realistic results and conclusions which are of real relevance to road engineering practitioners.

It is important to note that the provision of adequate nearside shoulders should supplement the installation of a central safety barrier in a narrow median. The provision of sufficiently wide nearside shoulders permit recovery of errant vehicles, manoeuvres around object hazards on the road, emergency break down or access, and width to allow traffic diversion during maintenance, repair or recovery. Other supplementary treatments should include adequate superelevation on curves, clear pavement markings, audio-tactile edge lines and road markers (Austroads, 2006).

2.2.1 Central safety barrier types

There is a vast range of proprietary safety barrier products available within each safety barrier group. All barriers should be approved by the relevant national or state road authority and tested in accordance with AS/NZS 3845 – 1999.

Concrete Safety Barrier

Concrete is available in two construction types: cast in-situ and pre-cast.

Cast in-situ

Cast in-situ concrete barriers are slip or hand formed on site. They are usually Type-F or single slope profile. The barrier is anchored into the pavement making it completely rigid. For this reason, the system has exemplary containment but this also leads to a higher severity index. Because of the negligible deflection, it is used where space is limited. is used where space is limited. Cast in-situ concrete installation is suitable for a horizontal radius of 15m or greater. This limitation is dictated by the slip forming construction process (Walsh, SP 2014, pers. comm., 28 October).

Pre-cast

The system can have various profiles including a Type-F and Tric-Bloc. Each pre-cast segment linked together with bolt connections to form a chain system. Although made of concrete the system exhibits some deflection because of the spaced anchorages and is therefore classified as a semi-rigid system (Main Roads WA, 2008).

The Tric-Bloc profile is no longer approved by the RMS. There was evidence that the profile was associated with vehicle rollover, particularly for small passenger vehicles.

There is no current acceptance for the use of precast Type F barriers as permanent barriers. Project specific acceptance for the use of precast Type F barriers as a permanent installation is possible. The precast anchorage system is somewhat questionable for permanent use. There needs to be further investigation and testing into the use of pre-cast system for use as a permanent installation (Loadsman, M 2014, pers comm., 28 October).

The pre-cast system is used at worksites for worker protection or when consistent with existing or adjoining barriers.

Pre-cast concrete installation is suitable for a horizontal radius of approximately 30m or greater. This limitation is dictated by the unit segment lengths and linkages (Walsh, SP 2014, pers. comm., 28 October).

Pre-cast concrete barriers have the following characteristics:

- Quick installation
- Modest deflection (Main Roads WA, 2008)
- Lower severity indices than cast in-situ because it deflects (RTA, 1996)
- Road surface water can flow underneath the barrier through slots
- Good containment
- Can be temporarily removed for road works or opened to facilitate contraflow
- Segments can be replaced incrementally

Wire rope safety barrier (WRSB)

The system uses a number of anchored, longitudinally tensioned cables supported by frangible posts to redirect and absorb crash energy. The WRSB system is very popular because of its energy absorbing capacity and associated lower SI.

WRSB is frequently viewed as the “best” barrier with regard to safety. Much research and documentation of the performance of WRSB has been completed. Much of this research was conducted or in reference to the Swedish WRSB experience.

Often, WRSB is dubbed as the most cost effective installation. This is true for the principle cost but is not necessarily the case for ongoing costs. The system requires repair post even minor collision.

Interestingly the implementation of the WRSB systems across the Swedish network was conducted by parties who did not have to fund or manage maintenance (Troutbeck, R 2014, pers. comm., 29 October).

WRSB installation is suitable for a horizontal radius of approximately 200m or greater. The system also has limitations on vertical curve, mostly notably in sag. These limitations are dictated by operational requirements during collisions (Walsh, SP 2014, pers. comm., 28 October).

Beam Guardrail

Guardrail is a proprietary product which consists of horizontal steel beams attached to steel posts which are driven into the ground. The steel rails typically come in two profiles: w-beam and thrie-beam as shown in Figure 3. Thrie-beam is more rigid than w-beam and is used in situations which require higher containment. W-beam has been used extensively on the NSW road network, particularly as a nearside barrier. Guardrail is not commonly used in narrow median applications on rural roads.

Beam guardrail installation is suitable for a horizontal radius of 2.5m or greater. This limitation is dictated by the physical properties of the rail (Walsh, SP 2014, pers. comm., 28 October).

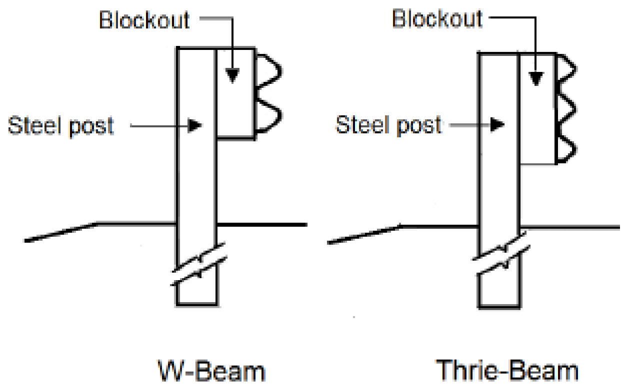

Figure 3 – Guardrail profiles (Austroads, 2009)

2.2.2 Central safety barrier properties

Severity index

The consequences of a crash are described by severity index. Severity indices assist in evaluating suitable treatments objectively. The Austroads Guide to Road Design, section 6 (2009) is provided for use to Australian road engineers and practitioners. Austroads acknowledges the source of the severity index tables are AASHTO (1996). Austroads state:

> *"The severity indices are based on average crash costs when a vehicle impacts the hazard."*

In NSW, the severity indices presented in Austroads (2009) section 6 has been supplemented by severity indices from RTA Road Design Guide (1996).

The severity index values for common central safety barrier treatment types from both sources have been reproduced in Table 4.

Table 4 – Severity indices for various safety barrier treatments

	Severity Index (100km/h)	
Roadside Feature	**AASHTO (1996) – adapted in Austroads - Section 6 (2009)**	**RTA Road Design Guide – section 6 (1996)**
WRSB	2.7	2.5
Beam Guardrail	2.7	3.0
Concrete Safety Barrier	2.7	3.5

Neither table supplied severity index evaluated for other vehicles as a hazard, even though in both the Austroads (2009) and RTA Road Design Guide (1996) collision with other vehicles was recognised as a major hazard. In order to objectively quantify risk, the author believes severity index should be indicated for particular crash types. For example head-on, side swipe and rear-end crashes should be quantified for a range of speeds. It is expected that the severity index values for head-on collision would be significantly higher than the severity index values for safety barriers. Having a quantified index severity value across a range of speed zones would set the baseline and aid in justification of safety barrier treatment.

Troutbeck completed a study in 2009 which tested all safety barrier systems (rigid Type-F, w-beam and WRSB) with light, average and large (4WD) passenger vehicles and an 8 tonne truck. He found that even with the varying SI of each barrier system, they all performed to a satisfactory degree and were useful in different situations. He noted that designing for the level of containment and height appropriate for the site conditions was important and they should be as flexible as can be accommodated. This view is somewhat contrary to the view that WRSB is the safest system available.

Dynamic Deflection

It is preferable that deflection is located within the median to reduce risk to other road users. However, in constrained road environments this may not be possible and encroachment may be permitted.

Table 5 – Safety barrier design deflection comparison (Nilsson& Prior, 2004)

	Dynamic Deflection (m) for straight line of Barrier			
Safety barrier system	**80km/h**	**90km/h**	**100km/h**	**110km/h**
WRSB	1.2	1.3	1.4	1.5
Steel guardrail	1.2	1.3	1.4	1.6
Concrete barrier	0	0	0	0

Median Width and Barrier Location

A narrow median is loosely defined as being between 1m and 4.5m wide.

Typically, the minimum median width is required to accommodate:

- Hardware geometry (footprint [system or terminal], and height [for sight])
- Dynamic deflection – lateral movement of barrier system during collision, as well as permanent deflection
- Sight distance – when on curves
- Stormwater capacity and drainage hardware
- Consideration of the shy line effect
- Consideration of impact angle

The typical widths of the median components derived from Austroads (2009) have been summarised in Table 6. Sight distance provision is discussed in detail in section 2.3.2.

Table 6 – Minimum median width components (Austroads, 2009)

Barrier Type	Hardware footprint (mm)	Dynamic Deflection at 100km/h (m)	Height (mm) (RTA, 1996)	Sight (Nilsson & Prior, 2004)	Shy Line at 100km/h (m) (AASHTO, 2006)
WRSB	120 400 (where anchors are provided	1.4	680-825	May restrict sight	2.4
Steel Beam Guardrail	625	1.4	710 - 885	Moderate	2.4
Concrete Barrier	600	0	800-820+	Most significant	2.4

The shy line effect is often viewed to have a speed reducing effect. This assumption has been questioned by research completed by Tay and Churchill (2007) which showed that the mean speed on sections with central safety barriers increased post construction when compared to similar roads without median barriers.

As the distance from the travel lane to the central safety barrier increases, the greater the recovery potential and lesser likelihood of collision. But those accidents which do occur will generally be at a higher impact angle resulting in higher severity, particularly with concrete barriers.

Contrarily, the closer the central safety barrier, the lesser the recovery potential and greater the likelihood of collision. Impact angle will usually be lower and likely result in a less severe impact (Austroads, 2009). In addition, the closer the central barrier the greater the impact on sight distance, particularly for concrete safety barriers. Austroads (2009) states that concrete barriers should be placed 1 to 3m from the edge of the travel lane and no further than 4m.

There is no mention of impact angle when a multilane carriageway is present. Although a concrete barrier may be located less than 4m from the offside edge line, an errant vehicle from the nearside lane could make a higher impact angle with the safety barrier.

Cyclists

As vulnerable road users, motorcyclists (particularly on high speed rural roads) and cyclists (more common in urban environments) need to be considered when installing any barrier.

> *"Motorcycling fatality rates are estimated at almost 30 times that of other modes per kilometre travelled… Motorcycles are especially vulnerable to collisions on bends and curves" (Anderson et al, 2012)*

There has been widespread unacceptance of WRSB within the motorcyclist community. The WRSB system has been referred to as "widow maker" and "cheese grater", representing the viewed effect the wire rope may have on an errant motorcyclist.

Wire rope and w-beam posts can snag riders making them particularly threatening to errant motorcyclists. Although the concrete barrier system offers a more uniform, smooth profile, its high SI is still not forgiving for motorcyclists.

Guardrail systems can be improved with the retrofit of a rub-rail or flexible mesh motorcycle protection systems shown in Figure 4. These systems protect an errant rider from the metal posts. The protection systems are gaining popularity within NSW and interstate.

Figure 4 – W-beam retrofitted with rubrail and flexible mesh (Anderson et al, 2012)

Maintenance

Due to its higher SI, it is uncommon for concrete safety barriers to require extensive maintenance post collision, in contrast to flexible barrier systems which have a loss of functionality and require repair post collision. In the Swedish experience, it has been documented that maintenance is a source of major concern (Larsson et al, 2010). In the same paper, it was documented that one serious incident involving collision of a passenger car colliding with a road lane closure device at high speed had occurred. Also mentioned was another area of concern being emergency blockages and emergency vehicle operation.

Concrete barriers are often viewed as maintenance free and are the preferred system of Asset Managers for this reason.

As mentioned in section 2.1, collisions with the barrier are to be expected. If the barrier treatment requires maintenance to restore functionality, maintenance crews will be required to attend sites frequently. The ongoing maintenance will put maintenance crews at high exposure to live traffic.

WRSB can be damaged even with a moderate impact. This damage may allow barrier penetration for errant vehicles. WRSB systems require maintenance after every collision and periodic inspection (Kentucky Transportation Cabinet, 2008). Although high tension cables may return to the original height post collision, no manufacturer will claim that the product remains functional (AASHTO, 2011).

The minimal maintenance and functionality post collision make concrete barriers an attractive alternative to WRSB and guardrail.

Costs

Nilsson & Prior compared safety barriers in order to justify which treatment to apply at the Pacific Highway sites they were investigating. Table 7 is a reproduction of the table presented in their paper.

Table 7 – Safety barrier comparison (Nilsson & Prior, 2004)

Safety barrier system	**Impact severity index at 100km/h**	**Accident costs over 30 year period (100km/h impact)**
WRSB	2.5	$89,500
Steel guardrail	3.0	$174,000
Concrete barrier	3.5	$243,3000

> *"The generic costs per accident include human and incident costs. Human costs include medical and care expenses, insurance claims, quality of life support and earnings related costs. Incident costs include vehicle repair, insurance administration, investigation, legal and alternative transport costs. "(Nilsson & Prior, 2004)*

What is not included is the cost of repair of the safety barrier system and ongoing maintenance costs. Nilsson and Prior (2004) based the decision not to provide these costs into the comparison as they expected installation and maintenance costs would be similar and the relativity of costs would vary with project size, location, availability of materials and life cycle costs.

Installation costs of the barrier alone were documented in a study completed by Agent and Pigman in 2008. The costs were derived from Washington State Department of Transportation. Given the costs presented were in American Dollars per foot and were quoted at a different time to the Nilsson and Prior costs, the cost comparison has been presented in Figure 5 ranked from lowest to highest.

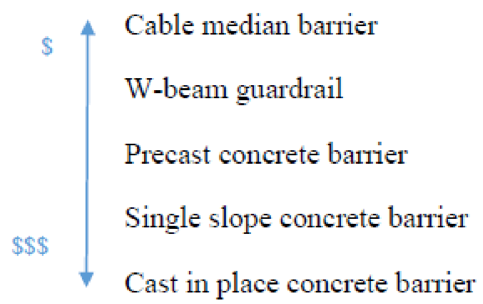

Figure 5 – Comparison of installation costs of barrier alone

Drainage

Drainage of road surface water is a very important consideration when designing a road. Aquaplaning occurs when a thin film of water, usually around 4mm thick, causes the vehicle's tyres to be separated (partially or fully) from the road surface. This results in loss of control of the vehicle (Austroads, 2013).

WRSB and guardrail systems have little impact on surface water drainage as the post separation provides adequate width for the water to flow from the road geometry. Contrarily, cast in-situ concrete barrier has a major impact on the flow of surface water because it is cast directly onto the road surface. Cast in-situ barrier is usually supplemented by longitudinal drainage for relief of surface water. Pre-cast barriers have a lesser effect on surface water as it has long open slots cast into the sections.

2.2.3 Concrete barrier delineation enhancement trial

CCSB curve markings have been trialled on the Great Western Highway since 2012. The curve markings consist of painted curve alignment markings on the inside of the bend. High resolution, reflective beads are incorporated into the markings which capture the light and better delineate the curve, particularly at night.

The bottom of Mount Victoria pass was first equipped with white markings. Two curves on the River Lett Hill project were delineated with yellow markings. The intention was to determine which colour markings is the most effective.

There has been no formal release on the success of the treatment, although a number of additional CCSBs on the Great Western highway and Bells Line of Road have been equipped with yellow markings since the initial trial.

2.2.4 Alternatives

Rumble Strips

The provision of rumble strips on the nearside and/or offside edge line has been researched extensively. There is merit in applying rumble strips to divided and undivided roads. The treatment can be an alternative or an enhancement to central safety barrier installation.

Rumble strips are often used on high order roads such as motorways and freeways to alert inattentive, drowsy or speeding motorists that their vehicle has drifted outside of the lane (Torbic et al, 2009). They have been used for many years on edge lines and are now more commonly being used on barrier lines (Bahar et al., 2001). Torbic et al. (2009) also mention rumble strips are being applied on divided rural highways in the USA.

Rumble strips warn drivers in the form of noise and vibration which is detected by the driver. In Räsänen’s (2005) study on the effect of rumble strip barrier lines on lane-keeping in a curve, he documented that although the rumble strips do not completely prevent collision, the consequences may be alleviated if the driver steers to avoid or brakes to avoid collision.

In 2003, Persuad et al. completed a before-and-after study of centreline rumble strips on treated, two-way, undivided, rural highway in the USA. They found that there was a 9 percent reduction of total crashes and 12 percent reduction of fatality and injury crashes post installation.

In 2007, Patel et al. completed a before-and-after study of shoulder rumble strips on two-lane, rural highway in Minnesota. The study covered 23 treatment sites which accounted for 183 miles (294.5 km) of roadway. The combination of the work completed by Patel et al. and Torbic et al. reported a 15 percent reduction in all single vehicle run off road accidents (SVROR) and a 29 percent reduction in SVROR causing injury and fatality.

The installation of rumble strips has been documented as a cost effective solution particularly when compared to barrier installation. It must be noted that rumble strip installation is only suitable for asphalt pavement and not spray seal. The installation of rumble strips is also limited by the site’s proximity to residences due to the noise generated. In an RMS road safety technical direction, rumble strips were ruled unsuitable within a 200m radius of residents. Rumble strips have also been documented as a potential hazard to motorcyclists and can cause surface drainage issues. (RTA, 2009)

The Minnesota Department of Transportation Technical Memorandum, developed by Arseneau (2011) states shoulder rumble strips may be placed at a posted speed of 55 mph (88.51 km/h) and where the paved shoulder is 4 feet (1.22m) or greater. Arseneau (2011) also expresses:

> *“Even in cases where shoulder rumble strips are not required due to a narrow paved shoulder width, their installation – or the installation of an edge line rumble strip – is encouraged for proactive safety reasons.”*

From the literature reviewed, rumble strips appear to be an effective enhancement to most road safety treatments targeting run-off road and cross-centreline crashes.

Wide Centreline Treatment

Wide centreline treatments have been tested at a variety of locations including Western NSW, South Australia, Queensland and New Zealand. The treatments tended to be tested as a result of findings from an American study on wide centreline performance, completed by the Federal Highway Administration (FHWA) in 2003. The study indicated that the wide centreline with rumble strips can be expected to reduce all crashes by 15% and crossover crashes by 55%.

Wide centreline treatments are essentially the same as usual centreline delineation markings with the exception of being separated by around 0.8 metre – 1.0 metre. The delineation is paired with rumble strip markings. The treatment can either prohibit overtaking like double-barrier line or allow the manoeuvre as depicted in Figure 6.

The intent of a wide centreline is to provide recoverable area in the centre of the roadway (Levett, 2009). The rumble strips target fatigued or distracted drivers. Wide centreline treatments are suitable for long stretches of road which do not have extensive auxiliary overtaking opportunity.

Of sites reviewed, the treatment was typically applied to long stretches of rural highways. These highways usually consisted of long straights and large radius curves in flat terrain. There does not appear to be research completed on the use of wide centreline treatments in curvilinear alignments or in undulating terrain.

Figure 6 – Line marking scheme for wide centreline (NSW Centre for Road Safety, 2011)

2.3 Sight Distance

2.3.1 The Normal Sight Distance Model

Sight distance (SD) is defined as the distance a driver can see ahead along the road to identify and react to a hazardous situation.

"The concept of sight distance provides a calculable parameter that can be related to the geometry of the road. This concept is based on a number of somewhat stylised assumptions of particular hazards and corresponding driver behaviour. The hazard is assumed to be an object, of sufficient size to cause a driver to take evasive action, intruding the driver's field of view." (Austraods, 2010)

Stopping Sight Distance

There are a number of sight distance models presented in Austroads (2010). The sight distance applicable to a mid-block, divided carriageway is referred to as Stopping Sight Distance (SSD). Austroads (2010) states:

"SSD is the distance to enable a normally alert driver, travelling at the design speed on wet pavement, to perceive, react and break to a stop before reaching a hazard on the road ahead."

"The distance is considered to be the minimum sight distance that should be available to a driver at all times."

Equation 1 for SSD is derived from the following components:

- The distance travelled during hazard perception
- The distance travelled whilst braking from the design speed to a stop

This is graphically represented in Figure 7.

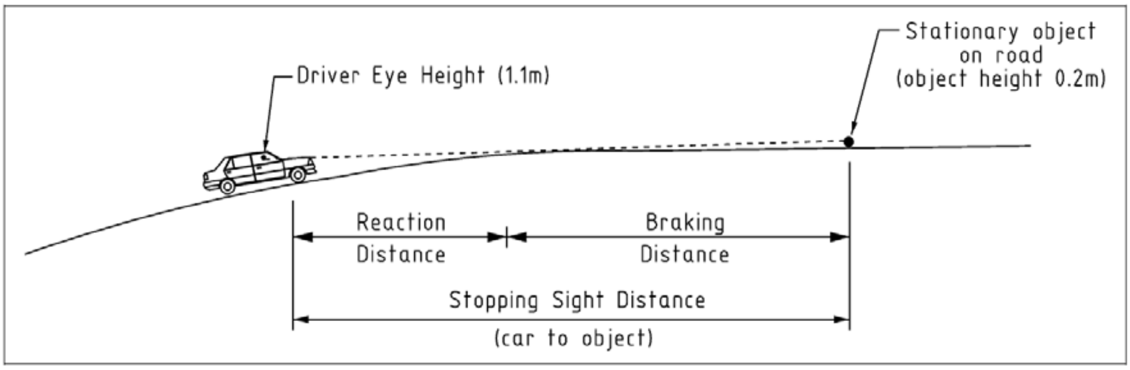

Figure 7 – SSD model (Austroads, 2006)

Car SSD is measured from driver eye height (1.1m) to object height (0.2m), as per Table 8, usually offset vertically from the middle of the lane.

Table 8 – Vertical height parameters (Austroads, 2010)

Vertical height parameter	Height (m)	Typical application
Height of eye of driver h_1		
1. Passenger car	1.1	All car sight distance models.
2. Truck	2.4	All truck sight distance models where a truck is travelling in daylight hours and at night-time where the road is lit.
3. Bus	1.8	Specific case for bus only facilities, e.g. busways.
Headlight height h_1		
1. Passenger car	0.65	1. Headlight stopping sight distance in sags. 2. Check case for night time stopping for cars (no road lighting).
2. Commercial vehicle	1.05	Check case for night time stopping for trucks (no road lighting).
Object cut-off height h_2		
1. Road surface	0.0	1. Approach sight distance at intersections. 2. Approach sight distance to taper at end of auxiliary lane. 3. Headlight sight distance in sags. 4. Horizontal curve perception distance. 5. Water surface at floodways.
2. Stationary object on road	0.2	Normal stopping sight distance for cars and trucks to hazard on roadway.
3. Front turn indicator	0.35	Minimum gap sight distance at intersections.

Vertical height parameter	Height (m)	Typical application
4. Car tail light/stop light/turn indicator	0.8	1. Car stopping sight distance to hazards over roadside safety barriers in constrained locations. (2) 2. Truck stopping sight distance to hazards over roadside safety barriers in constrained locations. 3. Stopping sight distance where there are overhead obstructions.
5. Top of car	1.25	1. Car stopping sight distance to hazards over roadside safety barriers on a horizontally curved bridge with road lighting. (2) 2. Truck stopping sight distance to hazards over roadside safety barriers in extremely constrained locations with road lighting. (2) 3. Intermediate sight distance. 4. Overtaking sight distance. 5. Safe intersection sight distance. 6. Mutual visibility at merges.

$$SSD = \frac{R_T V}{3.6} + \frac{V^2}{254(d + 0.01a)}$$

Equation 1

Where:

R_T = reaction time (sec)

V = operating speed (km/h)

d = coefficient of deceleration (longitudinal friction factor)

a = longitudinal grade (%, + for upgrades and – for downgrades)

The distance calculated is then checked in the design model (including vertical, horizontal, superelevation, safety barriers, batters etc.) for each direction from driver eye height to object height.

Reaction Time

Reaction time is the time taken for a driver to observe a hazard and take the necessary action. Austroads (2010) documents this time as being dependent on:

- Alertness of the driver
- Recognition of hazard
- Complexity of the decision or task

A study completed by Austroads (2002) recommended a reaction time of 2.5 seconds minimum and an absolute minimum of 2.0 for mid-block section. Reaction times from Austroads (2010) have been reproduced in Table 9. This 2.5 second recommendation is relevant to the ageing population and the expected reduction in reaction time. In a number of European countries, 2.0 seconds is the accepted value.

Table 9 – Reproduced driver reaction times (Austroads, 2010)

Reaction time, R_T (s)	**Typical road conditions**	**Typical use**
2.5	• Unalerted driving conditions due to the road only having isolated geometric features to maintain driver interest • Areas with high driver workload/complex decisions • High speed roads with long distances between towns	Absolute minimum value for high speed roads with unalerted driving conditions. General minimum value for: • high speed rural freeways • high speed rural intersections • isolated alignment features
2.0	• Higher speed urban areas • Few intersections • Alerted driving situations in rural areas • High speed roads in urban areas comprising numerous intersections or interchanges where the majority of driver trips are of relatively short length. • Tunnels with operating speed ≥ 90 km/h.	Absolute minimum value for the road conditions listed in this row. General minimum value for most road types, including those with alert driving conditions.

Reaction time, R_T (s)	Typical road conditions	Typical use
1.5	Alert driving conditions e.g.: • high expectancy of stopping due to traffic signals • consistently tight alignments for example, mountainous roads • restricted low speed urban areas • built-up areas – high traffic volumes • interchange ramps when sighting over or around barriers • tunnels with operating speed ≤ 90 km/h.	Absolute minimum value. Only used in very constrained situations where drivers will be alert. Can be considered only where the maximum operating speed is ≤ 90 km/h. Should not be used where other design minima have been used.

Notes: The driver reaction times are representative for cars at the 85th percentile speed and for heavy vehicles. The deceleration rates for heavy vehicles cover the inherent delay times in the air braking systems for these vehicles.

The above times typically afford an extra 0.5 s to 1.0 s reaction time to drivers who have to stop from the mean free speed. It is considered, for example, that the mean free speed is more representative of the speed travelled by older drivers.

Coefficient of Deceleration (Longitudinal Friction Factor)

The coefficient of deceleration is a measure of the longitudinal friction factor between the tyres and the road surface. The coefficient is dependent on:

- Speed of the vehicle
- Tyre condition and pressure
- Type of road surfacing, its condition and wetness

The values of the coefficient of deceleration have been reproduced in

Table 10. The typical value used for assessing a midblock, rural road is 0.36.

Table 10 – Coefficient of deceleration (Austroads, 2010)

Vehicle type	Coefficient of deceleration, (d)	Driver/road capability	Typical use
	0.61	Braking on dry, sealed roads.	Specific applications where the normal stopping sight distance criteria applied to horizontal curves produce excessive lateral offsets to roadside barriers/structures – refer Section 5.5 (used in conjunction with supplementary manoeuvre capability).
Cars	0.46	Mean value for braking on wet, sealed roads for a hazard. Maximum values when decelerating at an intersection.	Absolute maximum value for stopping sight distance. Only to be used in constrained locations, typically on: ▪ lower volume roads ▪ less important roads ▪ mountainous roads ▪ lower speed urban roads ▪ sighting over or around barriers ▪ tunnels.
	0.36	About a 90th percentile value for braking on wet, sealed roads. Maximum value allowed for deceleration lanes at intersections.	Desirable maximum value for stopping sight distance for most urban and rural road types, and level crossings.
	0.26	Comfortable deceleration on sealed roads. Normal driving event.	Desirable maximum value for stopping sight distance for major highways, freeways and for deceleration in turn lanes at intersections. Maximum value for horizontal curve perception sight distance.
	0.27	Braking on unsealed roads	Stopping sight distance on unsealed roads. This value is very dependent on the surface material and should be verified where possible.
Trucks	0.29	Braking by single unit trucks, semi-trailers and B-doubles on dry, sealed roads. Minimum value required by	Maximum value for truck stopping sight distance for most urban and rural road types, and level crossings.

Vehicle type	Coefficient of deceleration, (d)	Driver/road capability	Typical use
		vehicle standards regulations.	
Buses	0.15		Desirable braking to ensure passenger comfort approaching a bus stop.

2.3.2 Problems with the SSD model

SSD can be difficult to achieve even in a usual road environment when horizontal and vertical geometry is designed to standard.

The normal SSD model:

- Can result in very wide shoulders which can create other road safety issues
- May not replicate the likely reaction manoeuvre or physical ability of drivers
- Does not cater for night time driving
- Combines a number of conservative parameters

The equation for "centre of lane to centre of lane sight line clearance requirements from the edge line", (RMS, 2013) demonstrates the widening required to meet SSD adjacent barrier.

$$\boldsymbol{d = R - \left(R + {}^{l}/_{2}\right) \times \cos\left(0.5 \times \frac{SSD}{R + {}^{l}/_{2}}\right)}$$

Equation 2

Where:

R = horizontal radius (m)

d = horizontal offset from edge line to face of barrier (m)

l = lane width (m)

For example, a 100km/h design speed on a minimum horizontal radius, 500m curve, would require a shoulder width of 5.8m in front of a barrier.

A paper prepared by Arndt et al (2009) acknowledges this:

> *"Application of the normal stopping sight distance model around concrete safety barriers and structures often results in very wide shoulders being required."*

Arndt et al demonstrated this scenario in the real world, as per Figure 8. SD widening on Sydney Ring Road (M7) resulted in a shoulder width of 7.25m.

Arndt et al discussed the possible negative effects of the provision of very wide shoulders:

- Parked vehicles in the wide shoulder creating obstructions to adjacent travelling vehicles
- Exorbitant construction costs, particularly when on structure
- Additional resumptions which may not be socially or politically acceptable

Wide shoulders may give the impression of an overtaking or travel lane which may lead to crashes. The width may also give rise to more severe high entry angle crashes (Austroads, 2009).

Figure 8 – SD widening on the Sydney Ring Road (Arndt et al, 2009)

In contrast to the traditional SD model, a study by Cox (2002b) found that drivers were more likely to manoeuvre around an object on the road rather that coming to a complete stop before it. Cox (2003) summarised some views on SD based on discussion by Rahmann as follows:

> *"Rahmann proposed… that sight distance be based on the more likely event of vehicles manoeuvring around an obstruction rather than stopping for it."*

Austroads, 2010 suggests that another stopped vehicle to be the most common obstruction on a normal road. Sighting a vehicle could lift the object height up to 0.8m or 1.25m for car tail lights and top of car respectively. This height increase would make achieving SSD more achievable.

In an international study of SSD conducted in 1998, driver visual capabilities were discussed.

> *"The object probably will not be seen at distances greater than 130m even with sufficient sight distance. Using distances from the SSD formula, speeds greater than 90km/hr in daylight and 70km/h at night are beyond the visual capability of the driver."(Harwood et al, 1998)*

The SSD model is flawed by limitations at night time. The driver's sight is limited by the range of the vehicles headlights. This criterion is seemingly disregarded within the road design community. Austroads (2010) mentions the following in regard to SSD at night:

> *"The limitations of headlights on high beam of modern vehicles restrict the sight distance that can be safely assumed for visibility of an object on the roadway, to about 120 – 150 m. This corresponds to a satisfactory stopping distance for 80 km/h to 90 km/h, and a manoeuvre time of about 5 seconds at 100 km/h."*

In the majority of cases, stopping sight distance is not achievable within practical limits. This begs the question, why do road designers hold the SSD model so highly when it is based on a number of conservatives and is only relevant for part of the day?

The traditional stopping sight distance model combines a number of 85^{th} percentiles which have been recognised as a very conservative approach. Stopping sight distance is only relevant for a vehicle coming to a complete stop before hitting an object on the roadway. The probability of hazards occurring at locations where, in addition, sight distance is substandard may not be very high. As presented by Cox (2003), the probability of the occurrence is further exacerbated when combined with characteristics which are said to make up the model including:

- A short to average height driver
- A low height vehicle
- Slightly below average braking control capability
- Worn tyres
- Wet road condition
- A degree of road surface polishing
- Travelling the 85^{th} percentile speed, which can be about 10km/h above the posted speed

- Reduced reaction time (lethargic, ageing population)

The event of an older driver, in a low-slung sports car, with worn tyres, on a wet and polished road surface being faced with a hazard does not appear to represent an 85th percentile.

With the combination of all these rare cases, the stopping sight distance model ends up catering for an occurrence which is extremely unlikely (Cox, 2003). This combination no longer represents an 85th percentile.

