Motorcycle safety barrier trials in South Australia: Case study – Adelaide Hills

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ABSTRACT

Motorcycling fatality rates are estimated at almost 30 times that of other modes per kilometre travelled. In South Australia, motorcyclists have contributed 14% of all fatal and serious injuries for 2.4% of registered vehicles. Road trauma has generally been reducing in South Australia, yet this trend has not been reflected with motorcyclists.

The Adelaide Hills is recognised as popular for motorcycling and has also been known to experience regular high speed motorcycle casualty crashes. Site investigation of motorcycle crashes recommended that the installation of barrier protection systems for motorcyclists be further investigated. Research and crash analysis supported this, and a dedicated fund was established to enable innovative infrastructure trials such as motorcycle protective barriers.

A flexible fabric motorcycle barrier system developed to meet European crash test standards became available in Australia and was chosen first. Another system utilising a lower steel rail developed and tested to European standards became available in Australia and was installed.

The methodology for this research involved a literature search, crash data and speed survey collection and analysis, site visits, consultation with specialists and field staff and further investigation of individual crashes.

Results so far are positive in terms of crashes. Performance, operational issues and maintenance are discussed and recommendations are made.

KEY WORDS: Motorcycle protection system, motorcycle safety barrier, flexible mesh barrier, steel rub rail, guard rail.

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1. INTRODUCTION

The objective of this case study is to share the experiences of these new motorcycle barrier installations on Gorge Road and Cudlee Creek Road in the Adelaide Hills with other state road authorities and professionals. Motorcycling is becoming increasingly popular for both leisure and commuting. Australian Transport Safety Bureau figures show that motorcycling is the most dangerous form of land travel in Australia. For every 1 billion kilometres travelled by motorcycle riders, there were 117 motorcycle rider fatalities. This is almost 30 times the number recorded by operators of other vehicle types, who recorded fewer than 4 fatalities per 1 billion vehicle kilometres travelled. (Johnston et al, 2008; DPTI, 2011)

Concerns about the relative safety to motorcyclists of standard road safety barriers are recognised internationally (Quincy, 1988; ACEM, 2004; Peldschus et al, 2007; Grzebieta et al, 2010). In the USA, Ouellet (1982) and Gabler (2007) noted that crash barriers had been relatively more dangerous in motorcycle crashes. EuroRAP (2008) reported that hitting a safety barrier had been a factor in 8-16% of rider deaths in Europe and that a motorcycle rider was 15 times more likely to be killed than a car occupant as a result of crashing into a roadside barrier.

In South Australia the number of new motorcycle registrations has more than doubled since 2003 (DPTI, 2011). Table 1 below shows a 37% increase in registered motorcycles from 2006 to 2010 and indicates an over-representation of motorcyclists in road fatalities (14%) in relation to registered motorcycles as a percentage of all registered vehicles (2.4%).

Table 1: Motorcycle registrations and fatalities relative to all registrations and road fatalities in South Australia, 2006-2011

Year	Registered m/cycles as % of all registered vehicles	Motorcycles registered in SA	Motorcyclist fatalities as a % of all road fatalities
2006	2.10	30,000	19.7
2007	2.20	33,000	6.4
2008	2.50	37,000	17.2
2009	2.60	40,000	12.6
2010	2.60	41,000	13.6
5 year average	**2.4%**		**14%**

Figure 1 shows the number and percentage of motorcycle riders and pillion passengers killed or seriously injured on South Australian roads every year since 2001. Although South Australia has had a decreasing trend of fatal and serious injury (FSI) crashes, it has not been the same for motorcyclist crashes. Over the period motorcyclists have become a larger part of serious road casualties, increasing from 10% in 2001 to 14% in 2010.

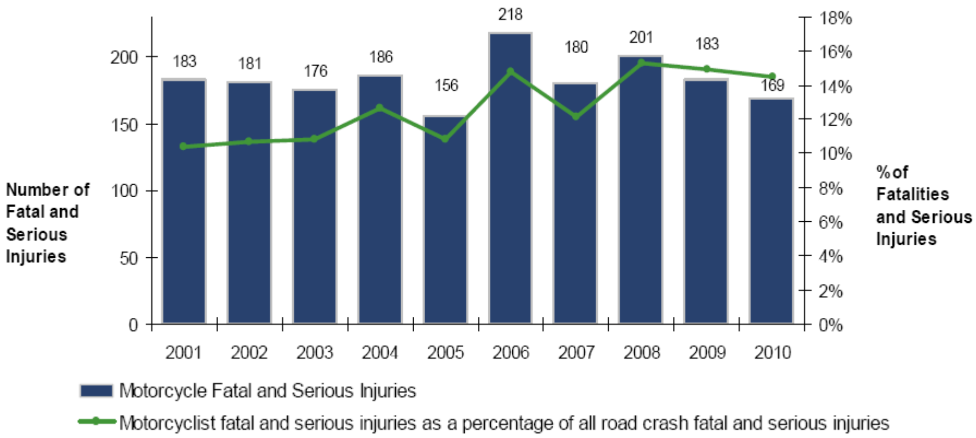

Figure 1: Annual motorcycle and pillion passenger fatalities and serious injuries as a percentage of all road crash fatal and serious injuries in South Australia, 2001-2010

Table 2 shows state-wide motorcycle casualty crashes by severity in comparison with motorcycle casualty crashes involving guard fence. Only crashes for speed limits greater than or equal to 70 km/h were considered to align with the general speed environment along the case study roads. Out of the total motorcycle casualty crashes, 6.5% hit guard fence yet contributed almost 17% of the total fatal crashes.