Arndt et al (2009) and Austroads (2010) provide a reasonable alternative that is in keeping with the findings of Cox, which suggest a higher object height, (brake light height) and sufficient shoulder width and perception time as presented in section 2.3.5.

2.3.3 Sight distance and road safety

In 2003, Cox stated there was no objective data which demonstrated that the road was unsafe when sight distance was less than provided by the road design standards. This was supported by Arndt et al (2009). Arndt et al acknowledged that numerous studies aiming to link stopping sight distance and accident rates for midblock sections of roadway had been conducted. Arndt et al (2009) summarised these studies which have been reproduced in Table 11.

Table 11 – Results of studies linking stopping sight distance to accident rates for midblock section of roadway from Arndt et al (2009)

Study	Result	Effect on Accident Rates by Decreasing SD
Choueiri et al (1994)	Suggests that accident rates are higher with low sight distances but change little when the sight distance exceeds 150m to 200m.	Increase
Olson et al (1984)	The accident rate on low sight distance crests (36 – 94m long) was 50% greater than on high sight distance crests (over 215m long) for operating speeds between 90 and 100km/h.	Increase
Fambro et al (1997)	Small increase in accident frequency with decreasing sight distance below 100m and negligible change with increasing sight distance above 100m.	Increase

Study	Result	Effect on Accident Rates by Decreasing SD
Iyinam et al (2003)	A 50% increase in accident rate for sight distance decreasing from 500m to 100m.	Increase
Elvik and Vaa (2004)	Cited two studies (Danish and British). Both suggested that increasing sight distance from less than 200m to more than 200m leads to a 23% higher accident rate	Decrease (2 studies)

From Table 11 it can be seen there is no conclusive evidence to suggest a link between sight distance and crash rates. Arndt et al (2009) comment,

> *"All that can be deducted … is that the number of studies indicating that a reduction in sight distance will increase accident rates is double the number indicating that a reduction in sight distance will reduce accident rates."*

Arndt et al (2009) also acknowledges that studies on sight distance may be more conclusive on freeways and interchanges, which was the premise of their paper. The reasoning for this is a higher likelihood of exposure to stopped vehicles and fallen objects, for example.

2.3.4 Central safety barrier impacts on sight distance

Central safety barrier has an impact on the sight distance on right hand curves.

A study conducted by Richl and Sayed (2005) presented a figure which illustrated the medians used in British Columbia. This illustration is reproduced in Figure 9. In the 'modified narrow median barrier' and 'barrier in narrow median to maximise sight distance', the median width is varied depending on the direction of curve. The widest part of the shoulder is on the outside of the barrier where sight distance will be obstructed the most. This layout seems logical for the reduction in sight distance, but there is a trade-off of recovery area at the outside of the curve travel path, where centrifugal force is acting. It is more likely for a vehicle to become errant on the curve toward the outside. The likelihood of the scenario the sight distance model is suitable for is seemingly much less likely, as mentioned in section 2.3.3. Therefore, the recovery width within the median is sacrificed where it is required most. This point is reinforced in Austroads (2009) section 6, which discusses the increase of clear zone on the outside of the curve with a curve correction factor. The factor can increase the clear zone by up to 50%.

Sufficient superelevation could counteract the lateral displacement of the vehicle on the curve. Although, it is likely that horizontal curves requiring median treatment would have substandard radii for the speed environment. As such, suitable superelevation for the horizontal radii and speed may exceed the maximum practicable. This offset layout was not observed in other literature reviewed outside of Canada.

Usually, when assessing visual impacts of safety barrier types, WRSB is regarded as having the least impact and there was little mention of SSD impacts within the literature reviewed. However, in version two of the Nilsson and Prior paper (2004b), it is acknowledged that sight is hindered with WRSB when located on tight curves, where:

> *“…the WRSB may appear just as dense and no-see through as other types of safety barrier.”*

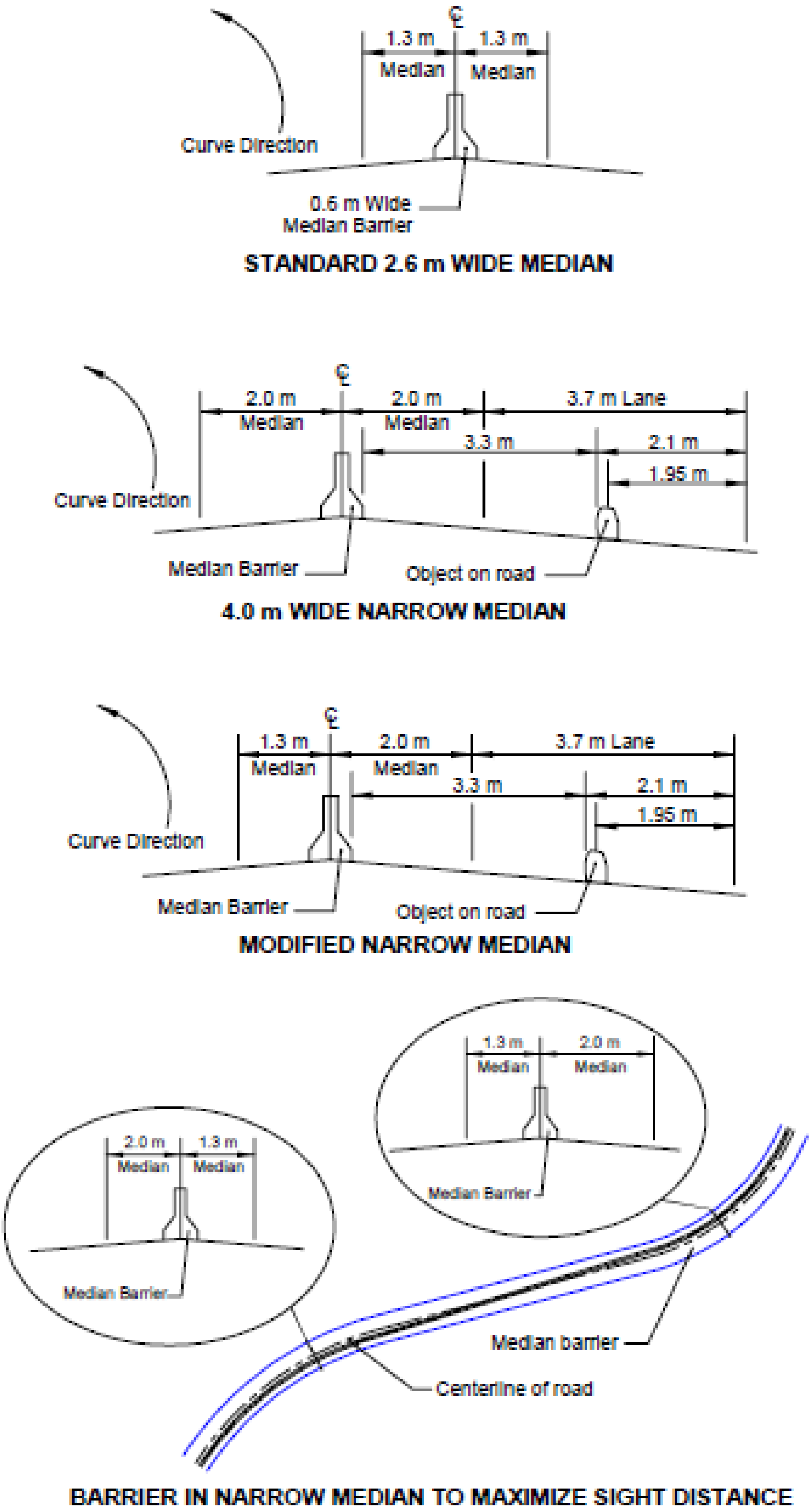

Figure 9 – Medians used in British Columbia (Richl & Sayed, 2005)

2.3.5 Alternatives to the SSD model

SD over Barriers (Austroads)

Austroads (2010) was the first Australia-wide guideline to give rise to a separate model for sight distance over barriers:

> *"In cases of sighting over roadside barrier in constrained cases, it may not always be practical to provide car stopping sight distance to a 0.2m high object."*

Instead, minimum nearside shoulder widths (2.5m) and minimum manoeuvre times applied where object heights greater than 0.2m are used. In this case, the perception time and a manoeuvre time of 2.5 sec is the distance required when analysing the design. An object height of 0.8m (tail brake light) has been the accepted parameter. The minimum shoulder widths and manoeuvre times for sight distance over barriers are reproduced from Austroads part 3 (2010) in Table 12.

This model assumes the shoulder is clear from obstruction.

> *"Additional manoeuvre time is required where drivers have to undertake evasive action on the inside of a tight horizontal curve." (Austroads, 2010)*

Table 12 – Minimum shoulder widths and manoeuvre times for sight distance over roadside safety barriers on horizontal curves (Austroads, 2010).

Case	Object height adopted for stopping capability 'h2'(m)	Minimum shoulder width on inside of horizontal curve for manoeuvring (m)(1)	Minimum manoeuvre time at the 85th percentile vehicle speed (s)(2)
Car stopping sight distance	$0.2 < h2 \leq 1.25$	2.5	Reaction time plus 2.5 s to a 0.2 m high object.
Truck stopping sight distance	$0.8 < h2 \leq 1.25$	3.5	Reaction time plus 3.0 s to a 0.8 m high object

1. The minimum shoulder width enables vehicles to manoeuvre around objects lower than the chosen object height. The minimum shoulder width must be the greatest dimension that satisfies both the car and truck stopping sight distance cases given in this table. It is preferred that the shoulder is fully sealed.

2. The minimum manoeuvre time provides drivers with sufficient time to react and take evasive action.

Note: Where a sight line passes over a median barrier, the line of sight should not be interrupted by vehicles in the on-coming carriageway. Typically, this means that the line of sight should not intrude more than 0.5 m into the closest on-coming traffic lane.

The sight distance over barriers model was first documented in the 2010 Austroads Guide to Geometric Road Design. This model provides for a realistic sight model in constrained road environments.

This model is in keeping with the findings of research completed by Arndt et al in 2009 which suggested that sight distance based on less conservative but justifiable criteria was more practical but still defendable.

3 METHODOLOGY

The major objective of the analysis was to observe the performance of CCSB in constrained road environment and consequently test the relationship between restricted sight distance and crashes. It was intended this knowledge would inform road engineers and practitioners so that effective treatments can be applied at sites of cross centreline related crashes in a timely and cost effective manner.

Deliverables include:

- Literature review
- Central barrier comparison table
- In service assessment of central barrier treatments
- Assessment of the impact of reduced SSD and altered surface drainage
- Application of research to a concept design (if time permits)

3.1 Literature Review

As part of this study, literature was reviewed from national and international sources to aid in the understanding of:

- The responsibility of road engineers and practitioners to road users
- Crash types associated with undivided carriageways in high speed environments
- The different types of safety barrier systems available and safety barrier alternatives.
- Performance and application of central safety barriers in a narrow median
- Additional considerations for safety barrier types
- Traditional sight distance model and alternatives

The review was completed to objectively compare different treatments. This was done to draw parallels and acknowledge the differences between the available systems. A better correlation between wire rope safety barriers (WRSB), where extensive research has been completed, and the other systems was desired also.

The review intended to evaluate and discuss the varied factors which set each system apart from the other. The comparison was relevant as there was extensive research into WRSB in particular, being the predominant source of the post construction evaluation. It was important to understand the context of WRSB system in regard to guardrail and concrete barrier if conclusions were to be objectively drawn.

3.2 Safety Barrier Comparison

A table collating and comparing the characteristics of each central safety barrier type was prepared as part of the literature review. It was found that there was no source which provided a quick reference to compare the available barrier types. Table 14 was presented to summarise all of the safety barrier performance and characteristics in the reviewed literature. Table 14 may also be of aid to road engineers and practitioners when evaluating the suitability of central safety barrier treatments or reviewing existing systems.

3.3 In-Service Assessment of Central Safety Barriers

It was observed there had been limited research into the post construction performance of central concrete safety barriers in NSW and thus the impact on crashes and the reduced sight distance associated had not been quantified. As there are a number of sites which had been constructed in the last decade it was believed there was enough data to conduct a before and after analysis.

3.3.1 Site Selection

The post construction performance of central safety barrier was investigated by assessing the before and after crash data. The prerequisites of the sites included:

- Within NSW to allow for CrashLink analysis and for access to project documentation
- Mid-block rural road
- Installation of concrete central barrier roughly between 2000 and 2011. This allowed for a couple of years of crash data to be analysed with the program

bandwidth. CrashLink data was available from 1 June 1996 and the crash data was 99% finalised until 31 March 2014 (as of 22 August 2014)

- Availability of project documents and design and/or as constructed model
- Within socially and/or environmentally constrained environment
- Substandard horizontal curve radius for posted speed zone
- Within a practical distance to travel by car for inspection

The CrashLink database is operated by the NSW Centre for Road Safety (Under the Transport NSW umbrella) and involves the NSW Police Force and Spinal Cord Industries Australia.

3.3.2 Site Visit

The site visit was carried out to observe the sites, take images and video footage and locate any points of interest. It was also important to view the context of the site and its adjoining road link, rather than focus on the site at the micro level.

The site visit included:

- Desktop assessment – determine any potential safety hazards, locate parking locations
- Safe work method statement (SWMS)
- Day and night visit - observe behaviours under different lighting conditions
- Taking photos
- Site drive-through using GoPro

The site visit was carried out before any crash analysis so that the visit was objective. This is common in Road Safety Audit practice. The SWMS and desktop assessment are included to meet the WHS requirements improving awareness of the sites and their conditions.

In the author’s experience with Road Safety Auditing, the use of GoPro drive through videos and still images had been very useful. The use of a GoPro attached to the vehicle also limits the exposure of the site attendees, as they will mostly be inside the car.

The GoPro was attached to the car in the middle of the bonnet approximately 1.1m above the road surface. This was done to mimic the sight distance model used in NSW Australia as described in section 2.3.1.

Observations were focussed on identifying any damage to barriers (nearside and offside), possible object/s which could enter roadway, skid marks, tyre tracking, road surface polishing, evidence of water ponding etc. This was done to enhance the crash data analysis where nuisance hits and near misses would not have been recorded into the system. The observations are shown graphically in section 5.2.1.Barrier damage was plotted on aerial imagery. This information was not incorporated into crash data but used to accompany the data analysis.

Further to the site visit, local Maintenance Engineers governing the sites were contacted to gather repair and maintenance data. This data was intended to add to the recorded crash data and potentially note low severity crashes where police did not attend. Unfortunately only maintenance information for three of the nine sites was provided.

3.3.3 Project Data Review

The project data document (design report, Road Safety Audits etc.) provided background and justification for the installation of concrete barrier. The data was collated in Table 16 (Appendix B: Site data table).

The project data also provided useful data to the post installation analysis.

Data gathered included:

- Construction dates
- Geometric data
- Constraints
- Design inclusions
- MX model data
- Project costs

The construction date was used to obtain three time frames used in the analysis:

- Post-construction test range– duration between construction completion until March 2014 (most current CrashLink data availability as shown in Table 13)

- Pre-construction test range – same duration as the post construction, taken back from the start of construction date
- Extended pre-construction – time range between July 1996 (beginning of CrashLink record) and the initiation of construction used to understand the need for the barrier treatment.

Table 13 – Reproduced dataset completeness for CrashLink as of 22 Aug 2014

Year	Q1	Q2	Q3	Q4
2014	99	81	7	0
2013	100	100	100	99

Data analysed was inclusive of quarter 4 of 2013 and quarter 1 of 2014 even though the crash data was only 99% finalised. This was not seen as a significant risk as the finalisation is usually only relevant to very serious incidents. Fortunately, to the author's knowledge there have not been any particularly serious incidents at the study sites in this time. As such there is low risk that the remaining 1% of crashes yet to be finalised are relevant to this study.

The construction period was adjusted to the start and end of the month to remove crashes which could be associated in disturbance due to construction.

The extended pre-construction data was used to observe the full extent of crash data available on CrashLink. This was used to understand the need for the barrier treatment, particularly where the sites have short study duration.

When two or more opposing travel direction vehicles were involved in a crash, the crash type was taken as 'head-on' regardless of the crash type code specified in the crash data.

The total duration was used to convert total crashes to average annual crashes when comparing the sites to each other.

Unfortunately, detailed speed studies, lane discipline and detailed crash data collection were outside the latitude of this project. This data was used effectively on the RMS (2011) trial of wide centreline treatment on the Newell Highway but was not considered practicable in this study due to the associated costs and timeframes. Crash activated cameras, which were used on the Princes Highway, would have enabled monitoring of vehicle lane discipline but were also considered unfeasible.

3.3.4 Before-and-After Crash Analysis

The before-and-after crash analysis was conducted to answer the following questions:

- Does crash frequency and severity increase or decrease post installation of a CCSB?
- Does the crash type vary pre and post-construction?
- Does the barrier cause drainage issues?

Crash data was obtained from CrashLink by input of the general parameters including:

- Dates (both test durations and the extended time range mentioned in section 3.3.3)
- Highway
- Region

Each study period (pre, post and extended periods mentioned in section 3.3.3) and highway was isolated in the general parameters. The particular site was then isolated using the CrashLink online GIS tool. This dataset was then used to prepare:

- Detailed crash report
- Summarised crash report
- Crash map

The detailed crash report data was used to divide the crash data into a table based on the following properties:

- Site location
- Crash type
- Crash severity
- Wet or dry pavement surface
- Incident or people involved

The project data and before-and-after crash analysis data was used to prepare:

- Crash type and frequency (based on incidence)
- Factored severity cost and crash type (based on people)

Factored severity cost has been utilised as a measure to combine crash severity and frequency. The factored severity cost (FSC) has been based on the Willingness to Pay Approach documented by Transport for NSW (2013). All factored severity costs were calculated based on the values in Table 1 regardless of the date of accident. This allows the comparison to be relative.

During initial observation of crash data, it was found that many crashes tended to occur in wet pavement conditions. A before-and-after crash analysis was conducted to compare wet/dry crashes pre and post barrier installation.

3.3.5 SD Analysis

The aim of the SD analysis is to answer the following questions:

- Are there more crashes post-construction on right hand bends at each site?
- Is there a relationship between the fraction of required SSD achieved and crash frequency and severity?

Given motorists travel on the left-hand side in Australia, SD from the installation of a central barrier is impacted most significantly on right hand-bends. Crash data for right hand bend crashes was compared before-and-after barrier installation in attempt to observe any shift in crashes which could be attributed to the reduction in sight distance.

Right hand curve crashes were totalled to include ‘off road right, right hand bend’ and ‘off road left, right hand bend’ and all other crash types which appeared to occur on a right hand bend. This was done for crashes before-and-after installation and then compared at all charts in a bar graph. On the horizontal axis is the site name and on the vertical axis is the weighted crash cost which was based on the willingness to pay method for $2012-2013, previously mentioned.

SD is impacted on left hand bends by nearside road furniture objects. For the analysis, it was assumed that the nearside objects remained in the same location pre and post-installation and so did not have significance on the SD analysis.

SSD post installation was obtained by using “Centre of Lane to Centre of lane sight line- clearance requirements from the edge line” mentioned in section 2.3.2. This equation is usually used to calculate how much widening will be required to maintain sufficient SSD adjacent a barrier. For simplicity, **Equation 1** has been rearranged to calculate the SSD which results given the median offset width, Equation 3.

$$SSD = \frac{\cos^{-1}\left(\dfrac{R-d}{R+{}^{l}\!/_{2}}\right) \times \left(R + {}^{l}\!/_{2}\right)}{0.5}$$

Equation 3

Where:

R = horizontal radius (m)

d = horizontal offset from edge line to face of barrier (m)

l = lane width (m)

$\cos^{-1}$ is in radians.

The SSD achieved at each site was then divided by the required SSD for the particular speed zone to obtain a fraction of required SSD. This was then plotted against the annual average factored severity crashes per 1000 AADT at the corresponding right hand curve. The conversions to annual crashes per 1000 AADT was done to keep the data relative between the sites. This was achieved by dividing the factored severity crash costs by the site study duration and the associated AADT/1000.

Vertical grade was not considered in the analysis as all sights maintain existing grading pre and post-installation. Therefore the grading adjustment would be the same and has been omitted.

3.3.6 Data limitations

The data being analysed has limited capabilities and typically has little data for low severity injury crashes and property damage crashes. Data is obtained from the NSW Police. Crashes are only recorded if the attend the incident. Data for property damage and low severity injury is therefore not complete. Also, near misses are not recoded. As such, this study is suitable to determine the shift in crash type and volume involving casualty and fatality which were recorded. Therefore the full extent of the crash type and volume shift due to the installation of central concrete safety barrier is not known.

The data is recorded for the first hazard hit. For example, a collision may occur with an object off curve, but the reason the car left the road was because of fatigue or avoiding another vehicle, or loss of control from previous curve.

One way to address this would be to install cameras at each site to record all crashes, but due to time and budget constraints this is not a feasible option.

The data will be consistent across all sights and the method has been considered a reasonable approach.

The location of the crash data is limited to where the officer manually enters the data. The location of the crash location might go to the nearest town centre.

3.4 Knowledge application site

The knowledge gained from the research applied to an existing site in attempt to employ the conclusions and recommendations in a practical sense. The site selected is located in East Lynne on the Princes Highway in southern NSW.

The knowledge application is presented in section 6.3

As there is very limited data available for the site the recommendation should be viewed as a discussion only and the recommended treatment should by no means be adopted or implemented.

4 INVESTIGATION SITES

Nine sites on three rural highways were analysed in the study. The sites, shown in Figure 10, included:

- Illawarra Highway
    - Robertson
- Princes Highway
    - South Batemans Bay
    - Dalmeny
    - Yowaka
- Great Western Highway
    - Mount Victoria – top
    - Mount Victoria – bottom
    - Hartley
    - River Lett Hill
    - South Bowenfels

Figure 10 – Overall site locations

4.1 HW1 Princes Highway

The Princes Highway runs for 1941km between Sydney (NSW) and Port Augusta (South Australia) via the coast. The NSW south coast rail network ceases at Bomaderry, near Nowra. Beyond this point, the Princes Highway is the only major land transport link. It is therefore a route used for freight, local, commuter, interstate and tourist movements.

The NSW south coast section of the highway is predominantly an undivided rural highway configured either as two-lane, or two-lane with an auxiliary climbing lane. The highway setting varies from undulating up to smaller sections of mountainous terrain. The alignment often follows ridgelines and has many locations of substandard horizontal and vertical geometry.

Characteristic constraints surrounding the Princes Highway include waterways, State and National Parks, topography, residential and rural land use, utilities, Aboriginal heritage and environmental constraints.

The traffic volumes on the highway can get quite low, particularly the further south the Highway travels.

There is currently no intention to upgrade or realign any of the Princes Highway analysis sites and so they were viewed as permanent solutions.

4.1.1 Princes Highway, Batemans Bay

The section of the Princes Highway is two kilometres south of Cranbrook Road, Batemans Bay. It has a posted speed limit of 90km/h. Curves within the section indicate a design speed of 70km/h. It comprised a northbound overtaking lane and a single southbound lane.

The site is bound by State Forest on either side of the road. It is also in particularly undulating terrain. Grades on the alignment range from 8-11%. Large cuttings are present on the west, adjacent the northbound lanes.

Pre-construction accident data indicated speed and substandard alignment were large contributing factors to the accidents in the area. Slightly over 50% of the crashes to occur on the road were run-off road incidents. Additionally, 10% of crashes were head-on crashes. It was highlighted that wet weather crashes were significant at the site pre--construction. It was assumed that the slots under the precast Type-F system allowed for adequate flow of surface water.

The precast Type-F central safety barrier system was retrofitted within a 1.6m median in 2011. The central barrier was installed as a road safety package in attempt to address the high volume of off-curve and head-on crashes. All works were completed on the southbound carriageway to reduce costs. Correction of existing vertical grading and superelevation was beyond the financial scope of the project. Horizontal alignment was marginally improved with pavement widening for increased lane width from 3.5m to 3.8m. This was done to better accommodate the swept path of vehicles on the curvilinear alignment. All works completed were contained within existing road boundaries. This allowed for shorter planning timeframes and reduced cost implications. Shoulders on the southbound carriageway were increased to 2.2m.

Sight distance pre-installation was suitable for about 70km/h. Post installation, SSD (1.1 to 0.2m) is as low as 43m – suitable for 50km/h. Post-installation SSD is only achieved at 45% of the site in both directions.

The northern approach to the site goes through the southern outskirts of the Batemans Bay area. There, the highway changes from a local arterial road with frequent access and junctions to a rural highway.

The southern approach is in a rural setting. The horizontal and vertical geometry on approach was generally to a higher standard.

4.1.2 Princes Highway, Dalmeny

This stretch of the highway lies between Dalmeny and Narooma which are both seaside towns. The project is bordered by State Forest on either side of the road. The site is signposted at a speed of 100km/h.

The site is mostly in cutting and consists of reverse curves, radius 185m and 170m. There is also a low-standard vertical crest, shown in Figure 11, which coincides with the northern 185m radius curve. The rest of the project is on a vertical grade. The adjoining road links to the north and south are to a higher standard.

Before the road safety treatment was investigated, two road seals were applied to combat wet weather problems and associated crashes. A 7mm seal was applied in April 2004 and 14mm slag seal in May 2004.

The central barriers at Dalmeny were installed to combat head-on crashes. The main objective of the proposed work was to eliminate the cross-centreline accidents by means of a central median barrier whilst also widening the shoulder to provide area for vehicles to take evasive action if needed. The key constraint was not to deviate substantially from the existing centreline, which will minimise the earthworks on the project. The client’s instruction was to retain existing vertical alignment. The existing vertical alignment is suitable for design speeds of between 55 to 60km/h only.

The road safety treatment included the installation of a 780m long precast Type-F, CCSB and end terminals. At the north, the additional width required for the central safety barrier treatment was gained from an existing overtaking lane which was claimed to have little use. The shortening of the existing southbound overtaking lane merge was also shortened by 200m to enable the completion of the merge prior to a sharp crest which may have presented as a surprise to motorists. No additional pavement or seal work was implemented because of previous treatment.

All works were completed on the northbound carriageway. Existing pavement was maintained in the travel lane. The formation was widened on the shoulder/verge in fill and for instating an SO profile gutter type and table drain in cutting. W-Beam guard fence was installed adjacent fill on the northbound carriageway.

WRSB was considered for use as the central barrier treatment but was not pursued due to the tight horizontal radius curves at the site.

Figure 11 – Horizontal curve concealed by sharp vertical crest on southbound carriageway, Princes Highway, Dalmeny.

4.1.3 Princes Highway, Yowaka

The site crosses and runs adjacent to the Yowaka River. The site is located 4.5km to the south of Pambula.

A precast concrete barrier was installed in the centre of the roadway in August 2006 to combat cross-centreline crashes. An accident analysis was undertaken by RMS which showed that 79.4% of accidents were northbound motorists who had lost control of their vehicle, with 72.8% of them crossing onto the incorrect side of the road. The design of a central concrete median barrier was deemed to be the appropriate solution for this site.

Yowaka River, nearby wetlands, adjacent land use, topography and funding were the most significant constraints when the project was being investigated. The road is constructed in side slope conditions, following the contours of the adjacent hill.

The site is sign posted at100km/h, although the horizontal curves are more appropriate for speeds around 60-70km/h. The vertical design standard is suitable for 65 – 75km/h. The design report recommended a posted design speed of 80km/h to be more appropriate. This was not adopted.

The approach geometry to the north and south is to a higher standard both horizontally and vertically.

Two private property accesses were maintained at the site as left-in, left-out treatment because of the barrier installation.

Other barrier options (wire rope and double-sided W-B-Beam) were considered. The wire rope was not feasible because of the small curve radii and replacement/repair to the W-Beam would disrupt traffic flow (lane closures) while being carried out. WH&S issues for maintenance personnel was also a factor in the decision to go with the concrete precast Type-F system.

The width of each carriageway is adequate for contraflow at low speed in the event of a carriageway closure.

4.2 HW25 Illawarra Highway

The Illawarra Highway stretches 65km between the Illawarra region and the Hume Highway. The highway is east-west running. The eastern end of the Illawarra Highway crosses the Illawarra escarpment through Macquarie Pass National Park. The mountain pass section of the highway consists of narrow formation, tight horizontal and steep vertical geometry. The pass is attractive to motorcyclists.

The highway is predominantly a two-lane rural highway and passes through a number of small towns.

The Macquarie Pass section of the highway is subject to thick fog and very high rainfall.

There is no passenger rail to the Southern Highlands via the Illawarra and so buses are utilised. There has been a steady increase of road freight movements due to the expansion of the port facilities at Port Kembla.

4.2.1 Illawarra Highway, Railway Crossing, Robertson

The site is approximately six kilometres east of Robertson on the Illawarra Highway.

The Railway crossing site is at the top of the escarpment. The highway runs with the contours and is located in side slope condition. The highway overpasses the Unanderra to Moss Vale rail line. The rail route is predominantly a freight route but also operates a recreation steam train on weekends.

A number of fatalities had occurred at the site before 2010. These involved motorcyclists crossing to the opposing lane of traffic.

Concrete barrier was selected as the most appropriate central barrier system due to the small radius 90m horizontal curves and the concrete barrier system being perceived to be more favourable to motorcyclists. It was identified that superelevation development and horizontal plan transitions at the site were substandard. The concrete barrier would also halve the required SSD. There was no scope to improve these parameters.

The RMS design team had great concern for the number of compromises being incorporated into the design. After considerable discussions with the RMS client and explanation of the potential risks, the RMS design team cancelled their involvement.

Subsequent construction was completed by RMS Road and Fleet Services. Local widening of the formation was required to enable the installation of the central barrier. This required widening of the existing bridge structure. The available shoulder width post road safety treatment is only about 1m. This does not provide refuge for a broken down vehicle nor does it provide adequate width for manoeuvre around an object on the trafficable lane. Errant vehicle recovery within the shoulder is also very limited.

A warning sign was also installed at both approaches to the stretch. The sign has flashing yellow lights which brings attention to the curve speed advisory of 55km/h for any vehicle entering the site.

As the treatment was constructed without design, the only design model available for analysis is the preliminary strategic model.

Graffiti is present on the concrete safety barrier in the eastbound on the bridge structure. It appears to have occurred more than once at this particular location as some existing work has been removed. This is very unsafe practice as the lanes and shoulders are very narrow. There is no area for refuge for a person on the carriageway if a vehicle was to drive into the section. Fortunately the sight at this particular location is not at minimum, being on the outside of a left hand bend.

4.3 HW5 Great Western Highway

The Great Western Highway stretches for 210km between Sydney and Bathurst. It connects the city with inland NSW, running in the east – west direction. The highway crosses the Great Dividing Range between Emu Plains and Mount Victoria. This route is based around the crossing formalised by Blaxland, Lawson and Wentworth back in 1813.

The highway serves as a key freight route between Sydney and central western NSW, tourist route and local route between towns and villages. Traffic volumes are quite high for a rural highway, around 20,000 AADT. The volumes are also composed of high heavy vehicle movements, up to around 20%.

Site topography is a combination of mountainous and undulating valleys.

The alignment in this area is characteristically curvilinear having many substandard horizontal radius curves. Black ice is an issue on the highway, particularly in the western sections west of the Blue Mountains.

Five concrete barrier projects were constructed between 2001 and 2012 between Mount Victoria and Lithgow.

As mentioned in section 2.2.3, there has been a trial on curve markings on the inside of left hand curves on the inside of the barrier.

A major project to realign the highway between Mount Victoria and Lithgow is in the final stages of concept design. Post construction, the major deviation to a 100km/h design standard will remove all of the sites analysed in this study.

4.3.1 Great Western Highway, Mount Victoria Pass

Mount Victoria Pass (top)

The site is approximately 19km west of Katoomba. At this location, the Great Western Highway weaves down the steep mountain and is in side slope or running on short ridgelines. Short lengths of the highway are built on structures erected by convicts. The curve is located approximately mid-way down the historic mountain pass causeway. Grades at the site are in the order of 5-11%.

Cast in-situ Type-F barrier was installed in late 2010. Head-on crashes were prevalent at the site with its steep grades and tight horizontal geometry. A single head-on crash led to the death of one and injury of two in early 2010. Cast in-situ Type-F barrier was selected due to the high containment required for the large percentage of heavy vehicles which travel through the site. Longitudinal drainage with precast pits were provided to ensure aquaplaning was mitigated.

Widening of the two westbound lanes accompanied the barrier installation. All widening was completed on the western side of the highway, in cutting.

The eastbound approach is a very long and steep uphill grade. The westbound approach is at the beginning of a steep downhill grade.

Mount Victoria Pass (bottom)

The site is approximately 20km west of Katoomba. The curve is located at the bottom of the mountain pass.

The curve is constrained by a large cutting to the south and embankment to north.

The eastbound approach is within the Hartley Valley where road geometry is to a much higher standard.

The required SSD was achieved at the site by introducing a widened median in which the sight line could be accommodated. The layout pushed the barrier to the eastbound lane which has a narrow median. This treatment is reminiscent of the layout presented in section 2.3.4. In order to develop the widening, channelisation was developed on the nearside of the eastern carriageway. This nearside channelisation was removed in March 2013, as shown in Figure 22.

Due to the excessive grades and low standard horizontal geometry, an arrester bed is located at the back of the right hand, downhill curve for errant vehicle recovery. Existing substandard, 10% superelevation was maintained at the site to reduce undercutting of the existing pavement. This was justified given no evidence of truck rollover in crash record history.

4.3.2 Great Western Highway, Hartley

Hartley bend is located adjacent to the historical town of Hartley. Hartley is located about 26km west of Katoomba.

Precast CCSB was installed by RTA Road and Fleet Services in early 2001 to combat a number of head-on crashes which led to approximately 9 injuries in the preceding five years. The project proposal suggested these crashes were linked to the tight radius curve and poor pavement surface conditions.

Precast concrete barrier, precast Type-F was selected as the appropriate barrier treatment due to:

- Horizontal curve radius less than 200m
- High level of containment required for heavy vehicles
- Narrow pavement width
- Treatment can be temporarily removed when pavement is being reconstructed or resealed

The curve is constructed in side slope conditions. The site is bound horizontally by two significant historic sites. The vertical grading is bound by undulating topography, an at-grade intersection and a structure over River Lett.

The site is signposted at 80km/h but was previously signposted at 90km/h. There is a speed camera to the west of the project. A point-to-point speed camera is being constructed encompassing the Hartley and River Lett Hill sites.

The vertical grade is up to approximately 10% sloping down into the Hartley valley for westbound traffic movement. There is a crest to the east of the project which appears to limit sight to the start of the project marginally. To the west of the project is the Old Great Western Highway junction, leading into Hartley.

Previous shoulder widening completed in 1998 permitted central barrier installation in 2001 to be contained within the existing road formation. As part of the treatment, resurfacing of the pavement was also carried out to combat road surface failures linked to the steep grade and high percentage of heavy vehicles.

4.3.3 Great Western Highway, River Lett Hill

River Lett Hill is located just to the west of the Hartley site. The eastern approach crosses River Lett. The site is 28km from Katoomba.

Cast in-situ Type-F barrier was installed by RTA Road and Fleet Services in May 2010 to combat a number of head-on crashes one of which included a double fatality. The cast in-situ barrier was not accompanied by the installation of longitudinal drainage; instead small slots were cast into the formed segments for about two metres.

The section of road is predominantly constructed in side slope conditions running along with contours of the hill. Significant widening to the west would have required extensive cutting and any widening to the east would have required extensive fill.

Vertical grading at the site varies between 7 and 10%.

The eastern approach is the Hartley bend site and to the west the alignment is to a much higher standard, with larger horizontal radius curves and moderate grades.

The construction was initially completed to include a single lane downhill, eastbound with a wide shoulder. This was subsequently line marked as two lanes downhill with a narrowed shoulder.

Ice and snow have been known to affect the site.

4.3.4 Great Western Highway, South Bowenfels

The South Bowenfels site is located about four kilometres south of Lithgow.

Precast CCSB was constructed in October 2005. The construction was likely in response to a serious head-on crash which led to the death of three and injury of one in August 2004.

Although the horizontal curve radius is 300m and could support WRSB installation, the higher level of containment was necessary at the site due to the high percentage of heavy vehicles using the section.

The alignment is constructed in side slope condition at the foot of the Hassan Walls mountain range to the north. There are private residences to the south. The vertical grading is around 7% sloping down toward the east.

As the Hassan Walls shadow the site from any direct sunlight, the site is prone to black ice conditions. A black ice monitoring system has been installed at the site and alerts drivers of icy conditions.

5 RESULTS AND ANALYSIS

5.1 Barrier comparison

The barrier comparison table is shown in Table 14. The table has been included to present some of the major considerations when selecting the appropriate barrier system. Table 14 is not an exhaustive list; rather, the aim was to collate parameters in a quick reference guide to generate further discussion specific to the site.

Table 14 – Guide to appropriate barrier selection

		Rigid		**Semi-rigid**	**Flexible**
Parameter		Type-F **(cast in situ)**	Type-F **(precast)**	**Guardrail**	**Wire rope**
Hardware footprint width RTA (1996)		0.6m	0.8m	0.625m	120mm, 400mm at anchors
Severity index for 100km/h	Austroads (2009)	2.7	NA	2.7	2.7
	RTA (1996)	3.5	3.0	3.0	2.5
Dynamic deflection (Austroads, 2009)	80km/h	0m	0.5m	1.2m	1.2m
	90km/h	0m	NA	1.3m	1.3m
	100km/h	0m	0.9m	1.4m	1.4m
	110km/h	0m	NA	1.6m	1.5m
Minimum median width (RTA, 1996)	80km/h	1.6m	1.8m	1.8m	2.2m
	90km/h	1.6m	2.0m	2.0m	2.4m

		Rigid		Semi-rigid	Flexible
Parameter		Type-F **(cast in situ)**	Type-F **(precast)**	**Guardrail**	**Wire rope**
	100km/h	1.6m	2.6m	2.0m	2.6m
	110km/h	1.6m	3.0m	2.2m	2.8m
Frequently used width in service, NSW (Birch, G 2014, pers. comm., 28 October).		1.6m – 2.6m	1.6m – 2.0m	Not typically used	1.6m – 2.6m
Containment (Austroads, 2009)		Best	Good	Moderate	Moderate
Performance post collision (Austroads, 2006)		Good	Good	Poor- moderate	Poor
Horizontal curve radius restriction (Walsh, SP 2014, pers. comm., 28 October).		>15m	>50m	>2.5m	>200m
Vertical curve restriction (Birch, G 2014, pers. comm., 28 October).		Minor	Minor	Moderate – requires bending of section	Limitations in sag curves due to chording of wire rope
Degree of SSD impact (Nilsson & Prior, 2004)		Major	Major	Moderate	Moderate
Shy line	Nilsson & Prior (2004)	Major	Major	Moderate	Moderate
	AASHTO (2006)	Equal			
Degree of impact on drainage (Walsh, SP 2014, pers. comm., 28 October).		Significant, longitudinal drainage should be considered	Moderate – long drainage slots	Minimal	Minimal

		Rigid		**Semi-rigid**	**Flexible**
Parameter		Type-F **(cast in situ)**	Type-F **(precast)**	**Guardrail**	**Wire rope**
Degree of impact on motorcyclists (Anderson et al, 2012), (McLachlan, P 2014, pers. comm., 28 October).		Moderate – higher severity index by less risk of snagging	Moderate – higher severity index by less risk of snagging	Major, Moderate if fitted with rub rail	Major
Maintenance (Walsh, SP 2014, pers. comm., 28 October). requirements	Routine	Minimal, clearing drainage	Minimal – clear drainage slots.	Minimal – weeding	High - tension checks and inspected after, weeding
	Pavement	Moderate -system is fixed but is uniform	Simple - system can be temporarily removed	Troublesome - system is fixed	Troublesome - system is fixed
	Post-crash	Minimal	Minimal	Major	Major
	Materials and storage	Minimal	Minimal	Major	Moderate
	WHS	System offers protection to workers and low frequency of exposure	System offers protection to workers and can be moved to facilitate contraflow	Post collision maintenance requirements expose workers to risk more frequently	Post collision maintenance requirements expose workers to risk more frequently
Initial cost (RMS, 2014)		High $350/m	High $400/m	Moderate $150/m	Low $150/m
Ongoing costs (Walsh, SP 2014, pers. comm., 28 October).		Low	Low	High (low frequency, higher cost)	High (high frequency, lower cost)

5.2 In-Service Assessment of Central Safety Barriers

5.2.1 Project data and site observations

Site data was collected and site inspections were carried out in mid-2014. All data and observations have been collated in Appendix B: Site data table.

Site damage and other observation photos are shown in Figure 12 to Figure 25.

Site layouts have been provided combined with crash data in Appendix B. Where curve numbers are mentioned, curve one starts from north or east, depending on the route direction.

In regards to Table 16 (Appendix B: Site data table), it was difficult to obtain vertical grading details from the design plans. Designers often do not include the vertical grading values in the design long section when the grading is based on existing vertical design. This can make the full impact of the barrier systems inclusion in the road environment difficult to understand during project development and review.

A summary of detailed crash data has been provided in Appendix D: Crash results. Detailed crash data will be provided at request.

Site observations were presented on aerial imagery. Table 15 is the legend for interpreting the site observations.

Table 15 – Site observation legend

	EB/SB offside barrier damage
	WB/NORTH BOUND offside barrier damage
	EB/SB nearside barrier damage
	WB/NORTH BOUND nearside barrier damage
	Road gouge marks
	Skid marks

	Offside barrier graffiti
	Cyclists
	Unfixed roadside objects (branches, rocks, roadkill etc.)

NB/EB/WB/SB – Northbound/Eastbound/Westbound/Southbound

Figure 12 – Batemans Bay site observations

Figure 13 – Batemans Bay central safety barrier ramping

Figure 14 – Batemans Bay site observations

Figure 15 – Dalmeny site observation

Figure 16 – Dalmeny site observation

Figure 17 – Yowaka site observations

Figure 18 – Robertson site observations

Figure 19 – Robertson graffiti and metal curve alignment markings fixed to the central barrier (red)

Figure 20 – Mount Victoria Pass (top) site observations

Figure 21 - Mount Victoria Pass (bottom) site observations – with westbound nearside chevron

Figure 22 – Mount Victoria Pass (bottom) removed chevron, westbound approach

Figure 23 – Hartley site observations

Figure 24 – River Lett Hill site observations

Figure 25 – South Bowenfels site observations

5.2.2 Before-and-after crash analysis

Crash type and severity analysis

Crash type and occurrence was plotted in Figure 26 for each site. This plot has not been adjusted for degree of severity. Each site has a different timeframe which is dependent on the investigation period documented in Appendix B: Site data table.

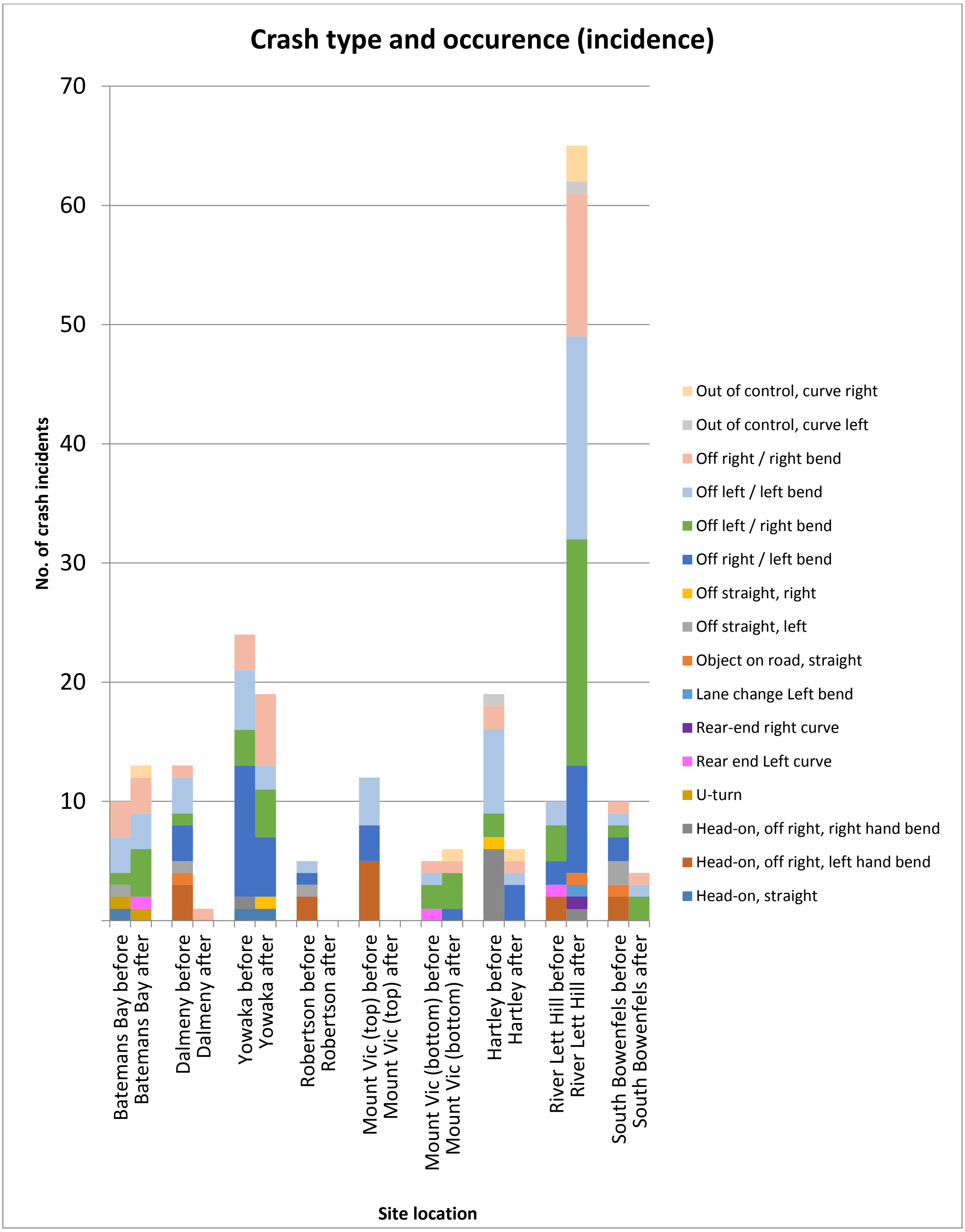

Figure 26 – Crash type and incidence for all sites

It can be seen in Figure 26, six of the nine sites have had a net reduction off all crash incidents post safety treatment installation.

When severity was factored on an individual person affected basis as per Figure 28, seven out of the nine sites had a reduction in crash severity which correlated to an increase in road safety.

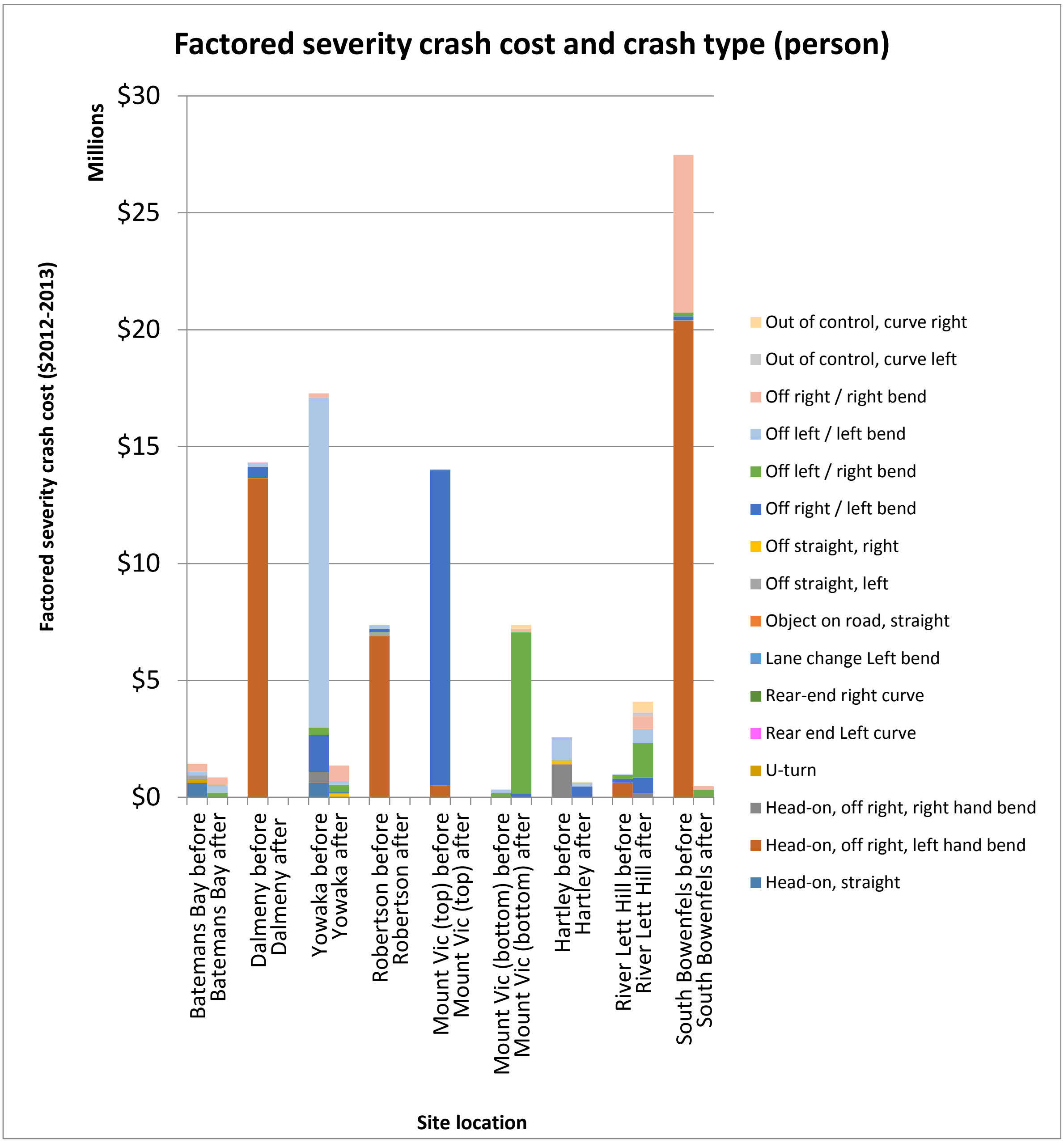

Figure 27 - Factored severity crash cost and crash Type-For individual people involved in crash incidents

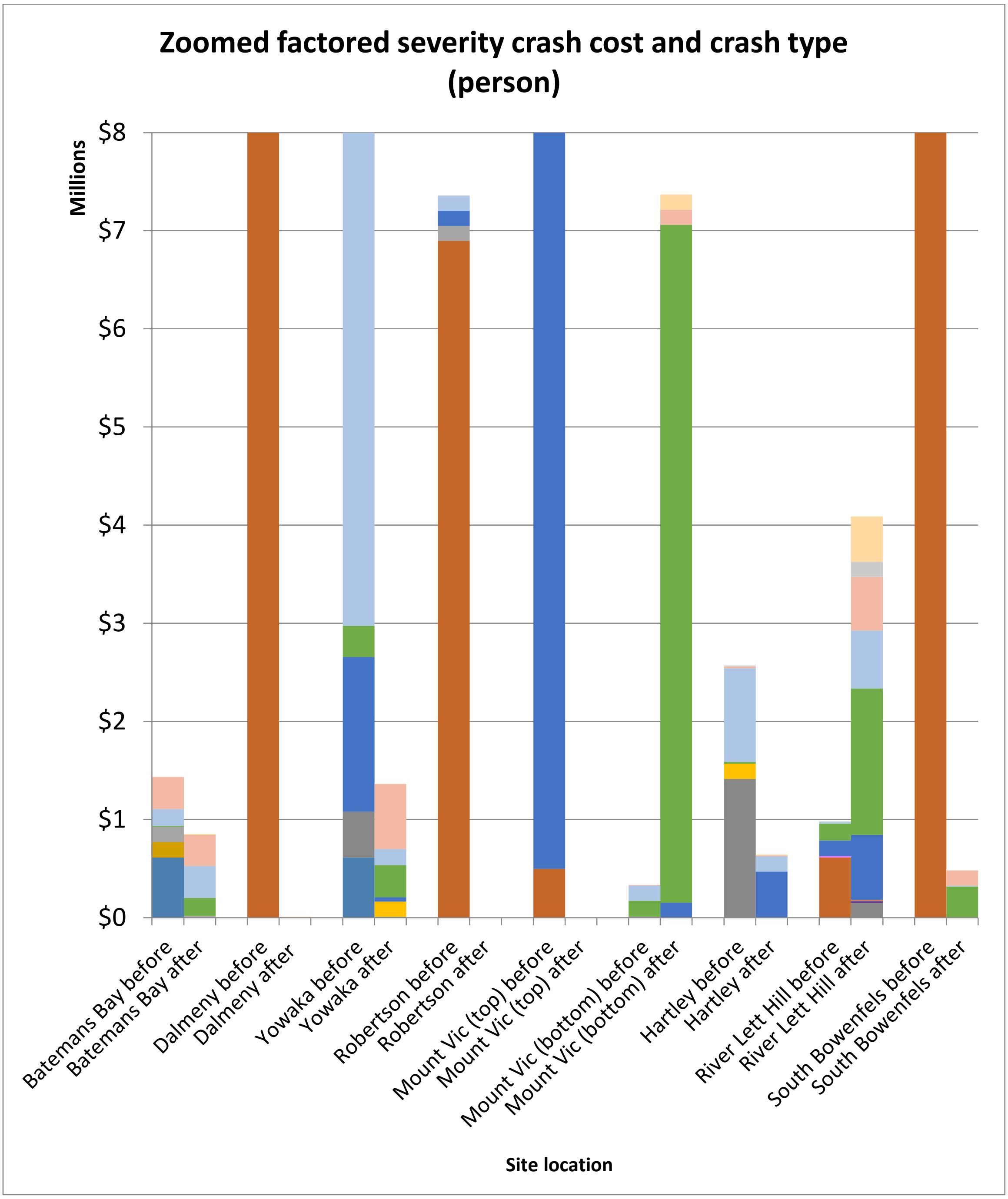

Figure 28 – Zoomed, factored severity crash cost and crash Type-For individual people involved in crash incidents

From Figure 28 it is clear how significant fatal crash costs are. The significance of head-on crash types is demonstrated at Dalmeny, Robertson and South Bowenfels. The 'off right, left curve' crash recorded at Mount Victoria (top) involved two vehicles and could also be considered a head-on crash.

It was found that road under movement (RUM) codes sometimes misrepresented crash type scenario. Often crashes involving two or more opposite direction travelling vehicles were labelled ‘out of control on bend’ for example. Without closer examination of the data this situation could misrepresent trends and analysis.

A table collating the before-and-after crash occurrence and FSC calculations has been included in Appendix D. These calculations were used in the site specific analysis in section 5.3.

In reference to Table 19 it was found the total average reduction in fatalities across all sites was 111% and factored severity costs in all accidents reduced by 200%.

Wet and dry crash analysis

Wet and dry pavement crashes were analysed in attempt to draw a relationship between crash occurrence and severity, as illustrated in Figure 29 and Figure 30.

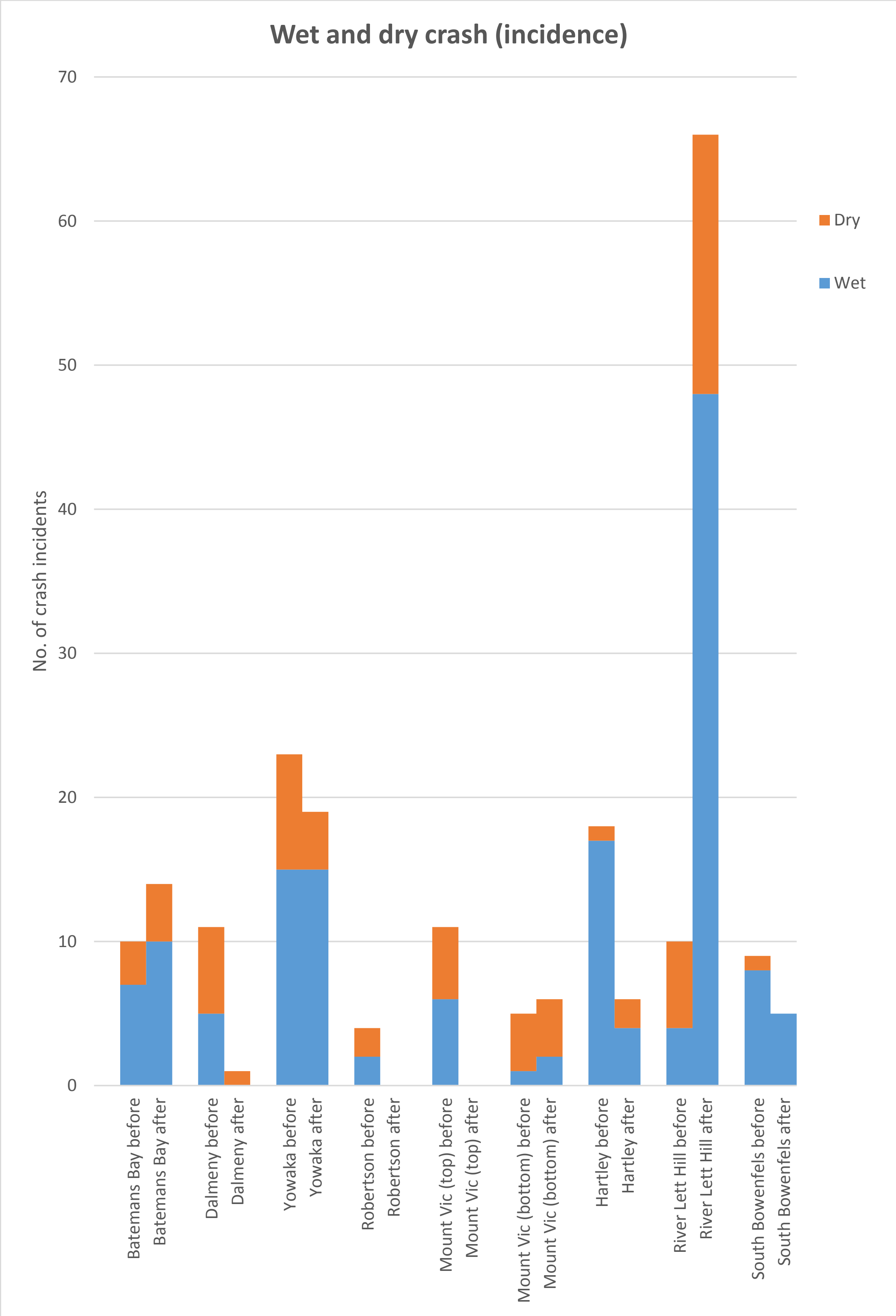

Figure 29 – Wet and dry crash incidence

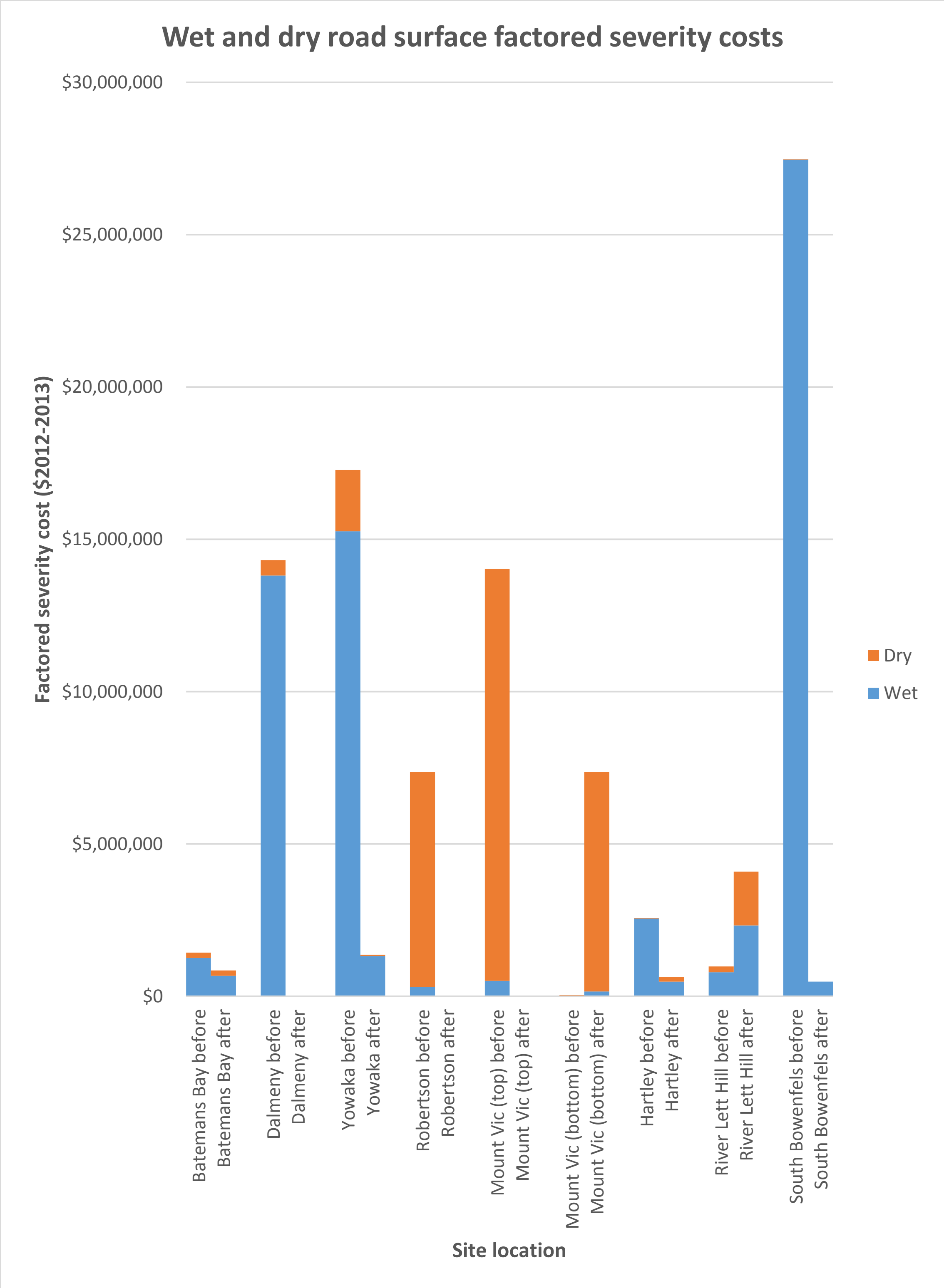

Figure 30 – Wet and dry factored severity costs

It can be seen that five (four being pre-cast) of the nine sites had a reduction in wet surface crash incidences and associated severity post installation. This suggests that the barrier has not had a negative impact on road surface drainage.

Two of the remaining sites had no change or an increase in crash incidence but had an overall reduction in severity.

River Lett Hill had a spike in wet crashes and has been discussed further in section 5.3.8.

Sight distance analysis

The SD analysis consisted of a right hand curve analysis for all sites, shown in Figure 31 and Figure 32.

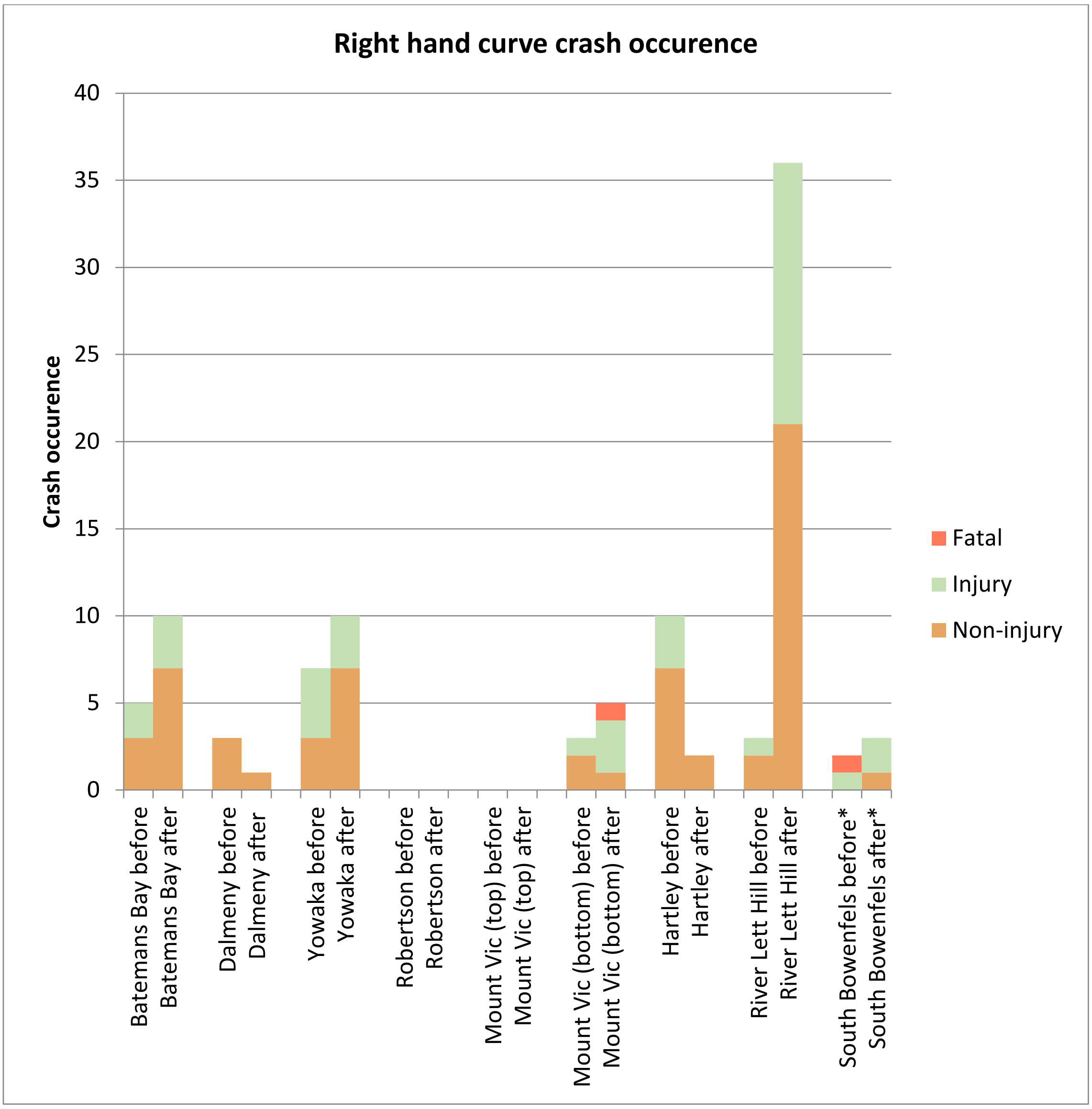

Figure 31 – Right hand curve crash incidence

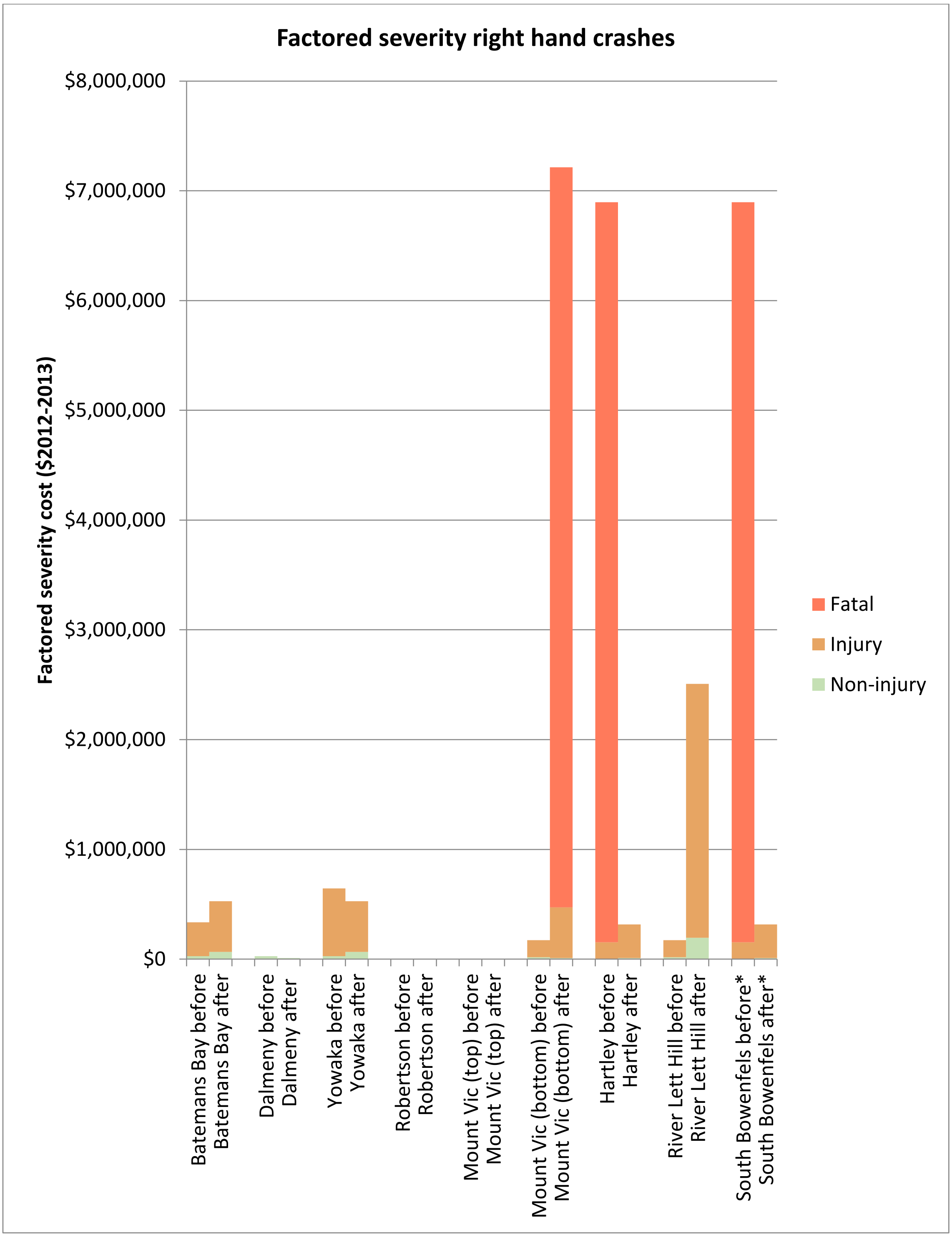

Figure 32 – Factored severity costs of right hand curve crashes

Five of the nine sites analysed had an increase in crash incidence. Of those five sites, two had a decrease in severity.

Most sites did not meet the requirements for the provision of ‘sight distance over barriers’. At the two sites which had shoulder widths less than the required 2.5m for manoeuvre there were no crashes recorded and a significant reduction in crashes recorded.

Interestingly, at the sites where no right hand curve crashes recorded in the pre-installation period, there was no record of post-installation crashes. This shows that the reduction in SSD has not created a road safety problem at the sites.

It could be deduced that the increase in crashes at the aforementioned five sites could be as a consequence of the introduction the barrier as a physical hazard and not because of the reduction of SSD.

Figure 33 and Figure 34 attempts to demonstrate any relationship between the fraction of SSD achieved versus crashes and costs respectively.

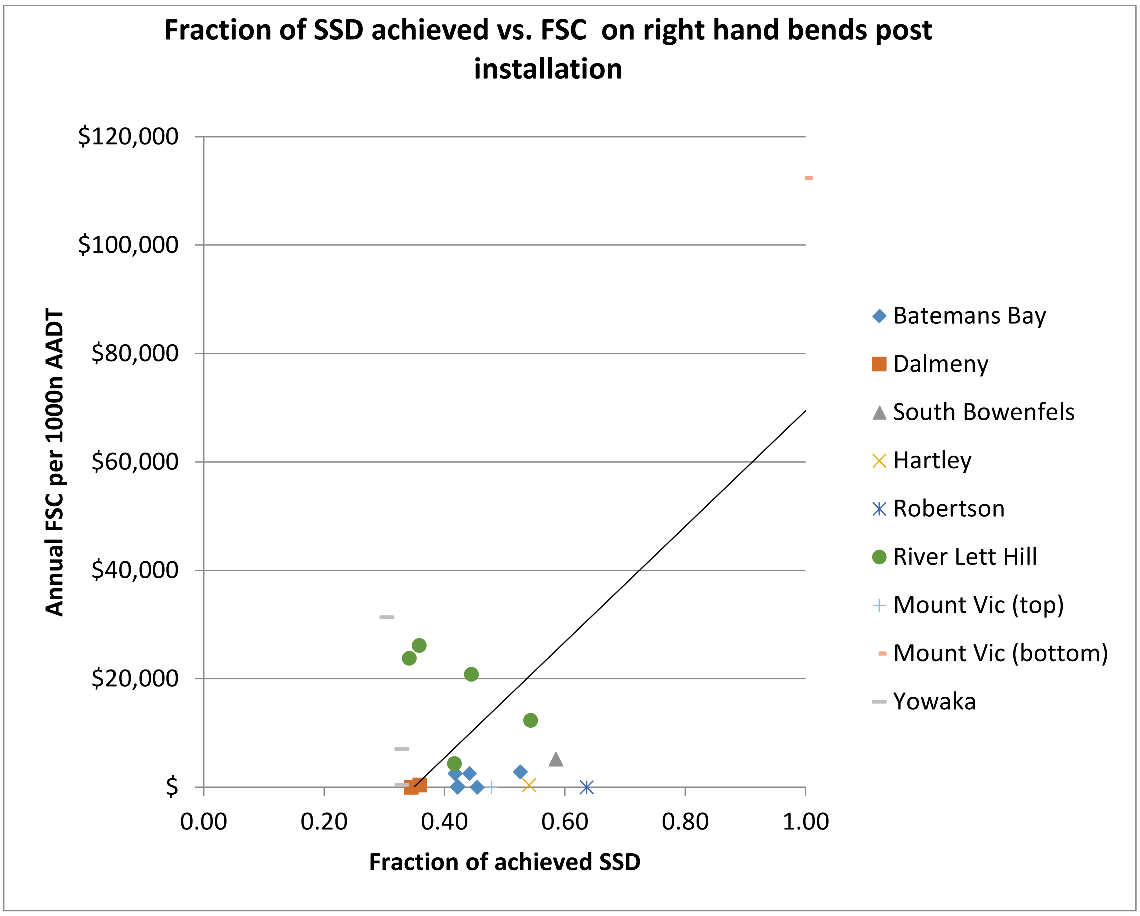

Figure 33 – SSD vs. factored severity crash costs

Figure 33 does not show a clear relationship between the fraction of SSD achieved and road safety which has been measured as factored severity crash costs. The high gradient, positive trend line was not expected. For the sites analysed, the trend line indicates that greater SSD has a higher risk of crashes. The fatality at the bottom of Victoria Pass skews the graph trend line significantly.

The fatal crash, discussed further in section 5.3.6 was at the bottom of a steep grade. With this knowledge Figure 31 was reproduced, shown in Figure 34 with formatting divided based on the right hand curve location being on uphill or downhill vertical gradient.

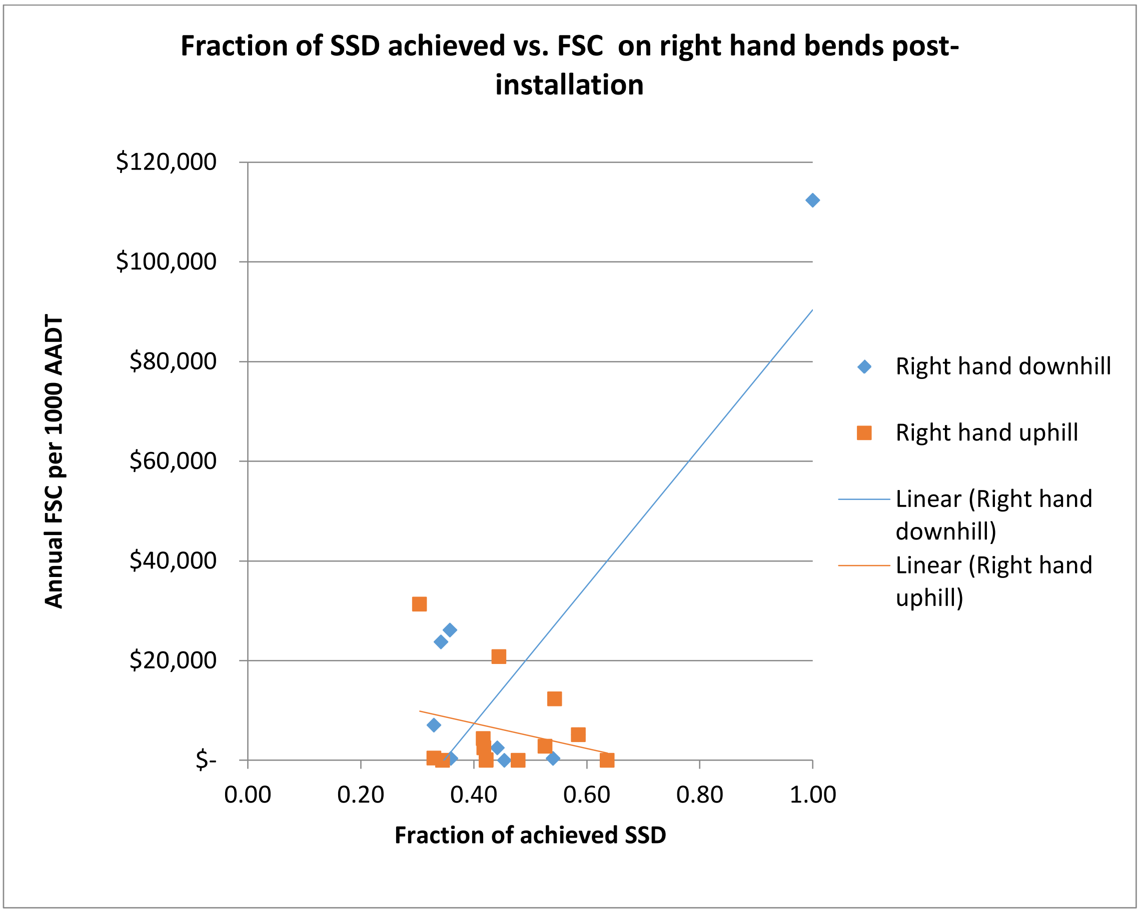

Figure 34 – Reproduced SSD vs. factored severity crash costs with uphill and downhill vertical grading highlighted

Figure 34 demonstrated that there are two different trends for uphill and downhill right hand bends. The uphill trend is more in keeping with the expectation that the lower the SSD available the higher the risk of crashes. The downhill trend could be indicating a higher risk of crashes at the bottom of steep grades, but as the degree of downhill grade nor the horizontal radius are not directly incorporated into this graph this cannot be conclusively connected.

5.3 Site specific Analysis

5.3.1 Princes Highway, Batemans Bay

Crash type, severity and location

- F decreased by 100% to zero

Although there was an increase in crashes, the severity of those crashes was reduced. This is demonstrated in Figure 26 and Figure 27/Figure 28 respectively. This is in keeping with the usual expectation post installation of a central safety barrier.

There was a significant increase in the following crash types:

- ‘Off left, right curve’ increasing in FSC by around 1860%
- ‘Off left, left curve’ increasing in FSC by almost 90%
- ‘Rear-end, left curve’ which was not recorded in the pre-construction test period

Overall, there was a FSC saving of around 40% over the study period.

There was evidence of vehicle ramping on the bottom slope of the barrier profile as shown in Figure 12.

Crashes remained scattered, predominantly on horizontal curvature. The southern curve had a gain in crashes post installation. Crashes in this location were recorded in the extended pre-installation period and so it does not appear out of character for the site.

The collision markings mapped from the site visit, as shown in Figure 15, indicate there have been a number of minor or near-miss hits not recorded in CrashLink. These are mainly concentrated around curve three in the southbound direction. Curve three is a left hand bend in the southbound direction. There were previously crashes recorded on this curve in the same direction.

Interestingly, many of the crashes were found to be northbound, in the uphill direction.

The installation has had a net benefit on road safety.

Drainage

Wet crash incidence increased by three but severity decreased resulting in a lower FSC. The distribution of wet to dry crashes marginally increased. The pre-installation period had 70% of crashes in the wet whereas post-installation, the site had 71.4% wet crashes.

Drainage does not appear to be an issue at the site.

SSD

The calculated SSD achieved varied between 42% and 53% of the required value.

Both non-injury (tow away) and injury right hand curve crashes increased post construction by 40% and 33.3% respectively. The FSC also increased for NI and I right hand curve crashes by 133% and 50% respectively. The increase in these values could also be associated with the curve or the close proximity of the barrier.

A potential SSD issue may have been created at the site due to the presence of the CCSB given there has been quite a significant increase in right hand curves.

5.3.2 Princes Highway, Dalmeny

Crash type, severity and location

The prevailing crash type pre-installation included:

- Head-on, left hand bend
- Off right, left hand bend

Head-on crashes alone led to the death of two and injury of one.

Dalmeny had a drastic reduction in crashes and crash severity post-installation. In the five years and seven months post-construction analysed, there was only a single non-injury (tow away) crash recorded. This was an ‘off right, right curve’ crash. The ‘head-on’, ‘off right, left hand bend’ and ‘off left, left hand bend’ crash types were no longer contributing crash types at the site.

The installation has had a profound improvement of road safety and associated cost savings. The post-installation FSC were reduced by 99.94% of the pre-construction period costs.

In reference to the CrashLink pre- and post-installation maps, crashes have been mitigated on curve two. The site analysis, shown in Figure 15, revealed barrier damage which was consistent with the post-installation crash location on curve one.

It is possible that crashes have reduced significantly due to a reduction in speed and additional precaution taken at the site due to the intrusive aesthetic of the treatment. The flashing light advisory sign may have also had an impact on travel speeds and driver awareness at the site. As speed data was not obtained, this theory cannot be quantified.

The installation has had a net benefit on road safety.

Drainage

The single crash recorded post-installation occurred during dry surface conditions.

The installation has not increased the frequency or severity of wet crashes and does not appear to have caused drainage issues which could compromise road safety at the site.

SSD

The calculated SSD achieved varied between 34% and 36% of the required value.

NI crashes were the only recorded crashes on right hand curves pre- and post-installation. There was a 66.7% reduction in right hand curve crashes post-installation.

Potential objects were observed at the site including rocks and logs, but it appears they have not caused any issues.

The significantly substandard SSD associated with the installation of the CCSB has not had a negative impact on road safety but has largely improved the site conditions.

5.3.3 Princes Highway, Yowaka

Crash type, severity and location

Overall, the crash incidence for:

- NI increased by 40%
- I decreased by 62%

- F decreased by 100% to zero

This resulted in an overall FSC reduction of approximately 92%. This significant cost reduction is indicative of the reduction in the number of people injured and killed at the site post-installation.

The prevailing crash type pre-installation included:

- Off left, left hand bend
- Off right, left hand bend
- Head-on, straight
- Head-on, right hand bend

The major crash type post-installation included:

- Off right, right hand bend, incidence increase of 300%, FSC increase of 284%
- Off left, right hand bend, remained the same

Head-on crashes have been eliminated at the site, although right hand curve crashes have resulted in a number of injuries.

Pre-installation, crashes were mainly centred around curve one and curve three. Post-installation, crashes are concentrated at curve one and curve two. This is consistent with the site observations of barrier damage shown in Figure 16, where barrier damage is mainly on curve one and two.

Observed hits on barriers, shown in Figure 17, tend to be on the inside of the curve toward the end of the curve. This could indicate motorists are losing control toward the outside of the curve and then overcorrecting into the barrier.

The installation has had a net benefit on road safety.

Drainage

The number of wet road surface crash incidents remained the same and dry incidents reduced by 50%. The severity of the crashes for both wet and dry crashes was reduced. This resulted in wet crash FSC reducing by 91% and dry conditions reducing by 98%.

The installation has not increased the frequency or severity of wet crashes and does not appear to have caused drainage issues which could compromise road safety at the site.

SSD

The calculated SSD achieved varied between 30% and 33% of the required value on right hand curves at the site.

Post-installation right hand bend crash analysis resulted in:

- NI crashes increased in FSC by 133%
- I crashes reduced in FSC by 50%
- No F crashes recorded

There does not appear to be any significant road safety issues linked to the reduction in SSD at the site.

5.3.4 Illawarra Highway, Railway Crossing, Robertson

Crash type, severity and location

Overall there was a 100% reduction in crashes post-installation given there have been no crashes recorded in the three years and seven months analysed post-construction.

The prevailing crash types pre-installation were:

- Head-on, left hand bend
- Off straight, left
- Off right, left hand bend
- Off left, left hand bend

Within the pre-installation study period, head-on crashes at the site led to the death of one and injury of another. In the extended pre-installation study period there was an additional fatality and two injuries related to head-on crashes. The crashes mostly involved motorcyclists.

Although no crashes have been recorded in CrashLink there have been a number of collisions at the site, shown in Figure 18. These collisions have mainly occurred in the eastbound direction into the CCSB.

The pre-installation crashes are concentrated around the apex of the curve and occur in the eastbound direction, in the downhill direction. This is consistent with the site observations.

As with all sites, metal barrier curve alignment tags were fixed to the concrete barrier at the site. This is shown in Figure 19. If a rider was to come off the bike and strike the metal tag there could potentially be catastrophic consequences.

The installation has had a net benefit on road safety.

Drainage

The wet to dry distribution was even for the pre-installation period with two crash incidents in both conditions. The FSC was much higher for dry road surface conditions, being 23 times greater than wet conditions. This is likely associated with the route being popular to motorcyclists. The two dry incidents both involved motorcycles which resulted in high severity crashes.

The installation has not increased the frequency or severity of wet crashes and does not appear to have caused drainage issues which could compromise road safety at the site.

SSD

The calculated SSD achieved was 64% of the required value on right hand curves at the site. Nearside shoulder widths did not permit vehicles to manoeuvre around any objects on the roadway. It is unlikely there would be small (<0.2m) objects such as rocks, branches etc. given the sites location in embankment, clear of trees and on structure.

As there were no recorded crashes at the site post-installation, there were no right hand curve crashes to analyse. In association with the observed damage at the site, there is very little damage on the right hand curve (westbound).

It is possible that due to the high level of constraint and visual intrusion the old view of the shy line effect, as mentioned in section 2.2.2, may come into play. This may explain the significant reduction in crashes.

Therefore, there does not appear to be any significant road safety issues linked to the reduction in SSD and inadequate shoulders width for manoeuvre at the site.

5.3.5 Great Western Highway, Mount Victoria Pass (top)

Crash type, severity and location

Overall, there was a 100% reduction in crashes post-installation given there have been no crashes recorded in the one year and three months analysed post-construction.

The prevailing crash types pre-installation were:

- Off right, left hand bend
- Head-on, left hand bend
- Off left, left hand bend

Within the pre-installation study period, head-on crashes at the site led to the death of three and injury of another three. In the extended pre-installation study period there was an additional fatality and 37 injuries related to head-on crashes. In one instance there was a head-on crash which injured 10 people. This site had an extremely high frequency of head-on crash. In the pre-installation period,5 out of 11 crash instances were head-on. Interestingly, most of these crashes were NI or I. The most significant FSC is attributed to an out of control truck which led to a double fatality. This crash only involved the one vehicle but it appears it was a cross centreline manoeuvre.

The pre-installation crashes are likely to be attributed to the long, steep grade and substandard horizontal curve.

Although no crashes have been recorded in CrashLink, there have been a number of collisions at the site, shown in Figure 20. These collisions have mainly occurred in the westbound direction into the CCSB in keeping with the pre-construction data. There was also evidence of collision in the uphill, eastbound direction into the CCSB and into the roadside guardrail. This could be explained by overcorrection when the vehicle is initially heading toward the back of the curve (toward guardrail).

The pre-installation crashes are concentrated around the apex of the curve and all occurred in the westbound direction, in the downhill direction.

The installation has had a net benefit on road safety.

Drainage

Longitudinal drainage was provided at the site.

The wet to dry distribution was close to even for the pre-installation period with six wet and five dry crash incidences. The FSC was much higher for dry road surface conditions being 25.6 times greater than wet conditions.

The installation has not increased the frequency or severity of wet crashes and does not appear to have caused drainage issues which could compromise road safety at the site.

SSD

The calculated SSD achieved was 48% of the required value on right hand curves at the site.

As there were no recorded crashes at the site post-installation, there were no right hand curve crashes to analyse. There was damage observed on site in the eastbound direction (on the right hand bend).

There is little evidence to suggest the barrier installation has led to road safety issues linked to the reduction in SSD at the site.

5.3.6 Great Western Highway, Mount Victoria Pass (bottom)

Crash type, severity and location

Overall, crash incidence for:

- NI decreased by 66.7%
- I increased by 200%

- F increase from zero to one

This resulted in an overall FSC increase of 2100%. This significant cost increase is associated with a fatal crash which occurred post-construction and the increase in injury crashes.

The prevailing crash type pre-installation included:

- Off left, right hand bend
- Off left, left hand bend

The major crash type post-installation included:

- Off left, right hand bend, incidence increase of 50%, FSC increase of 4125%
- Off right, right hand bend, incidence remain the same (NI to I) FSC increase of 1560%

There were only two instances of head-on collisions, which injured two people during the extended pre-installation period.

Given there was little evidence of a head-on crash issue at the site, considerable road safety improvement with the addition of the CCSB would not be expected and is evident in the post-construction analysis. The real issue appears to be the tight horizontal geometry at the bottom of a very long and steep grade. The treatment may have created another issue by pushing the westbound traffic closer to the back of the curve, giving less area for recovery in order to achieve SSD. The westbound approach channelisation directed the traffic more sharply toward the back of the curve. The channelisation curvature is on adverse crossfall which may have shifted loads in trucks leading to instability. 50% of the crashes recorded were heavy vehicle crashes - in keeping with this hypothesis. The channelisation was removed before the time of site investigation.

Most crashes are concentrated around the apex of the curve, mostly in the westbound direction. The site observations as shown in Figure 21 indicate there have been crashes on the eastbound carriageway. The curve is very sharp even for a vehicle approaching on an upgrade. It appears control can be lost toward the back of the curve, into the barrier.

The installation has had a negative impact on road safety.

Drainage

Longitudinal drainage was provided at the site.

The number of wet road surface crash incidence has increased by 100% and dry has remained the same. The severity of the crashes for both wet and dry crashes was increased significantly. This resulted in wet crash FSC increasing by 1660% and dry conditions increasing by 19290%. This extreme dry crash increase is attributed to the fatality mentioned previously, which occurred in dry conditions.

Although wet crashes doubled, from two to four crash incidents, it is unlikely the problem is drainage related.

SSD

SSD was provided at the site by incorporating a wide median on the right hand bend (westbound). The calculated SSD achieved was therefore 100% of the required value on the right hand bend.

Post-installation, right hand curve crashes had the following characteristics:

- NI crash incidence decreased by 50%
- I crash incidence increased by 200%
- F crash incidence went from zero to one

Given the site provides the required SSD, the increase in crashes is not likely related to any SD issues. The provision of SD is likely to have led to the increased incidence as previously mentioned.

5.3.7 Great Western Highway, Hartley

Crash type, severity and location

Overall, the crash incidence for:

- NI decreased by 73%

- I decreased by 62.5%
- F remained at zero

This resulted in an overall FSC reduction of approximately 75%. This significant cost reduction is indicative of the reduction in the number of people injured at the site.

The prevailing crash type pre-installation included:

- Head-on, right hand bend
- Off left, left hand bend

Interestingly, the head-on crashes at the site were as a result of eastbound vehicles crossing the centreline, likely attributed to an overcorrection movement. This crash type was very common contributing to 50% of all injuries pre-installation. One single crash resulted in the injury of seven people.

The major crash type post-installation included:

- Off right, left hand bend, from zero to three crash incidents, one NI and three I
- Off left, left hand bend incidence decrease of 86%, FSC reduction of 84%

Head-on crashes have been eliminated at the site and the left hand curve has become the leading cause of crashes for westbound, downhill traffic. The grade and associated speed into the substandard curve is still a problem at the site. The barrier is now taking the hits instead of the errant vehicle crossing into oncoming traffic.

Crashes have remained scattered along the site but were much less dense post-installation. Post-installation crashes have a higher proportion of westbound crashes compared to pre-installation crashes.

Observed hits on the barrier, depicted in Figure 23, show more collisions with the barrier for eastbound travelling vehicles. This is inconsistent with the CrashLink data but is consistent with the pre-installation data. It is possible that vehicles are still overcorrecting into the barrier resulting in property damage and the vehicle remaining driveable.

The installation has had a net benefit on road safety.

Drainage

The number of wet road surface crash incidents remained the same and dry incidents reduced by 76%. The severity of wet crashes decreased and resulted in an FSC reduction of 81%.

The installation has not increased the frequency or severity of wet crashes and does not appear to have caused drainage issues which could compromise road safety at the site.

SSD

The calculated SSD achieved 54% of the required value on the right hand curve at the site.

Post-installation right hand bend crash analysis resulted in:

- NI crashes increased from zero to one
- I crash incidence increased by 100% and in FSC by 100%
- F crash incidence reduced by 100%

As previously mentioned, site observations revealed collisions with the barrier on the right hand bend (eastbound traffic). As such, there could be a minor risk of road safety issues linked to the reduction in SSD at the site.

5.3.8 Great Western Highway, River Lett Hill

Crash type, severity and location

Overall, crash incidence for:

- NI increased by 600%
- I increased by 475%
- F remained at zero

This resulted in a total FSC increase of approximately 317%. This major cost increase is associated with the rise in NI and I crashes at the site.

The prevailing crash type pre-installation included:

- Head-on, left hand bend
- Off right, left hand bend
- Off left, right hand bend

During the extended pre-installation period there were 12 head-on crashes recorded which led to the injury of 14 and fatality of two.

The major crash type post-installation included:

- Off right, left hand bend, incidence increase of 350%, FSC increase of 4125%
- Off left, right hand bend, incidence increase of 533%, FSC increase of 4125%
- Off left, left hand bend, incidence increase of 750%, FSC increase of 4125%
- Off right, right hand bend, incidence increase from zero crashes to nine NI and three I

Most crashes are concentrated around the apex of the curve, mostly in the westbound direction post-installation. The site observations, as shown in Figure 24, are consistent with the CrashLink data, with collisions being scattered throughout the entire site but concentrated around the curves.

Based on the data analysed there has been a negative impact on road safety. However, pre-installation period crash data did not include any fatalities or display a high frequency of injury crashes. This is in contrast to the extended study period crash data which had a high occurrence of injury crashes and two fatal head-on crashes which killed three people. Had there been a single fatal crash in the analysed pre-installation period the performance would have been positive.

The installation has had a negative impact on road safety when considering the pre and post study periods. The system however has prevented any fatalities, which were prevalent in the extended period, from occurring.

Drainage

Longitudinal drainage was not provided at the site.

The number of wet road surface crash incidents were increased by 1100% and dry incidents have increased by 200%. The severity of the crashes for both wet and dry crashes increased significantly. This resulted in wet crash FSC increasing by 195% and dry conditions increasing by 820%. This significant crash increases for both pavement conditions could be attributed to the quantity in overall crash frequency and a possible drainage issue.

The increase in wet crashes could also be linked to debris and growth which was observed in the slots underneath the slip formed barrier. Blockage of the slots could lead to surface water not discharging toward to centre of curve. Aquaplaning and the associated loss of vehicular control may justify the significant increase in crashes post-installation.

As the road safety treatment was supplemented with a reseal, it is unlikely that a poor road surface aided in the increase of crashes in wet weather.

Ice and snow conditions prevalent at the site would further worsen drainage when combined with blockage of the slots.

It is likely that drainage issues have led to a compromise in road safety at the site.

SSD

The calculated SSD achieved varies between 34% and 54% of the required value on right hand curves at the site.

Post-installation right hand bend crash analysis resulted in:

- NI crash incidence increased by 950% and increased in FSC by 950%
- I crash incidence increased by 1400% and increased in FSC by 1400%
- F crash incidence remained at zero

The major increase in right hand curve crashes could indicate the compromised SD has led to a decrease in road safety at the site. The observation of road kill also correlates to this hypothesis.

5.3.9 Great Western Highway, South Bowenfels

Crash type, severity and location

Overall, the crash incidence for:

- NI decreased by 60%
- I decreased by 33.3%
- F decreased by 100% to zero

This resulted in an overall FSC reduction of approximately 98%. This significant cost reduction is indicative of the reduction in the injuries and fatalities at the site.

The prevailing crash type pre-installation included:

- Head-on, right hand bend, triple fatality and injury
- Off right, right hand bend, single fatality

The head-on crash at the site was as a result of eastbound vehicles crossing the centreline, likely attributed to an overcorrection movement.

The prevailing crash type post-installation included:

- Off left, right hand bend, incidence increased by 100%, FSC reduction of 106%
- Off right, right hand bend, incidence remained the same but FSC reduced by 98%

The increase of ‘off left, right hand bend’ is likely unrelated to the installation of the barrier and more as a result of physical forces on the curve.

All fatalities including head-on crashes have been eliminated at the site. It is worth noting that both fatal crashes involved heavy vehicles. This further supported the necessity for a rigid barrier type.

The remaining post-installation crashes are mainly attributed to the right hand bend which is on a downhill grade, but overall these crashes are not nearly as frequent or severe as the pre-installation crashes.

Crashes have remained scattered along the curve and remain quite evenly distributed between both directions of travel. This is in keeping with the site observations as shown in Figure 25.

The installation has had a major net benefit on road safety.

Drainage

The number of wet road surface crash incidents reduced by 37.5% and dry incidents reduced by 100% to zero. The severity of the crashes for wet crashes decreased and resulted in an FSC reduction of 98%.

The installation has not increased the frequency or severity of wet crashes and does not appear to have caused drainage issues which could compromise road safety at the site.

SSD

The calculated SSD achieved 59% of the required value on the right hand curve at the site.

Post-installation right hand bend crash analysis resulted in:

- NI crashes increased from zero to one
- I crash incidence increased by 100% and in FSC by 100%
- F crash incidence reduced by 100% to zero

There has been a slight increase in right hand curve crashes which could be as a consequence of the barrier installation, particularly given road kill was observed at the site. This marginal increase has not appeared to significantly impact road safety.

6 CONCLUSIONS AND RECOMMENDATIONS

Concrete central safety barriers (CCSB) were found to be an effective solution at eliminating head-on crashes at all nine sites investigated. Five of the analysis sites had a total factored severity cost (FSC) reduction of 90% or more. As such, the installation of CCSB has been an effective incremental solution at these sites.

For seven of the nine sites investigated, general road safety was observed be improved at highly constrained sites with the installation of CCSB. This is the case even with the inherent reduction of SSD and higher severity index of other safety barrier types. This is subject to provision of sufficient recovery for errant vehicles, particularly at bends end of steep downgrades, and appropriate treatment to ensure drainage of surface water is within tolerable limits.

All six of the sites with pre-cast CCSB installed had an overall positive impact on road safely even though the system is currently not an accepted barrier system in NSW.

The treatment does not solve the problem at the site but instead alleviates the consequences. As expected, the study generally confirms that NI crashes can tend to increase as a result of the barrier installation. The crash data generally confirmed that F crashes were turned into I crashes and I crashes turned into NI crashes.

Although the treatment may be effective when used appropriately, it should not be the initial or only solution investigated, particularly where sites do not have a high level of constraint. In addition, if there is not a problem with head-on crashes, CCSB could create other issues with higher risk and should not be used.

It was found that wet crashes could be increased post-installation of CCSB if drainage is not adequately considered in the design phase and/or the drainage slots onsite are not properly maintained. In particular cast in-situ Type-F barrier without longitudinal drainage was observed to increase the occurrence and severity of crashes. This could be related to aquaplaning issues at the site post construction. Road surface water needs to be analysed in the design phase to check flow depths do not reach a point where aquaplaning occurs. It is also recommended that this analysis be checked with full blockage of slots in order to observe the worst case scenario.

SSD is a conservative model which is dependent on an object being on the roadway. At sites with very low horizontal geometry, standard recovery width at the back of the curve, shoulder width, should not be sacrificed to facilitate SSD. Physical forces are absolutely in contrast to SSD, which is provisional to an object being on the road.

The analysis revealed there was also no clear trend which related the degree of SSD reduction to crashes. In fact it was found that some sites with highly constrained sight had a lower crash risk. This could be linked to the shy line effect where drivers may slow down or shy away from the barrier in response to its visual intrusion.

Not meeting SSD should not rule out a project’s development but should rather be progressed using a risk based approach.

There is potential that the reduction in SSD may have led to an increase in NI and I crashes at three of the nine sites, as these. These sites had an increase (pre to post-installation) in the total FSC on right hand bends.

A risk analysis needs to be conducted to identify any objects which could threaten motorists. Maintenance crews should be engaged to observe and remove any objects which pose a risk.

The analysis and site observations revealed there is likely a relationship between downhill grades and an increased crash risk post barrier installation. Crash damage observed on CCSB tended to be concentrated at the back of left hand curves at the end of steep grades. However, this analysis did not directly assess the relationship between crashes, grade and radius using the crash data and so additional research is required to quantify this risk.

The severity of head-on crashes was observed first-hand in the CrashLink data at the sites reviewed. There were a number of crash instances which killed multiple people and/or injured multiple people pre-construction. Head-on crashes involve at least two vehicles in a very high severity collision and so are more likely to lead to catastrophic consequences for more people.

Every hit marking on the CCSB observed during the site visit could have been a potentially fatal head-on crash. Based on this alone, the installation of the barrier has had positive impact.

As such, the installation of CCSB can be a suitable incremental solution at constrained sites which experience cross-centreline crash types.

6.1 Recommendations

- Cast in-situ concrete barriers should not be installed without longitudinal drainage unless there is modelled evidence the system will not cause aquaplaning with some degree of blockage applied to the slots.
- Where SD is limited, a risk assessment to identify likely objects which could enter the roadway should be conducted. These objects such as fauna could be eliminated from the roadway, in this instance by using fauna fences and underpasses.
- More testing of precast concrete systems should be conducted to enable its use as a permanent barrier system.
- No barrier system should be viewed as maintenance free. All systems require maintenance it is just to varying degrees.
- Operating speed analysis should be conducted, particularly where long, steep grades lead into tight horizontal radius curves. To facilitate understanding and accurate review, vertical grading values need to be displayed on long section plans even when based on existing grading.
- At sites with a risk of motorcycle crashes with the nearside guardrail, installation of rub rail beneath the primary rail may be beneficial.
- At sites with a high volume of cyclists/motorcyclists, metal curve alignment markers on top of the barrier should be replaced with plastic or flexible products to reduce injury risk to errant cyclists.
- CrashLink could be more powerful with the addition of data fields for road geometry including vertical grades, horizontal curve radius, direction of curve, pavement conditions etc. Locating data by Assetloc chainages would also make the data much more usable.
- Road user movement codes need to reflect the crash scenario

6.2 Further study

- Complete analysis on sites with GR and WRSB central safety barrier. Compare and contrast results
- Vertical grades relationship to crashes post installation of central barrier – is there a shift in location of crashes post barrier installation?
- Speed and lane discipline analysis before-and-after CCSB installation
- Detailed analysis of drainage at the study sites
- Relationship between crashes, vertical grades, length of grade and horizontal curves
- Shy line effect analysis at the sites. Vehicle speeds and lane discipline would be required.
- Vertical grading should be shown on long section drawings when adopting existing vertical geometry
- Are higher severity crashes recorded on multi-lane carriageways adjacent concrete barriers? Analysis of in-service entry angle severity index.
- Crash testing of pre-cast barrier systems including bolt connections and anchorage.

6.3 Knowledge application site, Princes Highway, East Lynne

The East Lynne site consists of reverse horizontal curves which pass over Middle Creek, in a two-way, two-lane, rural road environment. The site is approximately one kilometre in length and is located 96.1km to 97.1km from Nowra. The site is shown in Figure 35.

The site is characterised by:

- 100km/h posted speed
- Two-way, two-lane, lane widths approximately 3.5m
- Tight horizontal geometry (300m and 220m radius curves – both with 75km/h advisory speed signs)
- Grades ranging between 5-7% with what appears to be a substandard vertical curve at the north
- AADT of approximately 3300 with 15% heavy vehicles

- Narrow bridge (10m formation width)
- Unprotected roadside hazards such as non-frangible trees, culvert headwalls etc. within clear zone.
- Non-traversable batters in close proximity to travel lane (greater than 4:1)
- Insufficient shoulder widths (2m shoulders)
- There are areas of unsealed wide verge areas which could be pertinent to road widening.

Figure 35 – Princes Highway, East Lynne reverse curves over Middle Creek

6.3.1 Treatment considerations

Constraints

The major site constraints include:

- Low traffic volumes – the low traffic volumes at the site will make it difficult to obtain a high benefit to cost ratio and therefore may not attract significant funding.
- Structures (bridge and culverts) – there is an existing narrow bridge over middle creek which appears to be quite old. The structural integrity of the bridge is unknown. Widening or replacement of the bridge would incur significant

investigations and cost and time implications for construction. The bridge may have heritage value. Any widening would require extension of cross drainage culverts.

- Cut and fill embankment – widening of road formation will require widening of existing cut and fills. This is likely to have an impact on adjacent property boundaries.
- Property boundaries – property acquisition can be time consuming and costly
- Environmental – an environmental assessment would need to be conducted.

Crash history

Crash data was obtained from CrashLink. The time frame assessed was from 1 June 1996 until 31 March 2014, the duration of data available for the site.

In total there were 35 crashes including one fatal and fourteen injury crashes. 33 of the 35 crashes occurred on the curves. There were two head-on crashes. One was a non-injury (tow away) and the other was the fatality. The fatal crash occurred in December 2009 where a south bound petrol tanker crossed the centreline at the 220m radius curve and collided with three north bound vehicles. As a result, four were killed and five injured. This crash was not recorded as a head-on crash but rather as an ‘out of control on bend’ crash – as was the other crash which involved two vehicles travelling in opposing directions.

The most common crash type was ‘off road on curve, hit object’. Sixteen of these crashes were ‘off right, left hand bend into object’. These vehicles had therefore crossed the centreline and impacted an object adjacent the opposing lane of traffic. It is clear there is an issue with errant cross-centreline manoeuvres at the site. It is fortunate there have not been more head-on crashes. This is likely linked to the relatively low traffic volumes in this section of road.

The road geometry is likely to be the biggest contributor to these road crashes. The high volume of cross-centreline manoeuvres could be as a consequence of curve overcorrection.

For all object-hit crashes, the objects include:

- Tree/bush

- Embankment
- Drain/culvert
- Fence
- Sign
- Wombat

88.6 percent of crashes occurred in wet road surface conditions. It is possible there is already a drainage issue at the site either from poor surface drainage or poor road surface condition.

Crashes most commonly involved cars.

Additional investigations which would need to be carried out include:

- Detailed survey
- Bridge structural capacity
- Road surface drainage analysis
- Traffic composition – heavies, motorcycles, passenger cars etc.

6.3.2 Treatment options

Realignment

The only option which addresses the suspected real issue at the site is a full realignment. This option should always be considered first. In this scenario a full realignment to 100km/h standard would be at great cost and would be more likely a long-term target. Given the low traffic volumes and assumed low growth it is unlikely this scale of project would attract funding. The option would be viable if there were structural issues with the existing bridge or if there was motivation to upgrade the adjacent sections of road geometry.

An interim solution is necessary until the long stretch of adjacent, poor standard geometry can be improved.

Do nothing

Given there is only one occurrence of a fatal crash at the site, this could be a viable option. When considering the high occurrence of errant, cross-centreline manoeuvres, there is a high risk of potentially devastating collisions.

Widen shoulders

The high distribution of suspected overcorrection manoeuvres could be as a consequence of the narrow shoulders. Widening of shoulders may reduce the overcorrection manoeuvre and therefore reduce the risk of head-on crashes.

Wide centreline treatment

Wide centreline treatment could mitigate some of the crashes at the site by providing more width for recovery. This option would require widening. This widening should also accommodate widened shoulders. The treatment could be supplemented by nearside and offside rumble strips, but in this case the site is in too close in proximity to residents.

6.3.3 Central barrier treatment in narrow median

Given the fatal crash and high occurrence of errant, cross- centreline movements, a central safety barrier along with some additional widening is likely to improve road safety at the site. Central barriers essentially eliminate cross-centreline crashes, significantly reducing the risk of potentially catastrophic head-on crashes from occurring.

The installation of a central barrier will not completely fix this issue but is intended to reduce the severity of the crashes.

In order to determine which barrier system is the most appropriate for the site, there would need to be investigations into the following:

- The amount of widening allowable – dependent on funding, integrity of the bridge to be maintained with widening or the requirement for a full bridge replacement
- The budget – initial and ongoing.

- Composition of traffic – if there is a high volume of motorcyclists, wire rope may not be appropriate. Given there is no record of motorcycle crashes, this may not be an issue.

Because of the narrow formation of the road, all central barrier options will require widening. The widening should also facilitate a 2.5m nearside shoulder. This shoulder width will accommodate manoeuvres around an object on the road and would allow provision of low speed contraflow.

SSD will not be met at this site with the installation of a barrier. Sight distance over barriers should be checked but as the worst case, a regime to remove objects which may enter the roadway should be developed and maintained. The driver should be able to at least see the top of another vehicle as it is the most common object on the road.

Additional studies required to target issues related to the introduction of a central barrier include:

- Roadside object analysis
  - Fauna
  - Rocks
  - Trees
- Surface drainage assessment
- Operational speed assessment
- Pavement investigation

Concrete barrier

Concrete barrier in narrow median would be applicable given the narrow corridor and relatively high percentage of heavy vehicles. Even though concrete barrier has negligible deflection, widening would still be required at the site. Central concrete barrier in a 1.6m median with a 2.5m nearside shoulder should be adequate.

Both concrete options would require consideration of road surface drainage and SD. As the site is located in close proximity to an established State Forest and there has been an animal strike crash recorded, fauna fencing should be considered. Large trees also overhang the roadway and could drop branches onto the roadway, becoming a hazard to drivers in an area where SD is limited. This treatment should be supplemented by trimming or removal of nearby trees.

Over the long term, concrete would be less costly as the system does not usually require repair post collision.

Both concrete systems should not include metal curve alignment tags and should be further delineated with painted markings, as discussed in section 2.2.3.

Cast in-situ

Cast in-situ concrete would be the best option for:

- Reduced widening
- No encroachment
- Limited or no property impact
- High containment
- Reduced hazard exposure for maintenance and repair crews

However, given there might already be an issue with drainage at the site, the central barrier should be supplemented with longitudinal drainage. This would be at additional cost and require more time to construct.

This option would be quite expensive upfront, given it is likely that longitudinal drainage is required.

There could be conflicts with the boxing out of the existing pavement for the construction of the concrete plinth above culverts and on the bridge.

Pre-cast

Pre-cast Type-F system is not necessarily an approved permanent barrier system but has been assessed for application. A pre-cast system would be an appropriate option to achieve:

- Reduced widening
- Low encroachment (approximately 0.5m)
- Limited or no property impact

- High containment
- Quick installation and temporary removal
- No requirement for additional drainage (subject to modelling and maintenance regime to clear slots)
- No impact on pavement
- Minimal repair
- Reduced hazard exposure for maintenance and repair crews

Installed in a 1.6m median, the system could encroach the opposing lane by 0.5m based on a deflection of 0.9m as per Table 14.

WRSB

Given the horizontal radii of the curves, WRBS could be implemented at the site, although the system is very close to its physical limits of operation, mentioned in section 2.2.1. The system would offer lower severity index and may result in less injury post installation.

WRSB could be installed in the same median width as concrete systems, but a collision would result in encroachment into the opposing lane up to 0.8m. Barrier hardware could also remain in the adjacent lanes post collision, requiring repair. For this reason it is believed a median width of 2m would be more appropriate.

There could be conflicts with the boxing out of the existing pavement for the construction of the concrete plinth above culverts and on the bridge.

Guardrail

Guardrail could be installed in a 1.6m median. With a median of this width, a collision could encroach the opposing lane by 1.25m.

As with WRSB the barrier does not remain fully functional post collision and so repair is required. Repairing the barrier under traffic would require temporary contraflow conditions in order to keep crews adequately separated from the live traffic and outside of the deflection zone.

The posts would require semi-rigid connections to the pavement. These could conflict with the bridge deck and culverts. Additional investigation would be required to assess this.

6.3.4 Recommendation

For this case, with very limited site information available, a pre-cast, Type-F barrier is the recommended system. The recommendation is based on the system not requiring the penetration of hardware into the existing pavement for long lengths and can offer good containment in a narrow median with moderate encroachment post collision.

In planning for the installation, consideration should be given to assess potential surface drainage issues by:

- Modelling the surface drainage with the system and checking with a high degree of blockage to the slots.
- Development of a routine maintenance regime should be developed to clear slots.

The risk of SSD related crashes will be lessened if roadside objects are managed. These can be managed by provision of:

- Fauna fencing and separated fauna crossings – possibly through or under the existing bridge.
- Smooth finishing of cut batters or catch fences where this cannot be achieved.
- 2.5m shoulder to enable evasive manoeuvres to avoid objects.

Given the uncertainty with approvals of pre-cast Type-F system, the suggested next best option would be WRSB given its narrow hardware footprint, lower severity index and low initial cost.

It is possible the median could be locally narrowed, from 2 to 1.6m over the bridge. Given the short length of bridge, the consequential risk of encroachment in the narrow section would be low. This narrowing would reduce costs of the system.

It is recommended that whichever treatment is adopted, if any, the treatment is analysed pre- and post-installation to quantify its performance. More certainty of analysis would be gained with before-and-after measurement and collection of data, for example:

- Detailed crash reports
- Speed data
- Traffic composition
- Lane discipline (camera)
- Object observation
- Rainfall event data

6.4 Limitations

The road is a complex environment combining physical, environmental and behaviour aspects.

The analysis was restricted by CrashLink data, and site observations which were carried out for approximately 45 minutes at each site. CrashLink data is limited by the person who enters the data. This data is not always accurate, particularly in regards to location and the crash type code.

The analysis is therefore not conclusive but involves hypothesising based on the author's knowledge of roads, the crash data and the observations.

Crash type and severity, right hand curve and wet crashes analyses for pre- and post-installation were not calibrated for traffic volumes. An increase or decrease in crashes could be linked to an increase or decrease in traffic. This is unlikely, as all sites assessed have had low growth or decline and consequently have quite stable volumes.

The right hand curve analysis has limitations because the crashes could be as a consequence of a number of different factors evident post-installation such as:

- An increase in speed
- Drainage
- Road surface conditions

Therefore, an increase in right hand crashes may not infer a SSD issue.

The drainage analysis has limitations given the instances and quantity of rainfall was not calibrated for pre- and post-installation cases. For example, an increase of wet crashes might be as a result of a higher frequency of rainfall for the post-installation period.

All graphs produced, except the SSD reduction vs. FSC graph, were not calibrated for study duration or traffic volumes between sites and are therefore not relative to each other.

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APPENDIX A: PROJECT SPECIFICATION

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111/4112 Research Project
Project Specification 2014

For: **Katherine Holzner**

Topic: Concrete Central Safety Barriers in Constrained Road Environments

Supervisors: Assoc. Prof. Ron Ayers

Peter Ellis, Roads and Maritime Services

Sponsorship: Roads and Maritime Services, NSW

Project Aim: Understand the performance of concrete central safety barrier in constrained road environment by analysing pre and post-installation crash data. The main focus on this study is the general increase/decrease of overall crashes and the impact on road safety as a consequence of restricted surface drainage and sight distance.

Programme: **Issue B, 27 October 2014**

1. Research international and national studies/standards/regulations on central barrier systems, cross centreline crashes, sight distance models, carriageway separation treatments, fatigue management, shy line effect.

2. Critically evaluate current road safety treatments at sites of cross centreline crashes.

3. Analyse pre and post-installation crash data to assess the overall performance of the barrier in mitigating crashes

4. Evaluate data findings with respect to crash relationship to stopping sight distance model (right hand curve analysis and SSD reduction vs. crash risk) and impact on surface water drainage (wet and dry crash analysis)

As time and data permits:

5. Apply the knowledge to the test site and evaluate expected outcomes.

Agreed:

__________ (student) __________, __________ (supervisors)

Date: 9/11/2014 Date: 9/11/2014 Date: / /

APPENDIX B: SITE DATA TABLE

Table 16 – Site data

Site	Batemans Bay*	Dalmeny*	Yowaka*	Robertson	Mount Vic. (Top)*	Mount Vic. (Bottom)*	Hartley	River Lett Hill*	South Bowenfels
Road	Princes Highway (HW1)	Princes Highway (HW1)	Princes Highway (HW1)	Illawarra Highway HW25	Great Western Highway (HW5)	Great Western Highway (HW5)	Great Western Highway (HW5)	Great Western Highway (HW5)	Great Western Highway (HW5)
RMS Region	Southern	Southern	Southern	Southern	Sydney / Western	Western	Western	Western	Western
Route direction	North -South	North -South	North -South	East-West	East-West	East-West	East-West	East-West	East-West
Speed Zone	90km/h	100km/h	100km/h	60km/h	60km/h 40km/h for trucks	60km/h 40km/h for trucks	80km/h	80km/h	90km/h
AADT	8,050	4,100	3,900	3,000	11,500 vpd -2011	11,500 vpd -2011	10,000 vpd	10,000 vpd	10,000 vpd
Percentage Heavies	8%	9%	11%	9%	25%	25%	18%	18%	18%
Length of barrier	969m	760m	615m	760m	190m	265m	310m	1180m	400m
Minimum horizontal radius required (non-grade adjusted)	340m	460m	460m	90m	90m + grade correction	90m + grade correction	240m	240m	340m
Vertical grade	5-10% down to south 7.5% at southern NORTH	7% down toward south	1-5% down toward south, Crest at curve 1	7% down toward east	Max 11% for WB Min 5%	Max 11% for WB Min 5%	10%	7-10%	7%

Site	Batemans Bay*	Dalmeny*	Yowaka*	Robertson	Mount Vic. (Top)*	Mount Vic. (Bottom)*	Hartley	River Lett Hill*	South Bowenfels
	BOUND approach								
Radius (post-construction)	155m 152m 180m 155m 170m 242m	185m 170m	132m 155m 155m (60km/h to 70km/h)	90m	50m 45km/h)	77.7m	170m 7% super	77m 180m 105m 70m 120m	300m 7% super
Vertical curve standard	50-80km/h	55 to 60km/h	65km/h to 75km/h	NA	NA	NA	NA	90km/h	NA
Lane Width	3.8m	3.5 – 3.8m	3.8m	3.5m	3.5 – 4.5m	3.5 – 4.1m	EB: 3.4m WB: 4.2m	3.5 – 4.2m	3.6m
SSD required	126m	165m	165m	64m	64m	64m	103m	103m	126m
SSD existing	95m	-	65m	-	-	-	-	-	-
SSD (1.1 – 0.2m) post construction	55m	55km/h (worst case) 80m (70km/h) on northern curve	40m	35m	31m	73m	56m	35 – 56m	73m
Manoeuvre SD required (1.1m to 0.8m) **	112.5m	125m	125m	75m	75m	75m	100m	100m	112.5m
Manoeuvre SD achieved for whole site?	No	No	No	No, inadequate shoulder width	Potential	Yes	NA	NA	No, inadequate shoulder width
Central Barrier Types	Type F (pre-cast)	Type F (pre-cast)	Type F (pre-cast)	Type F (pre-cast)	Type-F (cast in-situ)	Type-F (cast in-situ)	Type F (pre-cast)	Type-F with drainage slots (cast in-situ)	Type F (pre-cast)

Site	Batemans Bay*	Dalmeny*	Yowaka*	Robertson	Mount Vic. (Top)*	Mount Vic. (Bottom)*	Hartley	River Lett Hill*	South Bowenfels
Pavement drainage provided	No	No	No	No	Yes	Yes	No	No	No
Seal improvement	Reseal formation (14mm seal)	Reseal formation (14mm seal)	Reseal formation (14mm seal)	Reseal formation (14mm seal)	Reseal formation (14mm seal)	Reseal formation (14mm seal)	NA	Reseal entire formation (14mm seal)	NA
Terminal treatment	Tracc	Tracc	Tracc	Tracc	Tracc	Tracc	Quadguard	Tracc	Quadguard
Construction Date	February 2011 – August 2011	June 2008 – August 2008	August 2006 – November 2006	June – 12 August 2010	November 2011 to December 2012	November 2010 to April 2011	2001	May 2010 to June 2010	Oct-05
Dates Analysed	01/06/96 to 31/01/11 01/07/08 to 31/01/11 01/09/11 to 31/03/14	01/06/96 to 31/05/08 01/11/02 – 31/05/08 01/09/08 – 31/03/14	01/06/96 to 31/07/06 01/04/98 to 31/07/06 01/12/06 to 31/03/14	01/06/96 to 31/05/10 01/11/06 to 31/05/10 01/09/10 to 31/03/14	01/06/96 to 31/10/2011 01/07/10 to 31/10/2011 01/01/13 to 31/03/2014	01/06/96 to 31/10/10 01/12/07 to 31/10/10 01/05/11 to 31/03/14	01/06/96 to 31/12/00 01/01/02 to 30/06/06	01/06/96 to 31/03/10 01/09/06 to 31/03/10 01/07/10 to 31/03/14	01/06/96 to 31/08/05 01/12/05 to 31/03/14
Study Duration (either side of installation period)	2 years, 7 months	5 years, 7 months	8 years, 4 months	3 years, 7 months	1 year, 3 months	2 years, 11 months	4 years, 7 months	3 years, 9 months	9 years, 4 months
Total median width	1.6m	1.8m	1.8m	1.8m	1.6m	1.6m - 4m	1.6m	2.1m	1.6m
Number Lanes / Lane Width	SB: 1 NB: 2 (1 + climbing lane)	SB: 1 NB: 2 (1 + climbing lane)	SB: 1 NB: 1	WB: 1 EB: 1	WB: 1 EB: 2?	WB: 1 EB: 1	WB: 1 EB: 2(1 + climbing lane)	WB: 2 (1 + climbing lane) EB: 2	WB: 1 EB: 1
Near-side shoulder width	2.2m	2.5m	2.5m	1.0m	2.5m	2.5m	2.0m	WB: 0.5m – 3.0m + EB: 0.5m – 3.0m	2.0m

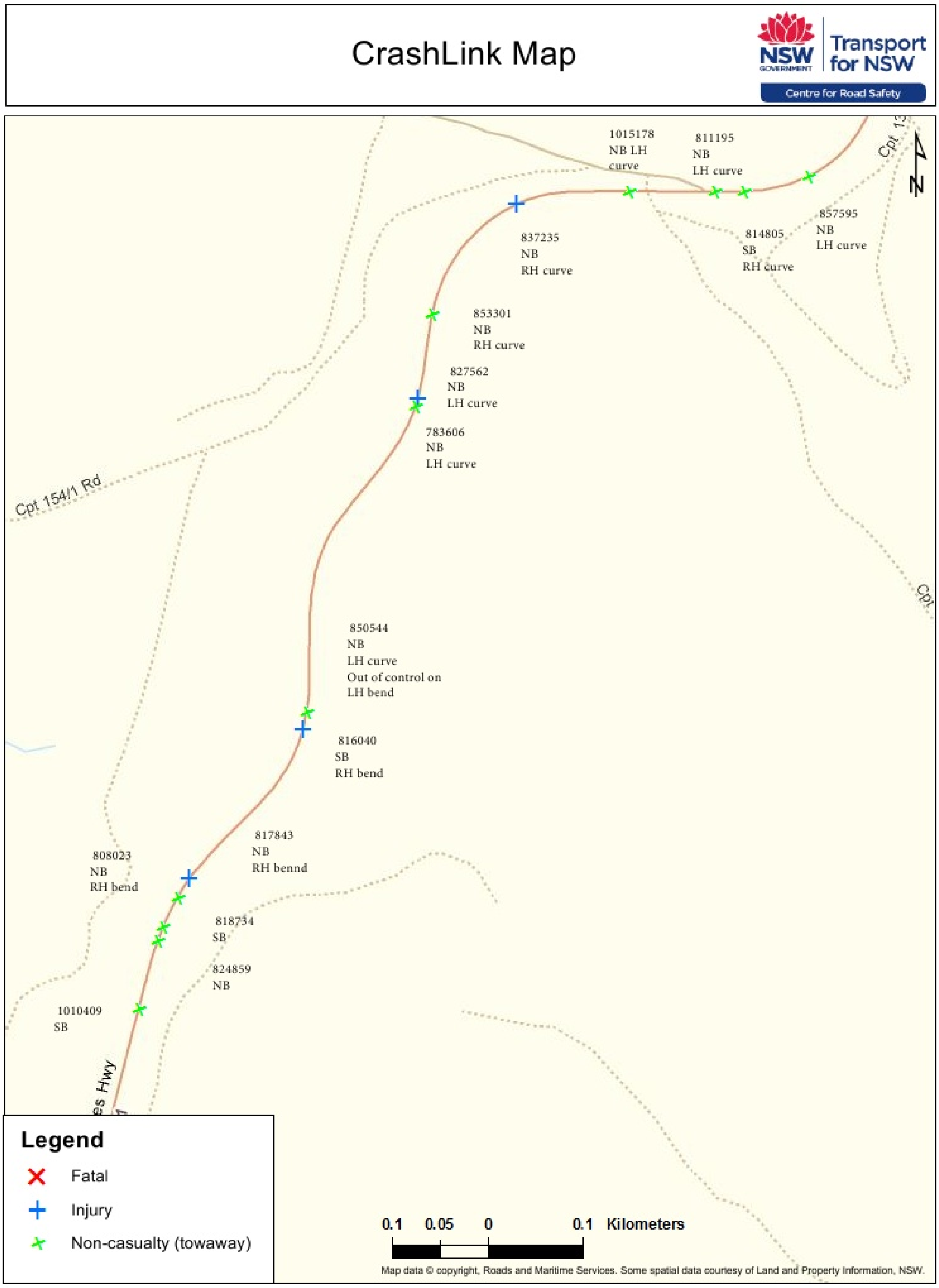
Site	Batemans Bay*	Dalmeny*	Yowaka*	Robertson	Mount Vic. (Top)*	Mount Vic. (Bottom)*	Hartley	River Lett Hill*	South Bowenfels
Off-side Shoulder Width	0.5m	0.6m	0.6m	0.6m	WB: 0.5 – 1.0m EB: 0.5m	3.0m	0.5m	0.4m	0.5m
Cost at time of construction	NA	$2,650,000 (estimate)	$1,712,000	$1,122,528	NA	NA	$150,600	$3,900,000	NA
Level of observed damage	Moderate	Low	Moderate, mostly on back of curve	High, mostly toward back of curve	High, gouges in pavement surface, hits on barrier mostly on westbound approach (downhill grade)	Moderate	High, barriers have been shifted and have markings for most of the site length	Very high, hits along most of the central and roadside barriers	Moderate
Observed non-fixed roadside objects	-	Tree logs at top of cutting,	Cyclists	Cyclists	-	Tree branches	-	Road kill	Road kill (wallabies)
Other observations	Skid marks	Bicyclists were observed riding in shoulders No audio tactile strips	Pavement surface polishing, cyclists observed	Fog, heavy rainfall, high volume of motorcyclists, flashing advisory speed sign at both approaches, metal barrier delineators, cyclists	Located between two RMS regions, gouge marks in pavement, trucks overtaking trucks, high speeds	High speeds, vehicle arrester bed	Crest at northbound approach limits sight to start of curve and barrier. Speed camera to west Intersection	Grass growth in drainage slots, High speeds Speed camera to east Incorrect CAM used on WB carriageway Painted CAM on barriers (trial)	Road surface ice monitoring system, grass growth in barrier drainage slots

* Site layouts available in Appendix B

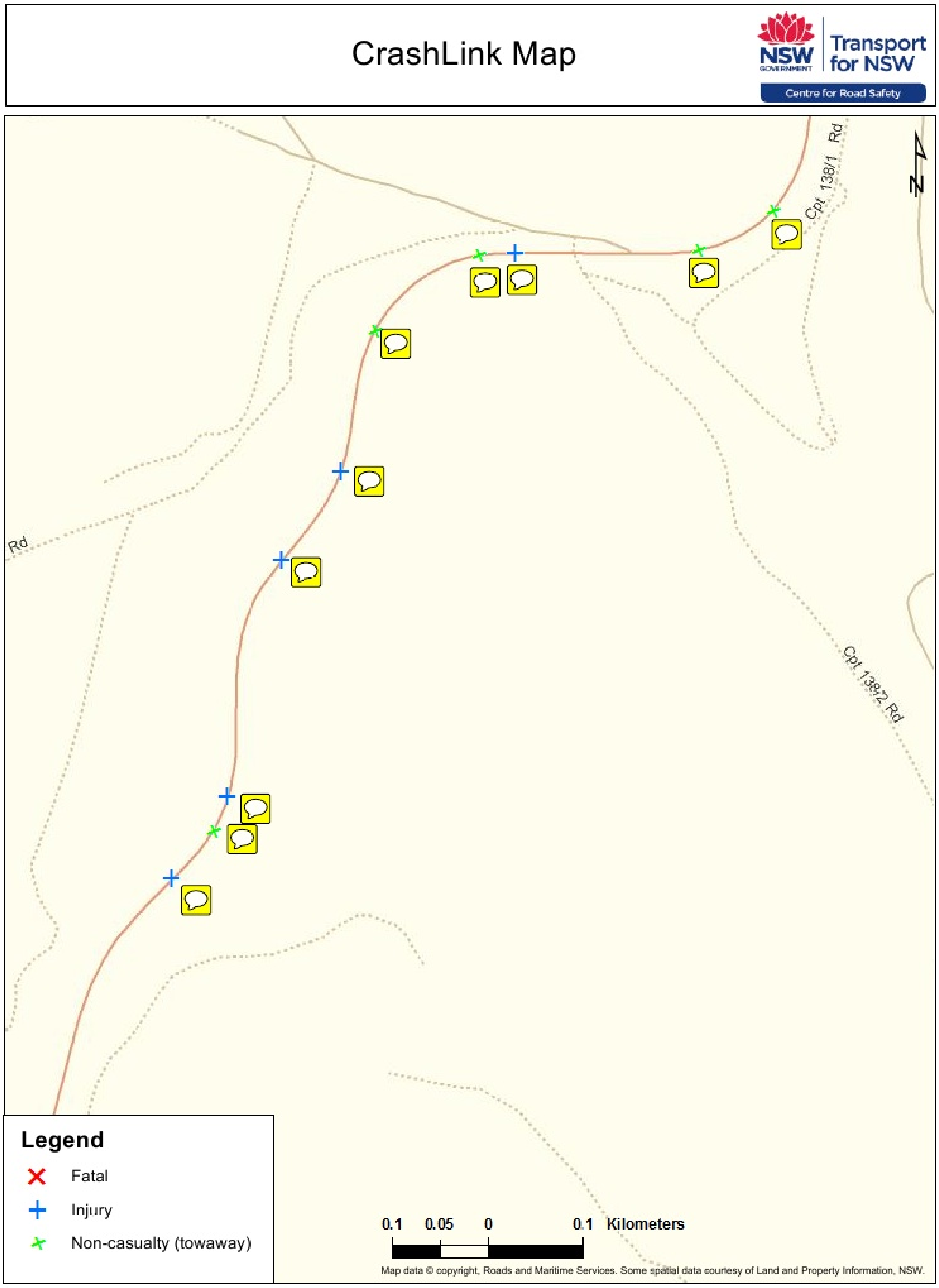
** As per Table 12with reaction time as 2.0 seconds considering the barrier sites generally for short stretches in rural environment

APPENDIX C: CRASHLINK DATA

Princes Highway, Batemans Bay



BATEMANS BAY - POST CONSTRUCTION


CrashLink Map
NSW GOVERNMENT
Transport for NSW
Centre for Road Safety
Cpt. 138/1 Rd
Cpt. 138/2 Rd
Rd
N
Legend
Fatal
Injury
Non-casualty (towaway)
0.1 0.05 0 0.1 Kilometers
Map data © copyright, Roads and Maritime Services. Some spatial data courtesy of Land and Property Information, NSW.

Summary Crash Report

# Crash Type		
Car Crash	14	93.3%
Light Truck Crash	1	6.7%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	1	6.7%
'Heavy Truck Crash	(1)	(6.7%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(6.7%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	1	6.7%
Non intersection	14	93.3%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	13	86.7%
Multi Vehicle	2	13.3%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	15	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	12	80.0%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	7	46.7%
Rain	7	46.7%
Overcast	1	6.7%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	10	66.7%
Dry	5	33.3%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	14	93.3%
Dusk	0	0.0%
Darkness	1	6.7%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	1	6.7%
Rear-end	1	6.7%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	1	6.7%
Out of control on straight	0	0.0%
Off road, on curve	2	13.3%
Off road on curve, hit object	8	53.3%
Out of control on curve	1	6.7%
Other crash type	1	6.7%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	14	93.3%
60 km/h zone	0	0.0%	100 km/h zone	0	0.0%
70 km/h zone	1	6.7%	110 km/h zone	0	0.0%

CRASHES	15	
Fatal crash	0	0.0%
Injury crash	4	26.7%
Non-casualty crash	11	73.3%

CASUALTIES	5	
Killed	0	0.0%
Injured	5	100.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	1	6.7%	4.2%
07:00 - 07:59	1	6.7%	4.2%
08:00 - 08:59	1	6.7%	4.2%
09:00 - 09:59	2	13.3%	4.2%
10:00 - 10:59	2	13.3%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	2	13.3%	4.2%
14:00 - 14:59	2	13.3%	4.2%
15:00 - 15:59	1	6.7%	4.2%
16:00 - 16:59	1	6.7%	4.2%
17:00 - 17:59	1	6.7%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	1	6.7%	8.3%

Street Lighting Off/Nil			% of Dark
1	of	1 in Dark	100.0%

Crashes		Casualties
1	2014	0
7	2013	3
7	2012	2

~ School Travel Time		
Involvement	3	20.0%

McLean Periods			% Week
A	2	13.3%	17.9%
B	1	6.7%	7.1%
C	8	53.3%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	1	6.7%	10.7%
G	1	6.7%	7.1%
H	1	6.7%	7.1%
I	0	0.0%	12.5%
J	1	6.7%	10.7%

Day of the Week								
Monday	4	26.7%	Thursday	2	13.3%	Sunday	1	6.7%
Tuesday	2	13.3%	Friday	3	20.0%	WEEKDAY	13	86.7%
Wednesday	2	13.3%	Saturday	1	6.7%	WEEKEND	2	13.3%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	1	6.7%	December SH	0	0.0%

Session dataset Southern RMS Region Princes Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Sep 2011 to 31 Mar 2014. Batemans Bay - Post construction - 01/09/11 â€" 31/03/14

Note: Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 12/10/2014 19:29

Summary Crash Report

Transport for NSW – Centre for Road Safety

# Crash Type		
Car Crash	10	100.0%
Light Truck Crash	0	0.0%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	(0)	(0.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(0)	(0.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	10	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	7	70.0%
Multi Vehicle	3	30.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	10	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	8	80.0%
Fatigue	2	20.0%
Alcohol	0	0.0%

Weather		
Fine	3	30.0%
Rain	4	40.0%
Overcast	3	30.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	7	70.0%
Dry	3	30.0%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	8	80.0%
Dusk	0	0.0%
Darkness	2	20.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	1	10.0%
Opposing vehicles; turning	0	0.0%
U-turn	1	10.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	1	10.0%
Out of control on straight	0	0.0%
Off road, on curve	2	20.0%
Off road on curve, hit object	5	50.0%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	8	80.0%
60 km/h zone	0	0.0%	100 km/h zone	2	20.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES	10	
Fatal crash	0	0.0%
Injury crash	5	50.0%
Non-casualty crash	5	50.0%

CASUALTIES	9	
Killed	0	0.0%
Injured	9	100.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	1	10.0%	4.2%
08:00 - 08:59	2	20.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	1	10.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	4	40.0%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	1	10.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	1	10.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil		% of Dark
2	of	2 in Dark 100.0%

Crashes		Casualties
6	2010	2
4	2009	7

~ School Travel Time		
Involvement	3	30.0%

McLean Periods			% Week
A	3	30.0%	17.9%
B	0	0.0%	7.1%
C	1	10.0%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	1	10.0%	10.7%
G	3	30.0%	7.1%
H	1	10.0%	7.1%
I	1	10.0%	12.5%
J	0	0.0%	10.7%

Day of the Week								
Monday	2	20.0%	Thursday	0	0.0%	Sunday	1	10.0%
Tuesday	3	30.0%	Friday	4	40.0%	WEEKDAY	9	90.0%
Wednesday	0	0.0%	Saturday	0	0.0%	WEEKEND	1	10.0%

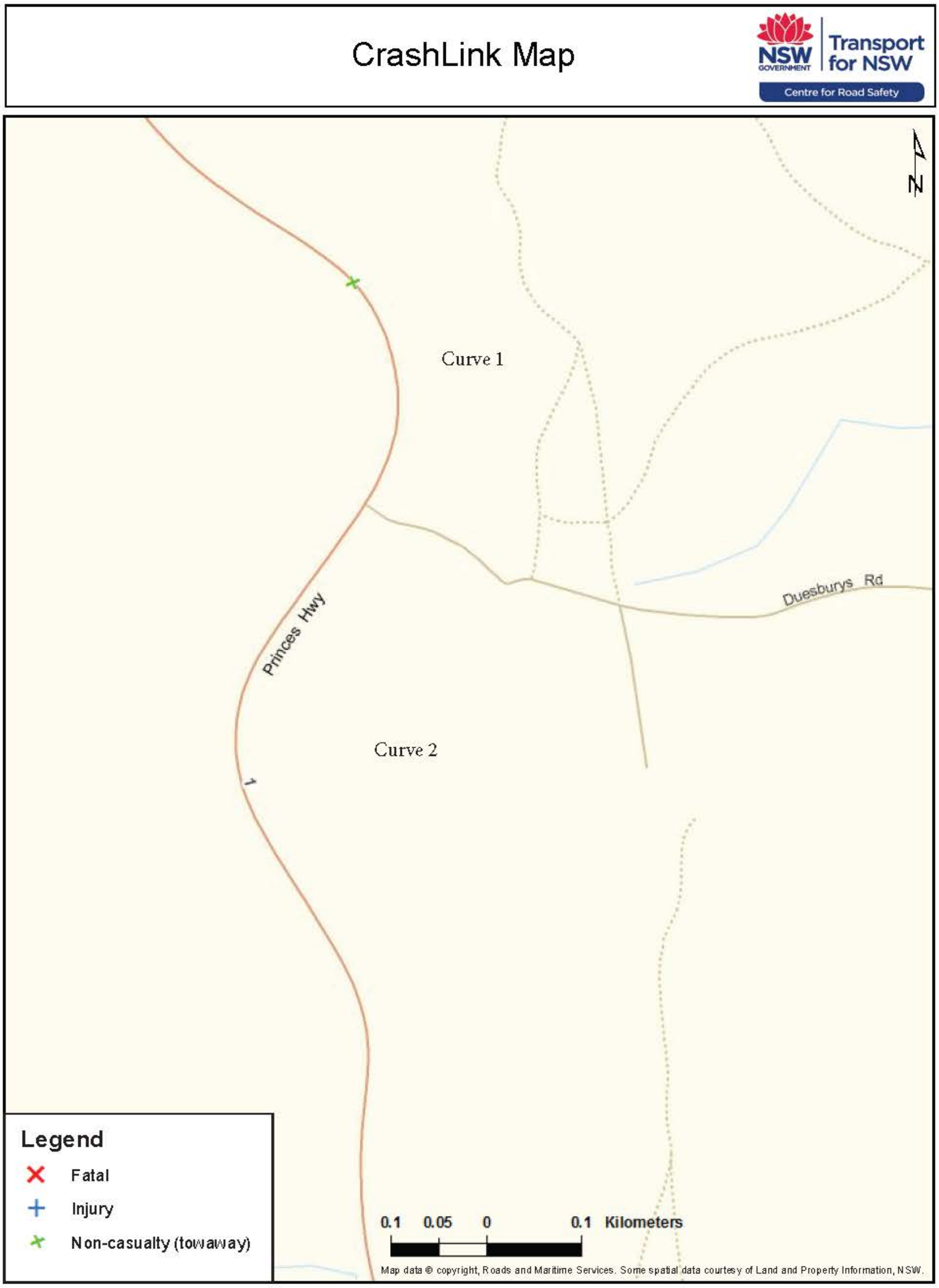
# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	1	10.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	1	10.0%
Anzac Day	0	0.0%	January SH	0	0.0%	December SH	0	0.0%

Session dataset Southern RMS Region Princes Hwy Country non-urban, Country unknown; all crashes for 01 Jul 2008 to 31 Jan 2011. Batemans Bay - Pre Costruction - 01/07/08 â€" 31/01/11

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk   Page 1 of 1   Generated: 12/10/2014 16:46

Princes Highway, Dalmeny



DALMENY - POST CONSTRUCTION - 01-09-08 à 31-03-14

Summary Crash Report

# Crash Type		
Car Crash	0	0.0%
Light Truck Crash	0	0.0%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	1	100.0%
'Heavy Truck Crash	(1)	(100.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(100.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	1	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	1	100.0%
Multi Vehicle	0	0.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	1	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	0	0.0%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	1	100.0%
Rain	0	0.0%
Overcast	0	0.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	0	0.0%
Dry	1	100.0%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	1	100.0%
Daylight	0	0.0%
Dusk	0	0.0%
Darkness	0	0.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	1	100.0%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	0	0.0%	100 km/h zone	1	100.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES	1	
Fatal crash	0	0.0%
Injury crash	0	0.0%
Non-casualty crash	1	100.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	1	100.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil			% of Dark
0	of	0 in Dark	0.0%

CASUALTIES	0	
Killed	0	0.0%
Injured	0	0.0%
^ Unrestrained	0	0.0%

Crashes		Casualties
1	2012	0

~ School Travel Time		
Involvement	0	0.0%

McLean Periods			% Week
A	1	100.0%	17.9%
B	0	0.0%	7.1%
C	0	0.0%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	0	0.0%	10.7%
G	0	0.0%	7.1%
H	0	0.0%	7.1%
I	0	0.0%	12.5%
J	0	0.0%	10.7%

Day of the Week								
Monday	0	0.0%	Thursday	0	0.0%	Sunday	0	0.0%
Tuesday	1	100.0%	Friday	0	0.0%	WEEKDAY	1	100.0%
Wednesday	0	0.0%	Saturday	0	0.0%	WEEKEND	0	0.0%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	0	0.0%	December SH	0	0.0%

Session dataset Eurobodalla LGA Princes Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Sep 2008 to 31 Mar 2014. DALMENY - POST CONSTRUCTION - 01-09-08 â€" 31-03-14

Note: Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 31/08/2014 14:54

Summary Crash Report

Transport for NSW — Centre for Road Safety

# Crash Type		
Car Crash	9	81.8%
Light Truck Crash	1	9.1%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	1	9.1%
'Heavy Truck Crash	(1)	(9.1%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(9.1%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	1	9.1%
Non intersection	10	90.9%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	9	81.8%
Multi Vehicle	2	18.2%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	11	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	8	72.7%
Fatigue	2	18.2%
Alcohol	1	9.1%

Weather		
Fine	8	72.7%
Rain	1	9.1%
Overcast	2	18.2%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	5	45.5%
Dry	6	54.5%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	7	63.6%
Dusk	0	0.0%
Darkness	4	36.4%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	1	9.1%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	1	9.1%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	1	9.1%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	2	18.2%
Off road on curve, hit object	6	54.5%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	1	9.1%
60 km/h zone	0	0.0%	100 km/h zone	10	90.9%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		11
Fatal crash	1	9.1%
Injury crash	3	27.3%
Non-casualty crash	7	63.6%

CASUALTIES		7
Killed	2	28.6%
Injured	5	71.4%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	2	18.2%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	1	9.1%	4.2%
09:00 - 09:59	2	18.2%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	2	18.2%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	2	18.2%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	1	9.1%	8.3%
22:00 - 24:00	1	9.1%	8.3%

Street Lighting Off/Nil			% of Dark
2	of	4 in Dark	50.0%

Crashes		Casualties
1	2006	0
4	2005	1
4	2004	5
2	2003	1

~ School Travel Time		
Involvement	2	18.2%

McLean Periods			% Week
A	2	18.2%	17.9%
B	1	9.1%	7.1%
C	2	18.2%	17.9%
D	0	0.0%	3.5%
E	2	18.2%	3.6%
F	2	18.2%	10.7%
G	0	0.0%	7.1%
H	0	0.0%	7.1%
I	0	0.0%	12.5%
J	2	18.2%	10.7%

Day of the Week								
Monday	2	18.2%	Thursday	0	0.0%	Sunday	2	18.2%
Tuesday	2	18.2%	Friday	1	9.1%	WEEKDAY	7	63.6%
Wednesday	2	18.2%	Saturday	2	18.2%	WEEKEND	4	36.4%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	1	9.1%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	1	9.1%	Christmas	0	0.0%	Sept./Oct. SH	1	9.1%
Anzac Day	0	0.0%	January SH	0	0.0%	December SH	0	0.0%

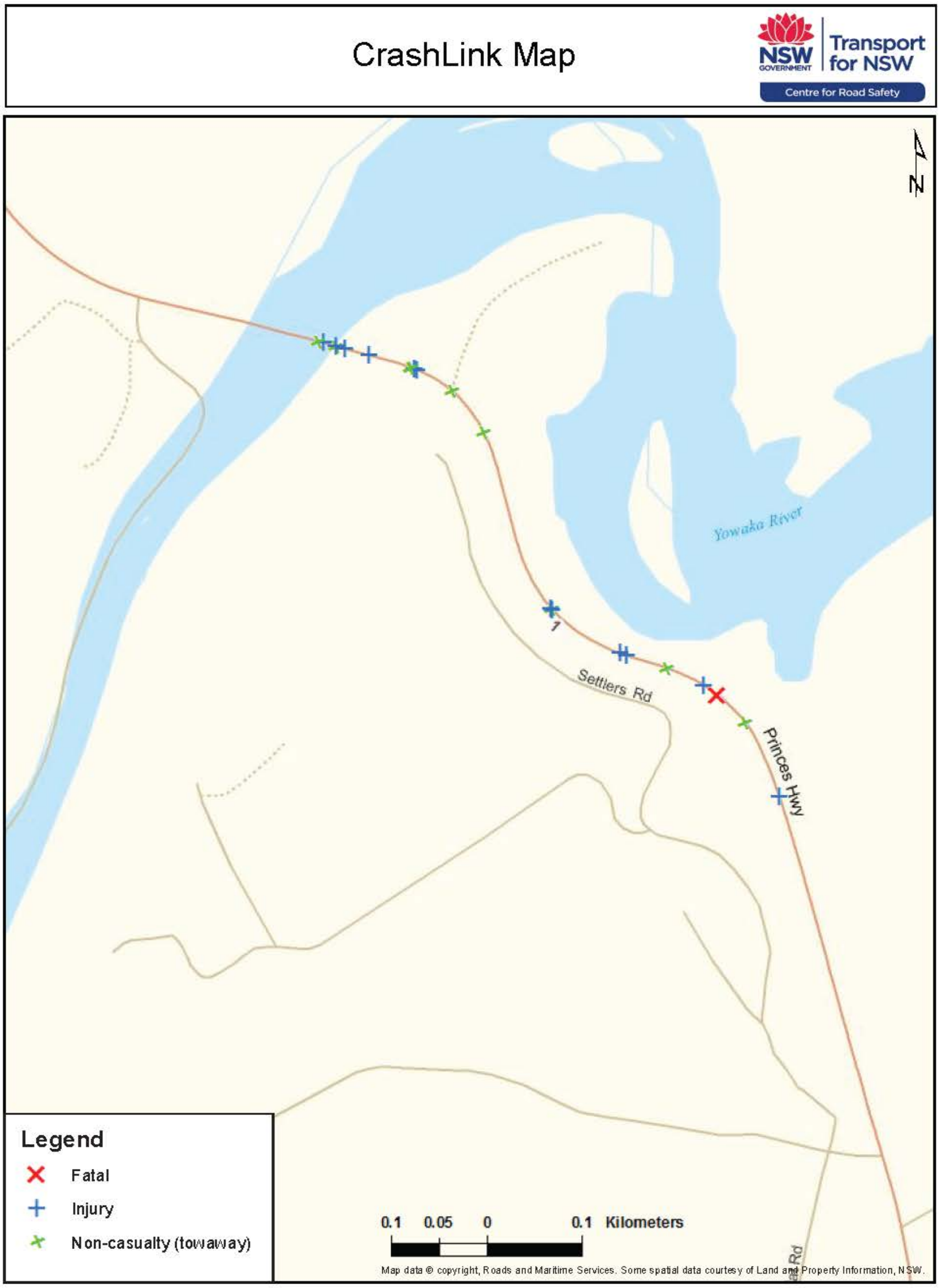
Session dataset Eurobodalla LGA Princes Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Nov 2002 to 31 May 2008. DALMENY - PRE CONSTRUCTION 01/11/2002 â€" 31/05/08

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 31/08/2014 14:43

Princes Highway, Yowaka

YOWAKA - POST CONSTRUCTION - 01-12-06 to 31-03-14



YOWAKA - PRE CONSTRUCTION - 01-04-98 to 31-07-06

[NO POST-INSTALLATION CRASH DATA TO SUMMARISE]

Summary Crash Report

Transport for NSW — Centre for Road Safety

# Crash Type		
Car Crash	20	87.0%
Light Truck Crash	2	8.7%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	1	4.3%
'Heavy Truck Crash	(1)	(4.3%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(4.3%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	4.3%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	23	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	19	82.6%
Multi Vehicle	4	17.4%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	23	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	21	91.3%
Fatigue	2	8.7%
Alcohol	2	8.7%

Weather		
Fine	9	39.1%
Rain	11	47.8%
Overcast	3	13.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	15	65.2%
Dry	8	34.8%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	1	4.3%
Daylight	14	60.9%
Dusk	1	4.3%
Darkness	7	30.4%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	2	8.7%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	4	17.4%
Off road on curve, hit object	17	73.9%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	2	8.7%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	1	4.3%	100 km/h zone	20	87.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		23
Fatal crash	1	4.3%
Injury crash	12	52.2%
Non-casualty crash	10	43.5%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	4	17.4%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	2	8.7%	4.2%
08:00 - 08:59	2	8.7%	4.2%
09:00 - 09:59	3	13.0%	4.2%
10:00 - 10:59	2	8.7%	4.2%
11:00 - 11:59	1	4.3%	4.2%
12:00 - 12:59	2	8.7%	4.2%
13:00 - 13:59	1	4.3%	4.2%
14:00 - 14:59	1	4.3%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	1	4.3%	4.2%
17:00 - 17:59	1	4.3%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	1	4.3%	4.2%
20:00 - 21:59	2	8.7%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil			% of Dark
7	of	7 in Dark	100.0%

CASUALTIES		26
Killed	2	7.7%
Injured	24	92.3%
^ Unrestrained	1	3.8%

Crashes		Casualties
4	2005	1
5	2004	8
3	2003	1
4	2002	9
3	2001	5
2	2000	0
1	1999	1
1	1998	1

~ School Travel Time		
Involvement	6	26.1%

McLean Periods			% Week
A	4	17.4%	17.9%
B	0	0.0%	7.1%
C	9	39.1%	17.9%
D	1	4.3%	3.5%
E	0	0.0%	3.6%
F	1	4.3%	10.7%
G	1	4.3%	7.1%
H	1	4.3%	7.1%
I	1	4.3%	12.5%
J	5	21.7%	10.7%

Day of the Week								
Monday	3	13.0%	Thursday	3	13.0%	Sunday	1	4.3%
Tuesday	3	13.0%	Friday	6	26.1%	WEEKDAY	19	82.6%
Wednesday	4	17.4%	Saturday	3	13.0%	WEEKEND	4	17.4%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	3	13.0%
Aust. Day	0	0.0%	Labour Day	1	4.3%	June/July SH	0	0.0%
Easter	1	4.3%	Christmas	2	8.7%	Sept./Oct. SH	2	8.7%
Anzac Day	1	4.3%	January SH	0	0.0%	December SH	2	8.7%

Session dataset Bega Valley LGA Princes Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Apr 1998 to 31 Jul 2006. YOWAKA - PRE CONSTRUCTION - 01-04-98 to 31-07-06

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk

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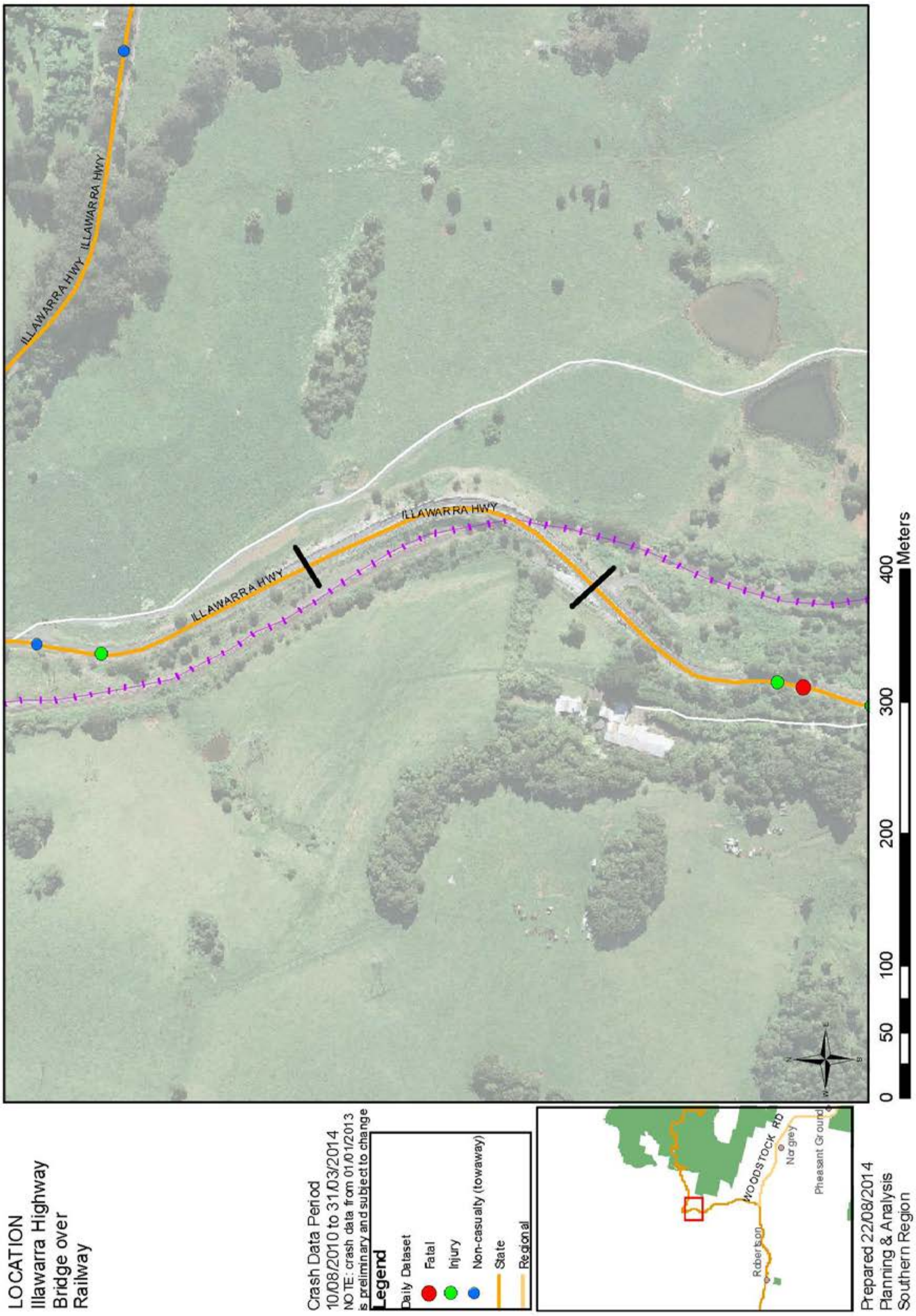
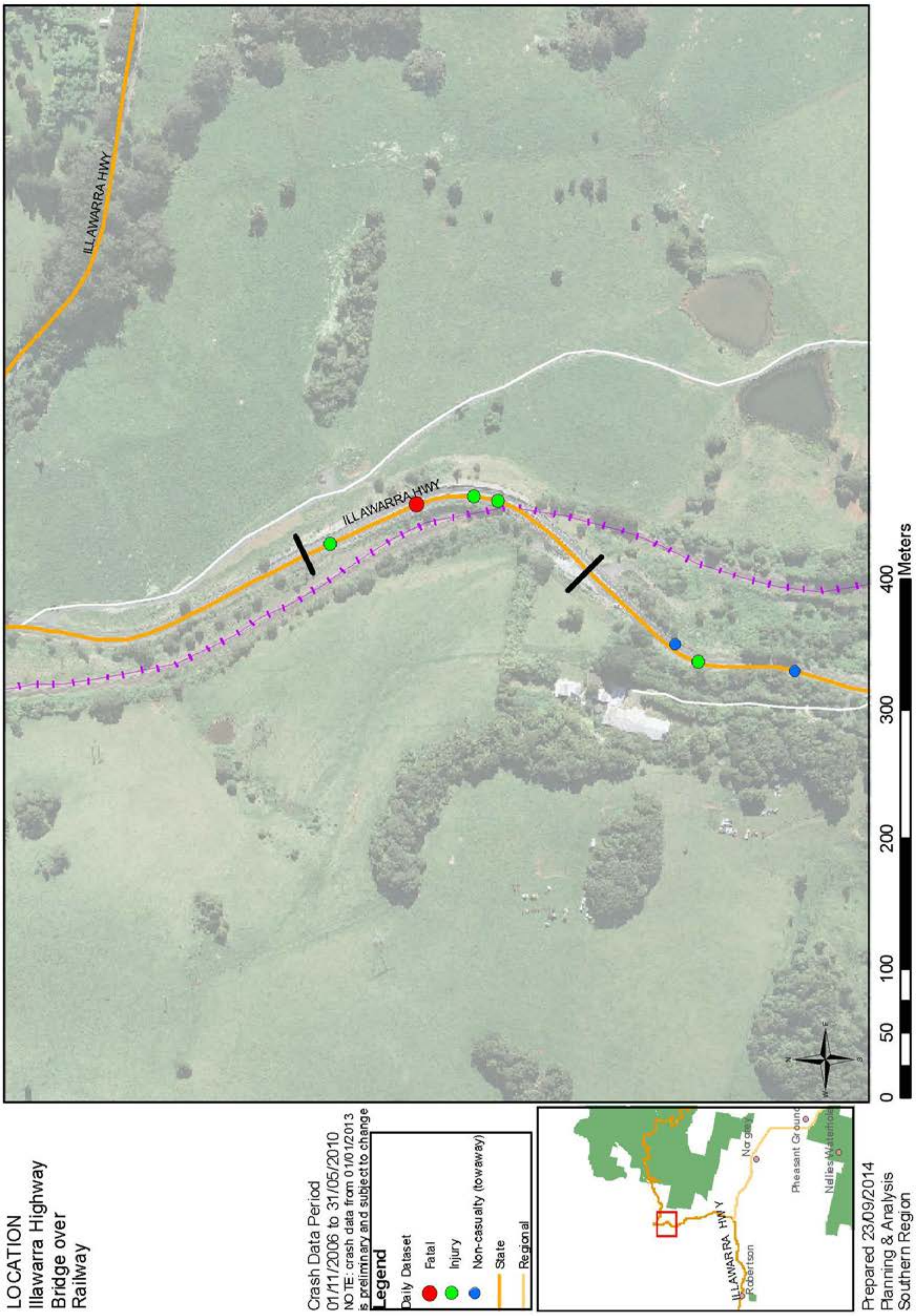
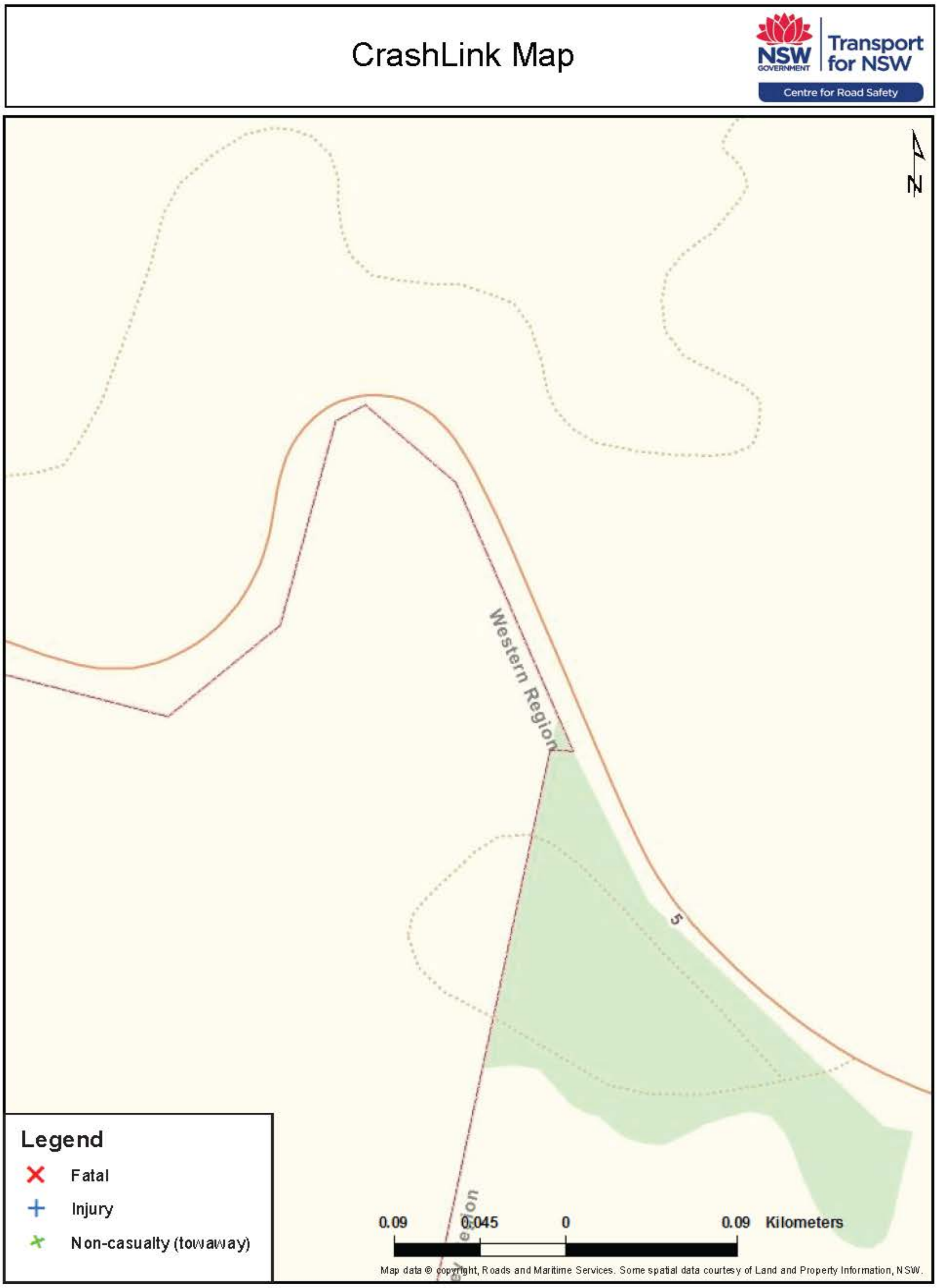
Illawarra Highway, Robertson





[NO POST-INSTALLATION CRASH DATA TO SUMMARISE]

Great Western Highway, Mount Victoria Pass (top)



MOUNT VIC (TOP) - PRE CONSTRUCTION - 01-01-13 to

CrashLink Map

MOUNT VIC (TOP) - PRE CONSTRUCTION - 01-07-2010 TO 31-10-11

[NO POST-INSTALLATION CRASH DATA TO SUMMARISE]

Summary Crash Report

# Crash Type		
Car Crash	9	81.8%
Light Truck Crash	2	18.2%
Rigid Truck Crash	1	9.1%
Articulated Truck Crash	2	18.2%
'Heavy Truck Crash	(3)	(27.3%)
Bus Crash	1	9.1%
"Heavy Vehicle Crash	(4)	(36.4%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	9.1%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	11	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	6	54.5%
Multi Vehicle	5	45.5%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	11	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	10	90.9%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	4	36.4%
Rain	5	45.5%
Overcast	1	9.1%
Fog or mist	0	0.0%
Other	1	9.1%

Road Surface Condition		
Wet	5	45.5%
Dry	5	45.5%
Snow or ice	1	9.1%

Natural Lighting		
Dawn	0	0.0%
Daylight	6	54.5%
Dusk	0	0.0%
Darkness	5	45.5%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	5	45.5%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	1	9.1%
Off road on curve, hit object	4	36.4%
Out of control on curve	1	9.1%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	1	9.1%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	10	90.9%	100 km/h zone	0	0.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES	11	
Fatal crash	1	9.1%
Injury crash	1	9.1%
Non-casualty crash	9	81.8%

CASUALTIES	5	
Killed	2	40.0%
Injured	3	60.0%
^ Unrestrained	2	40.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group		% of Day	
00:01 - 02:59	1	9.1%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	2	18.2%	4.2%
09:00 - 09:59	1	9.1%	4.2%
10:00 - 10:59	2	18.2%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	1	9.1%	4.2%
17:00 - 17:59	1	9.1%	4.2%
18:00 - 18:59	1	9.1%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	2	18.2%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil		% of Dark
5 of	5 in Dark	100.0%

Crashes		Casualties
8	2011	2
3	2010	3

~ School Travel Time		
Involvement	1	9.1%

McLean Periods			% Week
A	1	9.1%	17.9%
B	1	9.1%	7.1%
C	1	9.1%	17.9%
D	1	9.1%	3.5%
E	1	9.1%	3.6%
F	1	9.1%	10.7%
G	1	9.1%	7.1%
H	2	18.2%	7.1%
I	1	9.1%	12.5%
J	1	9.1%	10.7%

Day of the Week								
Monday	2	18.2%	Thursday	1	9.1%	Sunday	1	9.1%
Tuesday	0	0.0%	Friday	1	9.1%	WEEKDAY	6	54.5%
Wednesday	2	18.2%	Saturday	4	36.4%	WEEKEND	5	45.5%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	1	9.1%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	1	9.1%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	1	9.1%	December SH	0	0.0%

Session dataset Sydney, Western RMS Regions; Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Jul 2010 to 31 Oct 2011. MOUNT VIC (TOP) - PRE CONSTRUCTION - 01-07-2010 TO 31-10-11

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

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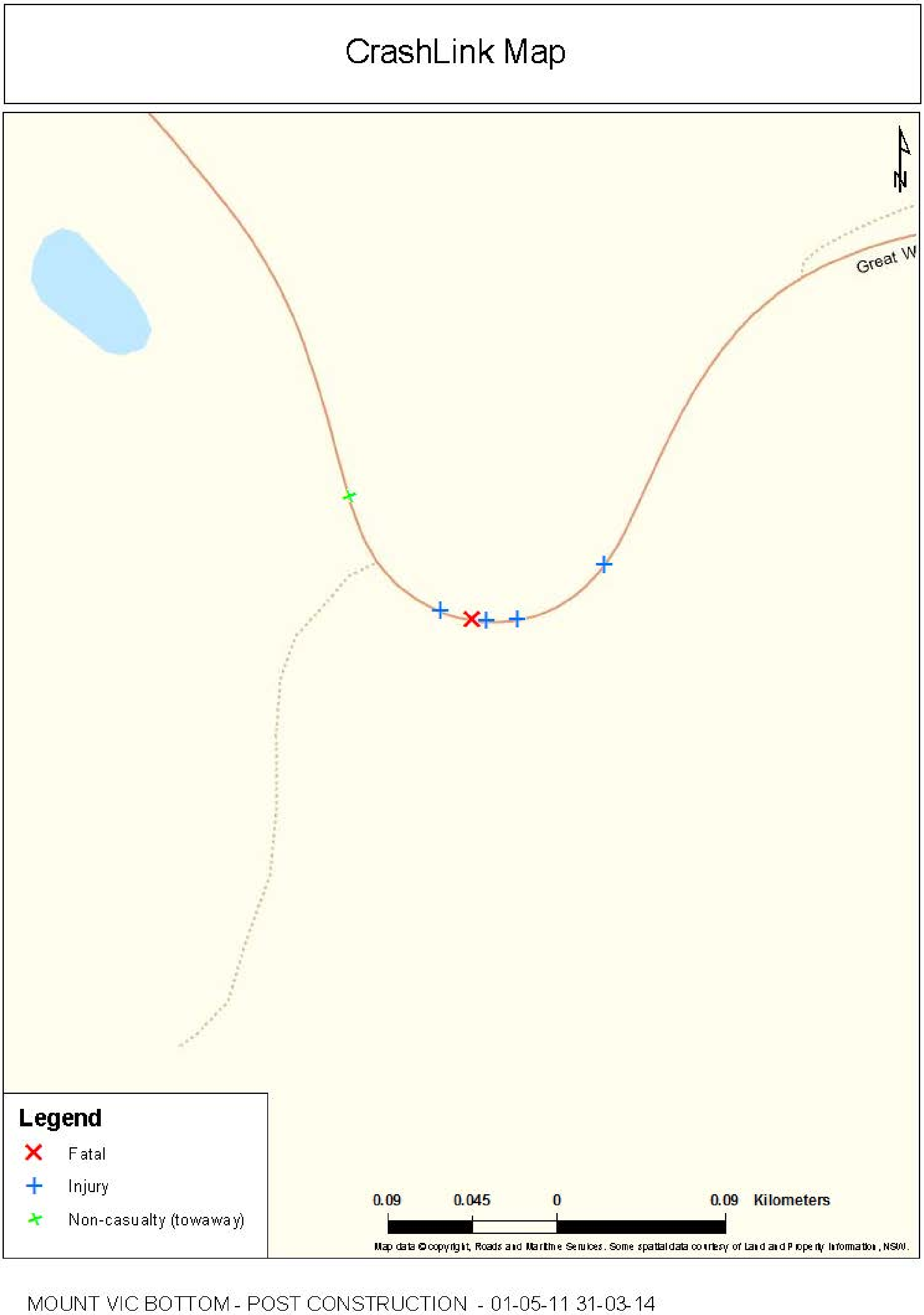
Great Western Highway, Mount Victoria Pass (bottom)



CrashLink Map

MOUNT VIC BOTTOM - PRE CONSTRUCTION - 01-12-07 31-10-10

Summary Crash Report

# Crash Type		
Car Crash	2	33.3%
Light Truck Crash	0	0.0%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	3	50.0%
'Heavy Truck Crash	(3)	(50.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(3)	(50.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	16.7%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	6	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	6	100.0%
Multi Vehicle	0	0.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	6	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	6	100.0%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	4	66.7%
Rain	1	16.7%
Overcast	1	16.7%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	2	33.3%
Dry	4	66.7%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	5	83.3%
Dusk	0	0.0%
Darkness	1	16.7%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	4	66.7%
Out of control on curve	2	33.3%
Other crash type	0	0.0%

Speed Limit			~ 40km/h or less	0	0.0%
40 km/h or less	2	33.3%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	4	66.7%	100 km/h zone	0	0.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		6
Fatal crash	1	16.7%
Injury crash	4	66.7%
Non-casualty crash	1	16.7%

CASUALTIES		5
Killed	1	20.0%
Injured	4	80.0%
^ Unrestrained	1	20.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group		% of Day	
00:01 - 02:59	1	16.7%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	2	33.3%	4.2%
11:00 - 11:59	1	16.7%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	1	16.7%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	1	16.7%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil		% of Dark
1	of	1 in Dark 100.0%

Crashes		Casualties
1	2014	1
1	2013	0
1	2012	1
3	2011	3

~ School Travel Time		
Involvement	1	16.7%

McLean Periods			% Week
A	0	0.0%	17.9%
B	0	0.0%	7.1%
C	4	66.7%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	0	0.0%	10.7%
G	0	0.0%	7.1%
H	1	16.7%	7.1%
I	0	0.0%	12.5%
J	1	16.7%	10.7%

Day of the Week								
Monday	1	16.7%	Thursday	1	16.7%	Sunday	1	16.7%
Tuesday	2	33.3%	Friday	0	0.0%	WEEKDAY	4	66.7%
Wednesday	0	0.0%	Saturday	1	16.7%	WEEKEND	2	33.3%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	1	16.7%	December SH	0	0.0%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 May 2011 to 31 Mar 2014. MOUNT VIC BOTTOM - POST CONSTRUCTION - 01-05-11 31-03-

Note: Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 04/09/2014 10:27

Summary Crash Report

# Crash Type		
Car Crash	3	60.0%
Light Truck Crash	1	20.0%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	(0)	(0.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(0)	(0.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	20.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	5	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	4	80.0%
Multi Vehicle	1	20.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	5	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	3	60.0%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	4	80.0%
Rain	0	0.0%
Overcast	1	20.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	1	20.0%
Dry	4	80.0%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	3	60.0%
Dusk	0	0.0%
Darkness	2	40.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	3	60.0%
Out of control on curve	1	20.0%
Other crash type	1	20.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	5	100.0%	100 km/h zone	0	0.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		5
Fatal crash	0	0.0%
Injury crash	2	40.0%
Non-casualty crash	3	60.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	1	20.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	2	40.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	1	20.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	1	20.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil			% of Dark
2	of	2 in Dark	100.0%

CASUALTIES		2
Killed	0	0.0%
Injured	2	100.0%
^ Unrestrained	0	0.0%

Crashes		Casualties
1	2010	0
2	2009	1
2	2008	1

~ School Travel Time		
Involvement	0	0.0%

McLean Periods			% Week
A	1	20.0%	17.9%
B	0	0.0%	7.1%
C	1	20.0%	17.9%
D	0	0.0%	3.5%
E	1	20.0%	3.6%
F	1	20.0%	10.7%
G	1	20.0%	7.1%
H	0	0.0%	7.1%
I	0	0.0%	12.5%
J	0	0.0%	10.7%

Day of the Week								
Monday	1	20.0%	Thursday	0	0.0%	Sunday	1	20.0%
Tuesday	0	0.0%	Friday	2	40.0%	WEEKDAY	4	80.0%
Wednesday	1	20.0%	Saturday	0	0.0%	WEEKEND	1	20.0%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	1	20.0%	December SH	0	0.0%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Dec 2007 to 31 Oct 2010. MOUNT VIC BOTTOM - PRE CONSTRUCTION - 01-12-07 31-10-10

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

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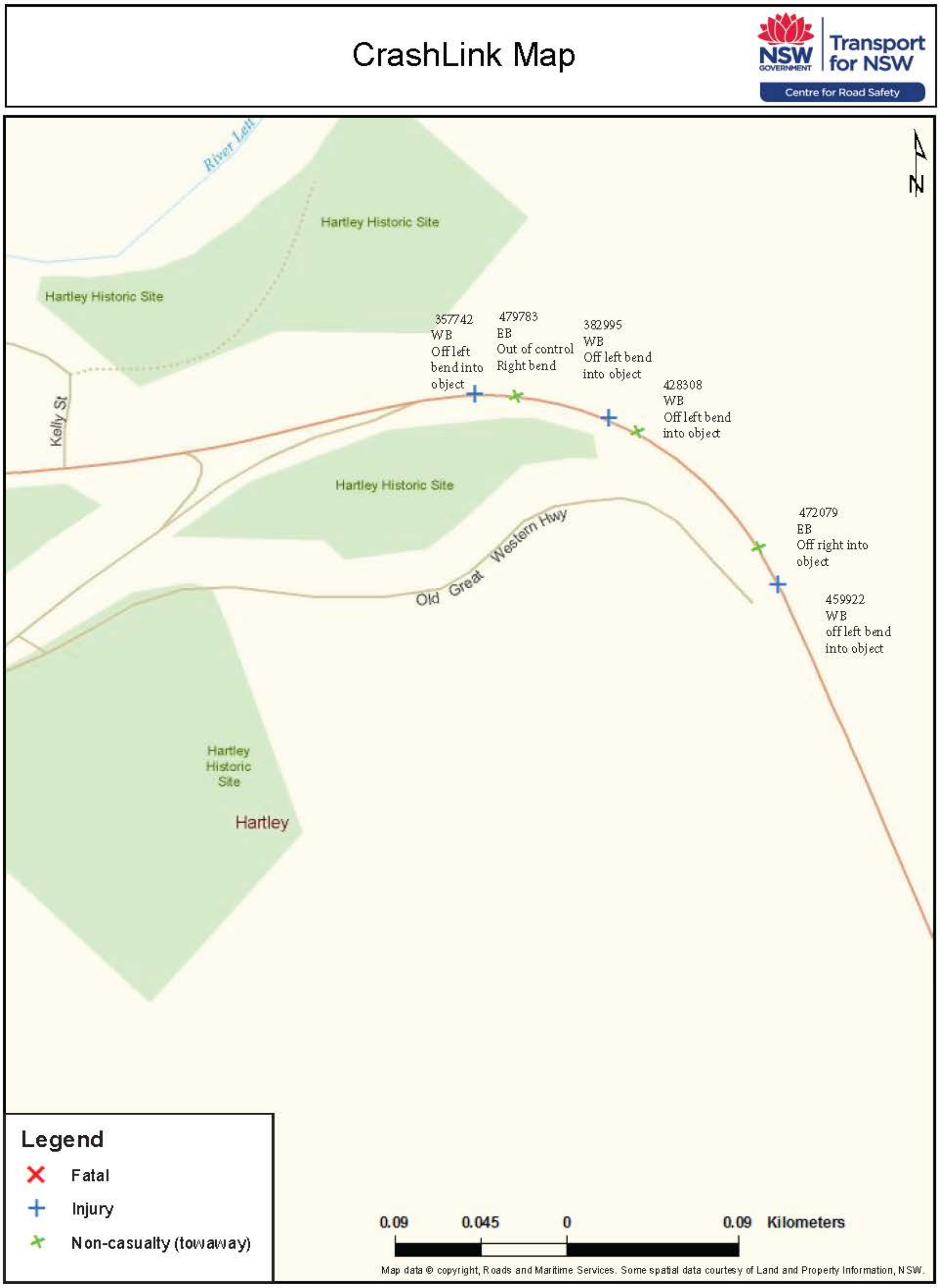
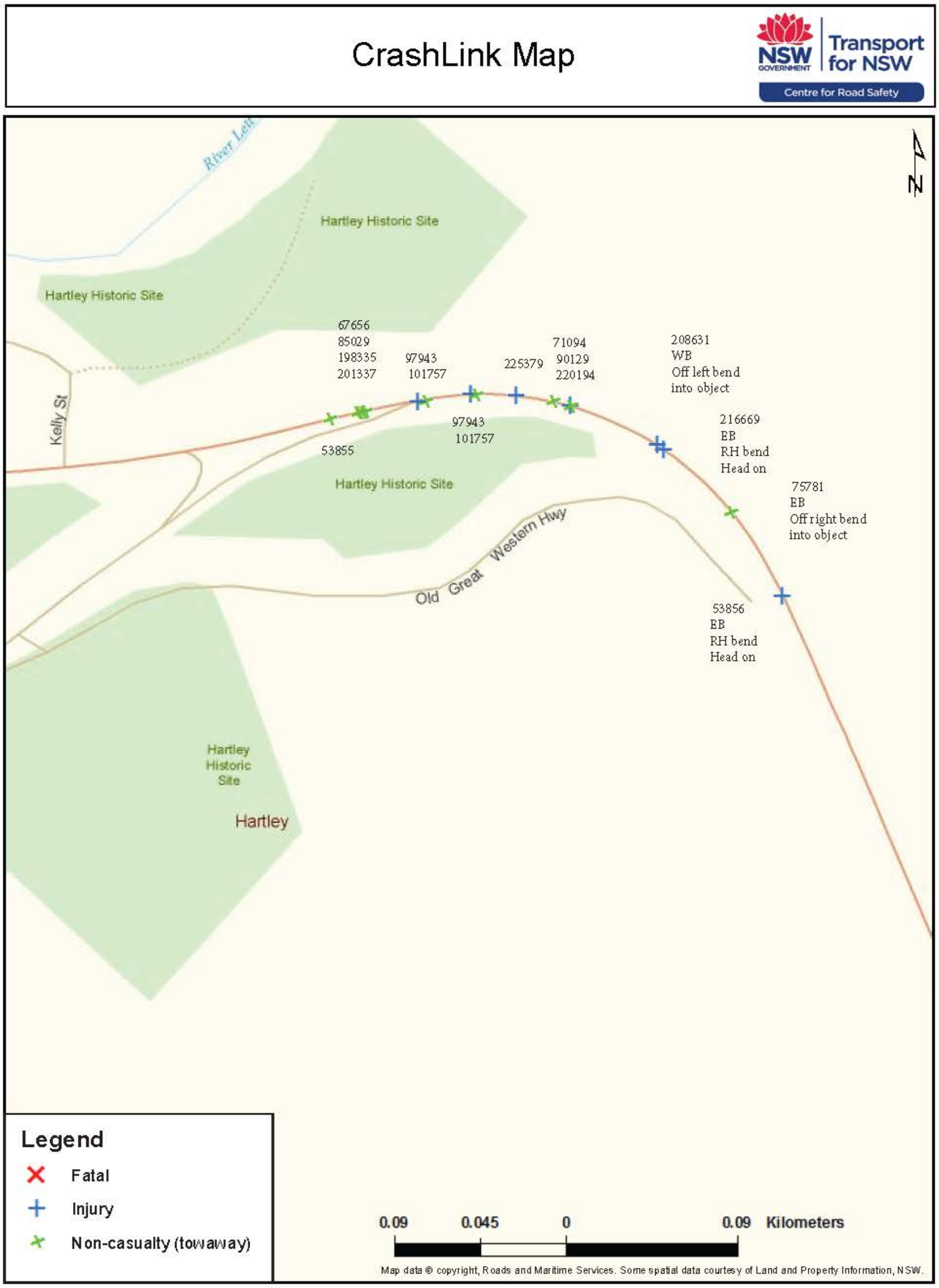
Great Western Highway, Hartley



Old Hartley - Post-construction - 01-01-02 to 30-06-06



Old Hartley - Pre-construction - 01-06-96 to 31-12-00

Summary Crash Report

# Crash Type		
Car Crash	1	16.7%
Light Truck Crash	1	16.7%
Rigid Truck Crash	1	16.7%
Articulated Truck Crash	2	33.3%
'Heavy Truck Crash	(3)	(50.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(3)	(50.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	16.7%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	6	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	6	100.0%
Multi Vehicle	0	0.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	6	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	6	100.0%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	2	33.3%
Rain	4	66.7%
Overcast	0	0.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	4	66.7%
Dry	2	33.3%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	6	100.0%
Dusk	0	0.0%
Darkness	0	0.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	5	83.3%
Out of control on curve	1	16.7%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	1	16.7%
50 km/h zone	0	0.0%	90 km/h zone	4	66.7%
60 km/h zone	0	0.0%	100 km/h zone	1	16.7%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		6
Fatal crash	0	0.0%
Injury crash	3	50.0%
Non-casualty crash	3	50.0%

CASUALTIES		4
Killed	0	0.0%
Injured	4	100.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	1	16.7%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	1	16.7%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	1	16.7%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	1	16.7%	4.2%
18:00 - 18:59	2	33.3%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil			% of Dark
0	of	0 in Dark	0.0%

Crashes		Casualties
3	2005	2
1	2004	0
1	2003	1
1	2002	1

~ School Travel Time		
Involvement	1	16.7%

McLean Periods			% Week
A	1	16.7%	17.9%
B	0	0.0%	7.1%
C	1	16.7%	17.9%
D	0	0.0%	3.5%
E	1	16.7%	3.6%
F	1	16.7%	10.7%
G	1	16.7%	7.1%
H	1	16.7%	7.1%
I	0	0.0%	12.5%
J	0	0.0%	10.7%

Day of the Week								
Monday	1	16.7%	Thursday	0	0.0%	Sunday	2	33.3%
Tuesday	1	16.7%	Friday	1	16.7%	WEEKDAY	4	66.7%
Wednesday	1	16.7%	Saturday	0	0.0%	WEEKEND	2	33.3%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	1	16.7%	Easter SH	1	16.7%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	1	16.7%	December SH	0	0.0%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Jan 2002 to 30 Jun 2006. Old hartley - Post-construction - 01-01-02 to 30-06-06

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 17/10/2014 11:53

Summary Crash Report

# Crash Type		
Car Crash	15	83.3%
Light Truck Crash	2	11.1%
Rigid Truck Crash	1	5.6%
Articulated Truck Crash	1	5.6%
'Heavy Truck Crash	(2)	(11.1%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(2)	(11.1%)
Emergency Vehicle Crash	1	5.6%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	18	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	12	66.7%
Multi Vehicle	6	33.3%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	18	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	13	72.2%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	1	5.6%
Rain	15	83.3%
Overcast	2	11.1%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	17	94.4%
Dry	1	5.6%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	13	72.2%
Dusk	1	5.6%
Darkness	4	22.2%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	6	33.3%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	1	5.6%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	2	11.1%
Off road on curve, hit object	8	44.4%
Out of control on curve	1	5.6%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	1	5.6%
50 km/h zone	0	0.0%	90 km/h zone	5	27.8%
60 km/h zone	0	0.0%	100 km/h zone	12	66.7%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		18
Fatal crash	0	0.0%
Injury crash	7	38.9%
Non-casualty crash	11	61.1%

CASUALTIES		16
Killed	0	0.0%
Injured	16	100.0%
^ Unrestrained	1	6.3%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	1	5.6%	4.2%
08:00 - 08:59	3	16.7%	4.2%
09:00 - 09:59	2	11.1%	4.2%
10:00 - 10:59	1	5.6%	4.2%
11:00 - 11:59	3	16.7%	4.2%
12:00 - 12:59	1	5.6%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	2	11.1%	4.2%
16:00 - 16:59	1	5.6%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	1	5.6%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	3	16.7%	8.3%

Street Lighting Off/Nil		% of Dark
4	of	4 in Dark 100.0%

Crashes		Casualties
4	2000	6
3	1999	1
10	1997	8
1	1996	1

~ School Travel Time		
Involvement	3	16.7%

McLean Periods			% Week
A	4	22.2%	17.9%
B	0	0.0%	7.1%
C	2	11.1%	17.9%
D	0	0.0%	3.5%
E	5	27.8%	3.6%
F	2	11.1%	10.7%
G	1	5.6%	7.1%
H	1	5.6%	7.1%
I	2	11.1%	12.5%
J	1	5.6%	10.7%

Day of the Week								
Monday	2	11.1%	Thursday	0	0.0%	Sunday	7	38.9%
Tuesday	1	5.6%	Friday	4	22.2%	WEEKDAY	11	61.1%
Wednesday	4	22.2%	Saturday	0	0.0%	WEEKEND	7	38.9%

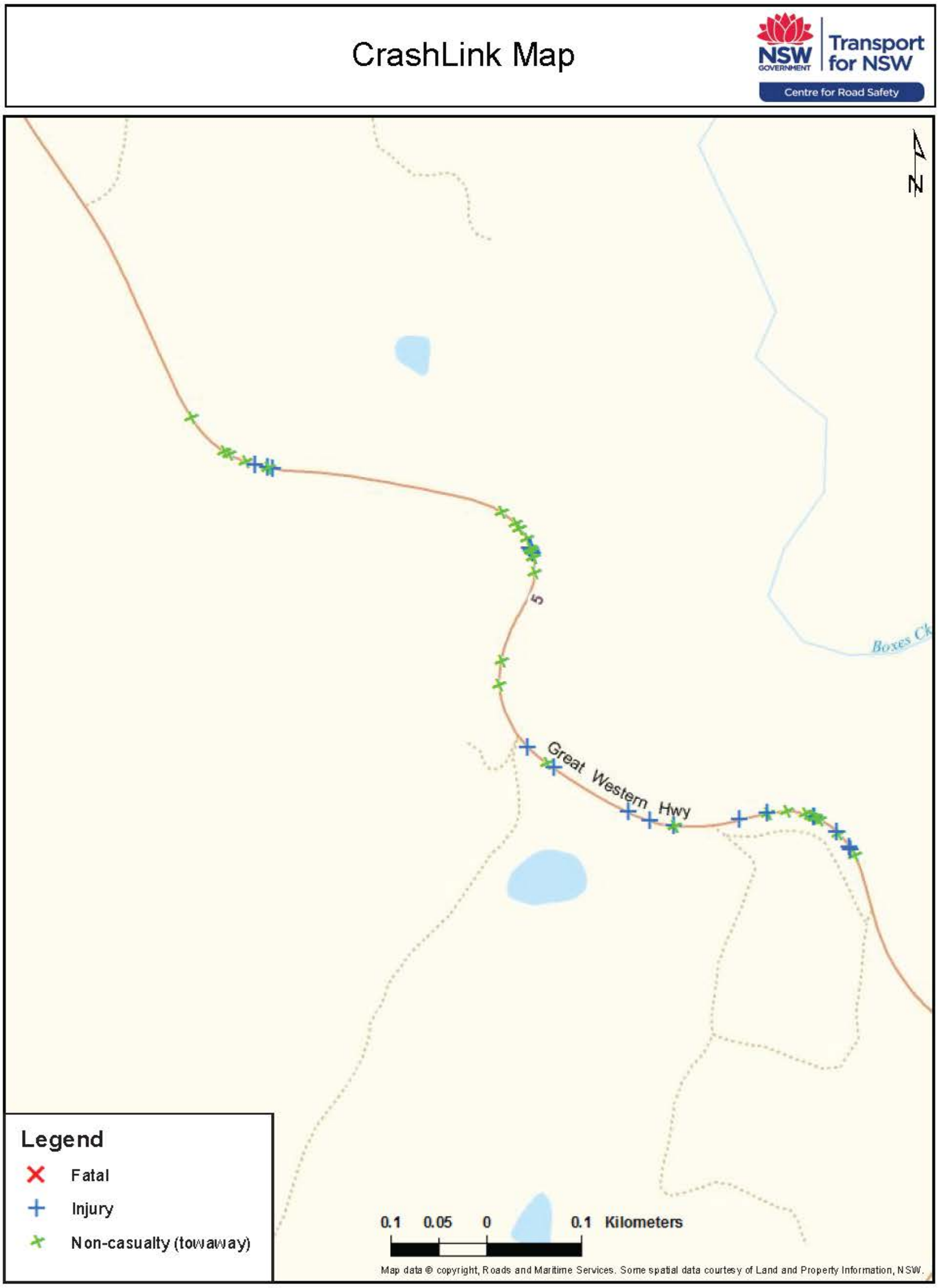
# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	1	5.6%
Aust. Day	1	5.6%	Labour Day	1	5.6%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	2	11.1%
Anzac Day	0	0.0%	January SH	3	16.7%	December SH	0	0.0%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Jun 1996 to 31 Dec 2000. Old Hartley - Pre-construction - 01-06-96 to 31-12-00

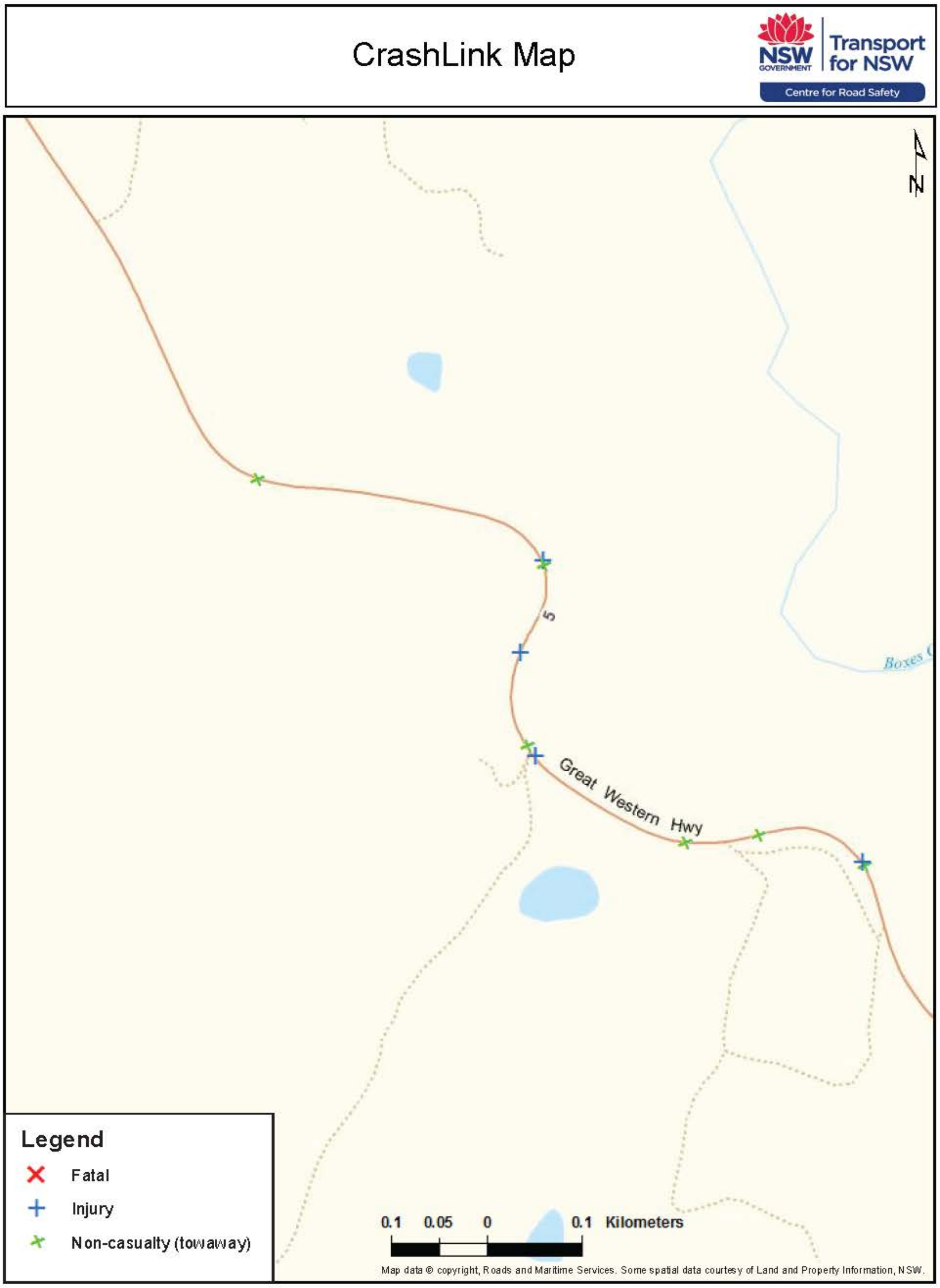
Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 17/10/2014 11:09

Great Western Highway, River Lett Hill



River Lett Hill - Post Construction - 01-07-2010 to 31-03-2014



River Lett Hill - Pre Construction - 01-09-2006 to 31-03-2010

Summary Crash Report

# Crash Type		
Car Crash	52	78.8%
Light Truck Crash	5	7.6%
Rigid Truck Crash	2	3.0%
Articulated Truck Crash	3	4.5%
'Heavy Truck Crash	(5)	(7.6%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(5)	(7.6%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	4	6.1%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	66	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	63	95.5%
Multi Vehicle	3	4.5%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	66	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	60	90.9%
Fatigue	6	9.1%

Weather		
Fine	15	22.7%
Rain	37	56.1%
Overcast	11	16.7%
Fog or mist	2	3.0%
Other	1	1.5%

Road Surface Condition		
Wet	48	72.7%
Dry	18	27.3%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	2	3.0%
Daylight	41	62.1%
Dusk	3	4.5%
Darkness	20	30.3%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	1	1.5%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	1	1.5%
Lane change	1	1.5%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	1	1.5%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	4	6.1%
Off road on curve, hit object	54	81.8%
Out of control on curve	4	6.1%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	2	3.0%	80 km/h zone	51	77.3%
50 km/h zone	0	0.0%	90 km/h zone	8	12.1%
60 km/h zone	4	6.1%	100 km/h zone	0	0.0%
70 km/h zone	1	1.5%	110 km/h zone	0	0.0%

CRASHES	66	
Fatal crash	0	0.0%
Injury crash	23	34.8%
Non-casualty crash	43	65.2%

CASUALTIES	24	
Killed	0	0.0%
Injured	24	100.0%
^ Unrestrained	1	4.2%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group		% of Day	
00:01 - 02:59	3	4.5%	12.5%
03:00 - 04:59	2	3.0%	8.3%
05:00 - 05:59	1	1.5%	4.2%
06:00 - 06:59	1	1.5%	4.2%
07:00 - 07:59	4	6.1%	4.2%
08:00 - 08:59	5	7.6%	4.2%
09:00 - 09:59	3	4.5%	4.2%
10:00 - 10:59	2	3.0%	4.2%
11:00 - 11:59	3	4.5%	4.2%
12:00 - 12:59	1	1.5%	4.2%
13:00 - 13:59	6	9.1%	4.2%
14:00 - 14:59	2	3.0%	4.2%
15:00 - 15:59	9	13.6%	4.2%
16:00 - 16:59	3	4.5%	4.2%
17:00 - 17:59	3	4.5%	4.2%
18:00 - 18:59	4	6.1%	4.2%
19:00 - 19:59	5	7.6%	4.2%
20:00 - 21:59	4	6.1%	8.3%
22:00 - 24:00	5	7.6%	8.3%

Street Lighting Off/Nil			% of Dark
19	of	20 in Dark	95.0%

Crashes		Casualties
2	2014	0
27	2013	14
17	2012	3
16	2011	6
4	2010	1

~ School Travel Time		
Involvement	12	18.2%

McLean Periods			% Week
A	9	13.6%	17.9%
B	4	6.1%	7.1%
C	11	16.7%	17.9%
D	4	6.1%	3.5%
E	2	3.0%	3.6%
F	10	15.2%	10.7%
G	10	15.2%	7.1%
H	5	7.6%	7.1%
I	5	7.6%	12.5%
J	6	9.1%	10.7%

Day of the Week								
Monday	12	18.2%	Thursday	8	12.1%	Sunday	7	10.6%
Tuesday	12	18.2%	Friday	12	18.2%	WEEKDAY	48	72.7%
Wednesday	4	6.1%	Saturday	11	16.7%	WEEKEND	18	27.3%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	3	4.5%	Easter SH	5	7.6%
Aust. Day	0	0.0%	Labour Day	1	1.5%	June/July SH	5	7.6%
Easter	3	4.5%	Christmas	1	1.5%	Sept./Oct. SH	1	1.5%
Anzac Day	0	0.0%	January SH	1	1.5%	December SH	1	1.5%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Jul 2010 to 31 Mar 2014. River Lett Hill - Post Construction - 01-07-2010 to 31-03-2014

Note: Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 19/09/2014 17:13

Transport for NSW — Centre for Road Safety

Summary Crash Report

# Crash Type		
Car Crash	7	70.0%
Light Truck Crash	3	30.0%
Rigid Truck Crash	1	10.0%
Articulated Truck Crash	1	10.0%
'Heavy Truck Crash	(2)	(20.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(2)	(20.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	10	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	7	70.0%
Multi Vehicle	3	30.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	10	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	9	90.0%
Fatigue	1	10.0%
Alcohol	1	10.0%

Weather		
Fine	5	50.0%
Rain	3	30.0%
Overcast	1	10.0%
Fog or mist	1	10.0%
Other	0	0.0%

Road Surface Condition		
Wet	4	40.0%
Dry	6	60.0%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	7	70.0%
Dusk	1	10.0%
Darkness	2	20.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	2	20.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	3	30.0%
Off road on curve, hit object	4	40.0%
Out of control on curve	0	0.0%
Other crash type	1	10.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	1	10.0%	80 km/h zone	5	50.0%
50 km/h zone	0	0.0%	90 km/h zone	1	10.0%
60 km/h zone	0	0.0%	100 km/h zone	3	30.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES	10	
Fatal crash	0	0.0%
Injury crash	4	40.0%
Non-casualty crash	6	60.0%

CASUALTIES	6	
Killed	0	0.0%
Injured	6	100.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	1	10.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	1	10.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	1	10.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	1	10.0%	4.2%
11:00 - 11:59	1	10.0%	4.2%
12:00 - 12:59	1	10.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	1	10.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	1	10.0%	4.2%
18:00 - 18:59	1	10.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	1	10.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil		% of Dark
2	of 2 in Dark	100.0%

Crashes		Casualties
2	2009	0
2	2008	3
3	2007	2
3	2006	1

~ School Travel Time		
Involvement	1	10.0%

McLean Periods			% Week
A	1	10.0%	17.9%
B	1	10.0%	7.1%
C	4	40.0%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	2	20.0%	10.7%
G	0	0.0%	7.1%
H	0	0.0%	7.1%
I	2	20.0%	12.5%
J	0	0.0%	10.7%

Day of the Week								
Monday	3	30.0%	Thursday	2	20.0%	Sunday	0	0.0%
Tuesday	1	10.0%	Friday	1	10.0%	WEEKDAY	9	90.0%
Wednesday	2	20.0%	Saturday	1	10.0%	WEEKEND	1	10.0%

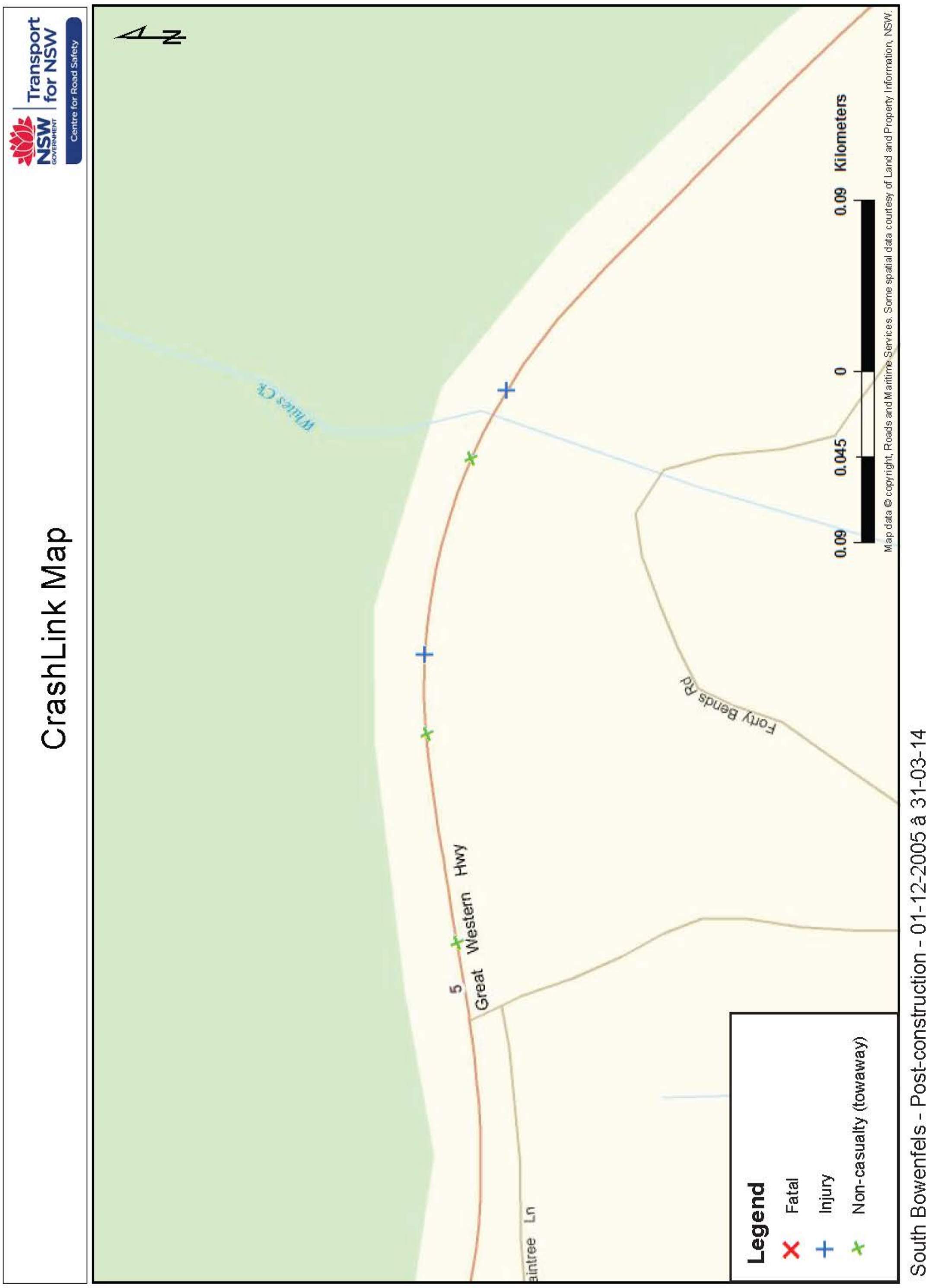
# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	1	10.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	2	20.0%
Anzac Day	1	10.0%	January SH	0	0.0%	December SH	0	0.0%

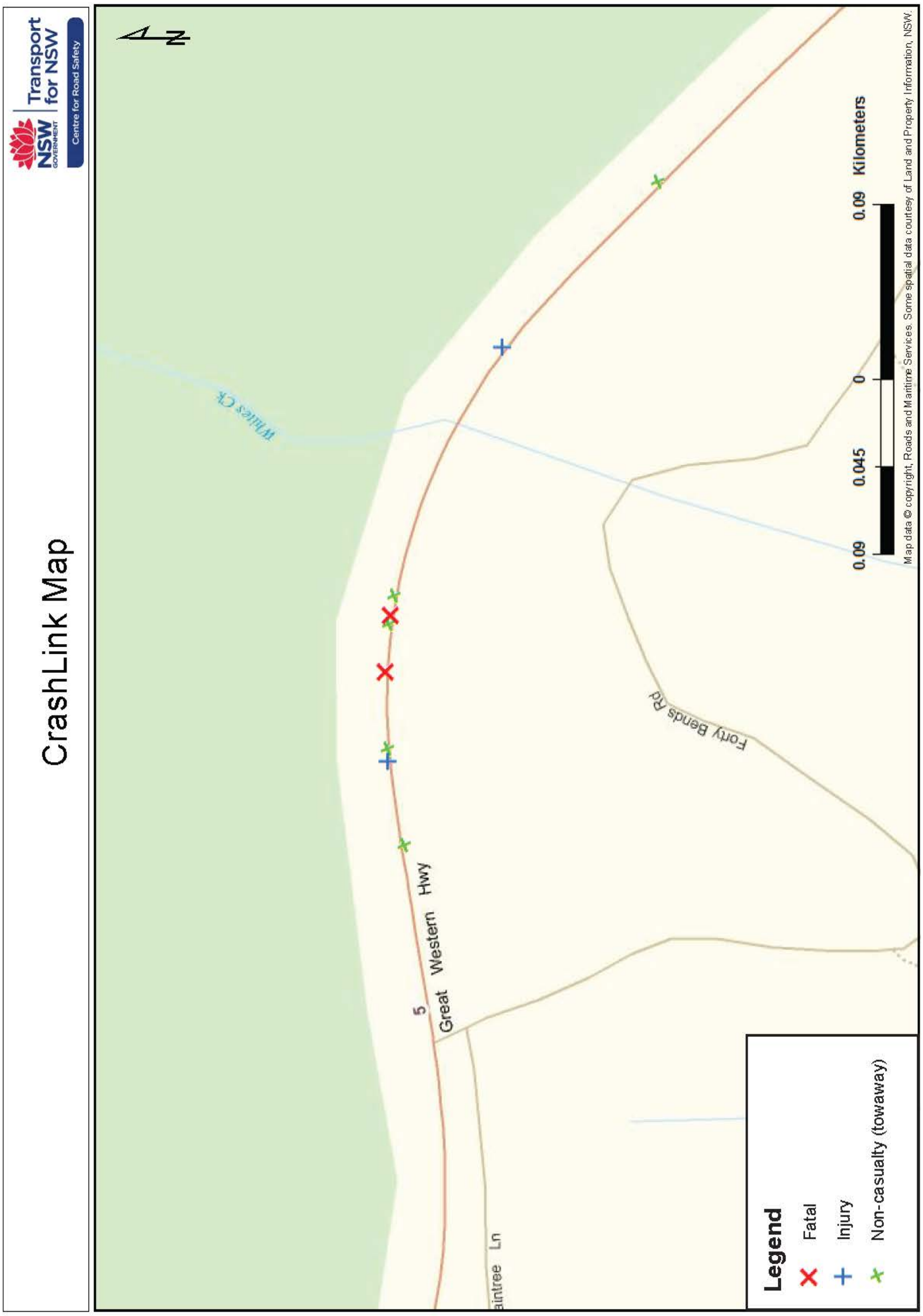
Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Sep 2006 to 31 Mar 2010. River Lett Hill - Pre Construction - 01-09-2006 to 31-03-2010

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Rep ID: REG01 **Office:** Hunter **User ID:** holznerk Page 1 of 1 Generated: 19/09/2014 16:39

Great Western Highway, South Bowenfels





South Bowenfels - Pre-construction - 01-03-96 à 31-08-2005

Summary Crash Report

Transport for NSW — Centre for Road Safety

# Crash Type		
Car Crash	4	80.0%
Light Truck Crash	0	0.0%
Rigid Truck Crash	0	0.0%
Articulated Truck Crash	1	20.0%
'Heavy Truck Crash	(1)	(20.0%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(20.0%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	5	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	5	100.0%
Multi Vehicle	0	0.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	5	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	4	80.0%
Fatigue	1	20.0%
Alcohol	0	0.0%

Weather		
Fine	0	0.0%
Rain	4	80.0%
Overcast	1	20.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	5	100.0%
Dry	0	0.0%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	1	20.0%
Daylight	1	20.0%
Dusk	0	0.0%
Darkness	3	60.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	5	100.0%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	5	100.0%
60 km/h zone	0	0.0%	100 km/h zone	0	0.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES	5	
Fatal crash	0	0.0%
Injury crash	2	40.0%
Non-casualty crash	3	60.0%

CASUALTIES	3	
Killed	0	0.0%
Injured	3	100.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	1	20.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	1	20.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	1	20.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	1	20.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	1	20.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil			% of Dark
3	of	3 in Dark	100.0%

Crashes		Casualties
2	2012	2
1	2011	1
1	2009	0
1	2008	0

~ School Travel Time		
Involvement	0	0.0%

McLean Periods			% Week
A	1	20.0%	17.9%
B	0	0.0%	7.1%
C	0	0.0%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	0	0.0%	10.7%
G	0	0.0%	7.1%
H	2	40.0%	7.1%
I	0	0.0%	12.5%
J	2	40.0%	10.7%

Day of the Week								
Monday	0	0.0%	Thursday	1	20.0%	Sunday	2	40.0%
Tuesday	0	0.0%	Friday	2	40.0%	WEEKDAY	3	60.0%
Wednesday	0	0.0%	Saturday	0	0.0%	WEEKEND	2	40.0%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	0	0.0%	December SH	0	0.0%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Dec 2005 to 31 Mar 2014. South Bowenfels - Post Construction - 01-12-2005 â€" 31-03-14

Note: Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

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Summary Crash Report

# Crash Type		
Car Crash	7	77.8%
Light Truck Crash	0	0.0%
Rigid Truck Crash	1	11.1%
Articulated Truck Crash	2	22.2%
'Heavy Truck Crash	(3)	(33.3%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(3)	(33.3%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	0	0.0%
Non intersection	9	100.0%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	8	88.9%
Multi Vehicle	1	11.1%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	9	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	5	55.6%
Fatigue	0	0.0%
Alcohol	0	0.0%

Weather		
Fine	4	44.4%
Rain	4	44.4%
Overcast	0	0.0%
Fog or mist	1	11.1%
Other	0	0.0%

Road Surface Condition		
Wet	4	44.4%
Dry	1	11.1%
Snow or ice	4	44.4%

Natural Lighting		
Dawn	1	11.1%
Daylight	4	44.4%
Dusk	0	0.0%
Darkness	4	44.4%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	1	11.1%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	1	11.1%
Off road, on straight	1	11.1%
Off road on straight, hit object	1	11.1%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	5	55.6%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit					
			~ 40km/h or less	0	0.0%
40 km/h or less	0	0.0%	80 km/h zone	1	11.1%
50 km/h zone	0	0.0%	90 km/h zone	6	66.7%
60 km/h zone	0	0.0%	100 km/h zone	2	22.2%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES		9
Fatal crash	2	22.2%
Injury crash	2	22.2%
Non-casualty crash	5	55.6%

CASUALTIES		7
Killed	4	57.1%
Injured	3	42.9%
^ Unrestrained	2	28.6%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Time Group			% of Day
00:01 - 02:59	1	11.1%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	1	11.1%	4.2%
06:00 - 06:59	1	11.1%	4.2%
07:00 - 07:59	1	11.1%	4.2%
08:00 - 08:59	1	11.1%	4.2%
09:00 - 09:59	1	11.1%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	2	22.2%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	0	0.0%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	0	0.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	1	11.1%	8.3%

Street Lighting Off/Nil			% of Dark
4	of	4 in Dark	100.0%

Crashes		Casualties
2	2004	5
1	2002	1
1	2001	0
2	2000	0
1	1997	0
2	1996	1

~ School Travel Time		
Involvement	1	11.1%

McLean Periods			% Week
A	4	44.4%	17.9%
B	0	0.0%	7.1%
C	1	11.1%	17.9%
D	0	0.0%	3.5%
E	2	22.2%	3.6%
F	0	0.0%	10.7%
G	0	0.0%	7.1%
H	0	0.0%	7.1%
I	1	11.1%	12.5%
J	1	11.1%	10.7%

Day of the Week								
Monday	1	11.1%	Thursday	3	33.3%	Sunday	2	22.2%
Tuesday	0	0.0%	Friday	1	11.1%	WEEKDAY	7	77.8%
Wednesday	2	22.2%	Saturday	0	0.0%	WEEKEND	2	22.2%

# Holiday Periods								
New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	1	11.1%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	0	0.0%	January SH	1	11.1%	December SH	0	0.0%

Session dataset Western RMS Region Great Western Hwy Country urban, Country non-urban, Country unknown; all crashes for 01 Mar 1996 to 31 Aug 2005. South Bowenfels - Pre-construction - 01-03-96 â€" 31-08-2005

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

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APPENDIX D: CRASH RESULTS

Table 17 – Wet crash data

			Head-on (straight)	Head-on, left hand bend	Head-on, right hand bend	U-turn	Rear end Left curve	Rear-end right curve	Lane change Left bend	Object on road, straight	Off straight, left	Off straight, right	Off right / left bend	Off left / right bend	Off left / left bend	Off right / right bend	Out of control, curve left	Out of control, curve right	Subtotal
Batemans Bay	Before	NI												1	1	1			3
		I	4								1				1	2			8
		F																	0
	After	NI												2	2	1		1	6
		I													2	2			4
		F																	0
Dalmeny	Before	NI													2				2
		I		1											1				2
		F		2															2
	After	NI																	0
		I																	0
		F																	0
Yowaka	Before	NI											4	1	3	1			9
		I			3								2	1	4	1			11
		F													2				2
	After	NI	1										4	1	1	3			10
		I										1		2	1	4			8
		F																	0
Robertson	Before	NI																	0
		I									1		1						2
		F																	0
	After	NI																	0
		I																	0
		F																	0
Mount Vic (top)	Before	NI		3											2				5
		I		3															3
		F																	0
	After	NI																	0
		I																	0
		F																	0
Mount Vic (bottom)	Before	NI														1			1
		I																	0
		F																	0
	After	NI												1					1
		I														1			1
		F																	0
River Lett Hill	Before	NI													2				2
		I		4									1						5
		F																	0
	After	NI						1		1			2	9	13	9			35
		I											3	5	2	2	1		13
		F																	0
South Bowenfels	Before	NI									2		1		1				4
		I		1									1	1					3
		F		3												1			4
	After	NI												1	1				2
		I												2		1			3
		F																	0
Hartley	Before	NI			3									2	2	2	1		10
		I			9							1			6				16
		F																	0
	After	NI														1		1	2
		I											2		1				3
		F																	0
Total			5	17	15	0	0	1	0	1	4	2	21	29	50	33	2	2	

Table 18- Dry crash data

			Head-on (straight)	Head-on, left hand bend	Head-on, right hand bend	U-turn	Rear end Left curve	Rear-end right curve	Lane change Left bend	Object on road, straight	Off straight, left	Off straight, right	Off right / left bend	Off left / right bend	Off left / left bend	Off right / right bend	Out of control, curve left	Out of control, curve right	Subtotal	Wet/dry total
Batemans Bay	Before	NI													1	1			2	5
		I				1													1	9
		F																	0	0
	After	NI					1				1			1					3	9
		I												1					1	5
		F																	0	0
Dalmeny	Before	NI								1		1	1	1		1			5	7
		I											3						3	5
		F																	0	2
	After	NI														1			1	1
		I																	0	0
		F																	0	0
Yowaka	Before	NI														1			1	10
		I	4										8	1					13	24
		F																	0	2
	After	NI											1	1		2			4	14
		I																	0	8
		F																	0	0
Robertson	Before	NI																	0	0
		I		1											1				2	4
		F		1															1	1
	After	NI																	0	0
		I																	0	0
		F																	0	0
Mount Vic (top)	Before	NI		1									1		2				4	9
		I																	0	3
		F											2						2	2
	After	NI																	0	0
		I																	0	0
		F																	0	0
Mount Vic (bottom)	Before	NI					1							1					2	3
		I												1	1				2	2
		F																	0	0
	After	NI																	0	1
		I											1	1				1	3	4
		F												1					1	1
River Lett Hill	Before	NI					1						1	2					4	6
		I												1					1	6
		F																	0	0
	After	NI							1				3	2	1				7	42
		I			1								1	4	1	1		3	11	24
		F																	0	0
South Bowenfels	Before	NI								1									1	5
		I																	0	3
		F																	0	4
	After	NI																	0	2
		I																	0	3
		F																	0	0
Hartley	Before	NI													1				1	11
		I																	0	16
		F																	0	0
	After	NI											1						1	3
		I											1						1	4
		F																	0	0
Total			4	3	1	1	3	0	1	2	1	1	24	18	8	7	0	4		

Table 19 – Site crash occurrence and FSC evaluation summary

		Number of incidence			Number of people		Factored severity costs				Total			
Site	Severity	Before	After	Fraction reduction / increase	Before	After	Before	After	Savings / cost	Fraction reduction / increase	Before	After	Savings / cost	Fraction reduction / increase
Batemans Bay	NI	5	9	-0.80	5	9	$ 46,445.00	$ 83,601.00	-$ 37,156.00	-0.80	$ 1,433,939.00	$ 854,431.00	$ 579,508.00	0.40
	I	5	4	0.20	9	5	$ 1,387,494.00	$ 770,830.00	$ 616,664.00	0.44				
	F	0	0		0	0	$ -	$ -	$ -	0.00				
Dalmeny	NI	7	1	0.86	7	1	$ 65,023.00	$ 9,289.00	$ 55,734.00	0.86	$ 14,320,953.00	$ 9,289.00	$14,311,664.00	1.00
	I	4	0	1.00	5	0	$ 770,830.00	$ -	$ 770,830.00	1.00				
	F	2	0	1.00	2	0	$ 13,485,100.00	$ -	$ 13,485,100.00	1.00				
Yowaka	NI	10	14	-0.40	10	14	$ 92,890.00	$ 130,046.00	-$ 37,156.00	-0.40	$ 17,277,974.00	$ 1,363,374.00	$15,914,600.00	0.92
	I	13	5	0.62	24	8	$ 3,699,984.00	$ 1,233,328.00	$ 2,466,656.00	0.67				
	F	1	0	1.00	2	0	$ 13,485,100.00	$ -	$ 13,485,100.00	1.00				
Robertson	NI	0	0		0	0	$ -	$ -	$ -	0.00	$ 7,359,214.00	$ -	$ 7,359,214.00	0.00
	I	4	0	1.00	4	0	$ 616,664.00	$ -	$ 616,664.00	1.00				
	F	1	0	1.00	1	0	$ 6,742,550.00	$ -	$ 6,742,550.00	1.00				
Mount Vic (Top)	NI	9	0	1.00	9	0	$ 83,601.00	$ -	$ 83,601.00	1.00	$ 14,031,199.00	$ -	$14,031,199.00	1.00
	I	1	0	1.00	3	0	$ 462,498.00	$ -	$ 462,498.00	1.00				
	F	2	0	1.00	2	0	$ 13,485,100.00	$ -	$ 13,485,100.00	1.00				
Mount Vic (Bottom)	NI	3	1	0.67	3	1	$ 27,867.00	$ 9,289.00	$ 18,578.00	0.67	$ 336,199.00	$ 7,368,503.00	-$ 7,032,304.00	-20.92
	I	2	4	-1.00	2	4	$ 308,332.00	$ 616,664.00	-$ 308,332.00	-1.00				
	F	0	1		0	1	$ -	$ 6,742,550.00	-$ 6,742,550.00	0.00				
River Lett Hill	NI	6	42	-6.00	6	42	$ 55,734.00	$ 390,138.00	-$ 334,404.00	-6.00	$ 980,730.00	$ 4,090,122.00	-$ 3,109,392.00	-3.17
	I	4	23	-4.75	6	24	$ 924,996.00	$ 3,699,984.00	-$ 2,774,988.00	-3.00				
	F	0	0		0	0	$ -	$ -	$ -	0.00				
South Bowenfels	NI	5	2	0.60	5	2	$ 46,445.00	$ 18,578.00	$ 27,867.00	0.60	$ 27,479,143.00	$ 481,076.00	$26,998,067.00	0.98
	I	3	2	0.33	3	3	$ 462,498.00	$ 462,498.00	$ -	0.00				
	F	2	0	1.00	4	0	$ 26,970,200.00	$ -	$ 26,970,200.00	1.00				
Hartley	NI	11	3	0.73	11	3	$ 102,179.00	$ 27,867.00	$ 74,312.00	0.73	$ 2,568,835.00	$ 644,531.00	$ 1,924,304.00	0.75
	I	8	3	0.63	16	4	$ 1,849,992.00	$ 0.75	$ -	0.00				
	F	0	0		0	0	$ -	$ -	$ -	0.00				

APPENDIX E: SOFTWARE APPLICATIONS

Programs used:

- CrashLink
- Microsoft Word
- Microsoft Excel
- Bentley Microstation
- Bentley MX SS3