Table 2: Motorcycle casualty crashes state-wide and hitting guard fence in South Australia (Speed limit ≥ 70), 2001-11

Severity	State-wide m/c crashes	Number hitting guard fence	% hitting guard fence
Fatal (F)	72	12	16.7
Serious Injury (S)	421	32	7.6
Minor Injury	618	29	4.7
Total Casualty	1111	73	6.5

The increasing exposure created by the increase in motorcycle volume requires the application of countermeasures directed at all elements in the system in order to create a safer system for motorcyclists. Under a Safe System the road user has a much lower risk of death or of suffering serious injury because:

- Road users are alert and aware of the risks and drive to the conditions
- Speed is managed to safe levels through more appropriate speed limits, self-explaining roads that encourage safe speeds and devices such as intelligent speed assist
- Vehicles will increasingly have advanced safety features including anti-lock braking systems and traction control for motorcycles
- Roads will be improved and roadside hazards removed or protection systems installed

Towards Zero Together South Australia's Road Safety Strategy 2020 sets targets to reduce road fatalities to less than 80 persons per year and serious injuries to less than 800 per year. Given the high over-representation of motorcycle riders in fatal and serious crash statistics, as indicated in Table 1, targeted improvements in motorcycle safety are likely to be productive in meeting road safety targets in South Australia.

An action identified in South Australia's Motorcycling Road Safety Strategy 2005-2010 was to "monitor international and national research to keep abreast of road environmental developments and potential safety impacts for motorcycle riders, including safety barriers".

There are a number of motorcycle barrier supplements available in Australia and retrofitting these devices to existing safety barrier systems has huge potential in reducing crash injury levels. In 2009-10 and 2010-11 funding was provided to implement innovative infrastructure treatments such as motorcycle protective barrier in South Australia.

2. METHODOLOGY

The methodology of this study involved the following steps:

- Collecting South Australian crash statistics, speed profiles and motorcycle barrier location information from departmental staff and records
- Analysing motorcycle crash data to identify any trends or patterns
- Viewing video records and mapping information
- Visiting the roads to identify the exact treated sites and to investigate if there were any marks from crashes that could have gone unreported
- A literature search and review of product information to provide background information and identify possible solutions
- Consulting key professional staff involved in planning and structural evaluation and field staff involved in implementation and installation to identify site difficulties, limitations and other issues
- Reviewing in depth motorcycle crash data for 'after' installation crashes

3. SITE SELECTION CRITERIA

Department of Planning, Transport & Infrastructure (DPTI) South Australia is responsible for identifying, analysing and prioritising crash locations and directing funds to road safety treatments that ensure the most cost-effective returns in crash and injury reduction. The majority of road safety investment has been directed towards the Metropolitan Adelaide road network and generally hilly terrain in recent years because of the high crash numbers.

DPTI has been implementing intensive roadside hazard safety treatments to address crashes, especially roadside safety barrier (usually w-beam guard fence). The aim is to reduce the frequency and severity of "single vehicle run off road" casualty crashes chiefly, being the predominant type of crash in rural South Australia. However, the guard fence installed at some locations, especially on curves has potentially become a new hazard for motorcycle riders. The process of identifying motorcycle crash locations and providing them in map format helps identify crash 'hot spots'. This site selection process attempts to look at patterns of motorcycle crashes in South Australia on popular motorcycle routes.

The Adelaide Hills and in particular Gorge Road is recognized as popular for motorcycling due to its geometry and amenity and vicinity to Adelaide. The motorcycle numbers on Gorge Road on weekdays can more than double on weekends as shown in Figure 2.

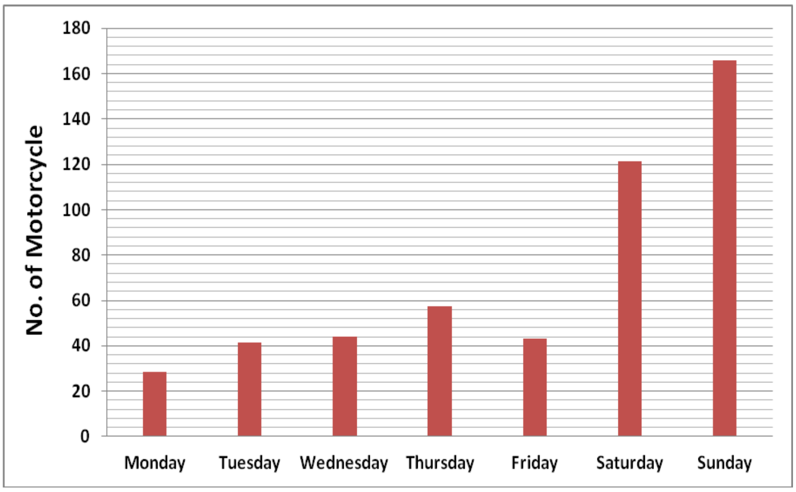

Figure 2: Motorcycle count on Gorge Road for different days of the week

The spatial locations of Gorge Road and Cudlee Creek Road are shown in Figure A, Appendix-A. Both roads were known to experience frequent motorcycle casualty crashes, sometimes involving guard fence as detailed in Table 3. This information was supported by the Road Safety Motorcycle Task Force and special speed surveys conducted by DPTI.

3.1 Crash Analysis

There have been numerous motorcycle crashes on Gorge Road and Cudlee Creek Road (both two lane undivided sealed roads). Between 2001 and 2010, 56 motorcycle casualty crashes were reported on Gorge Road resulting in 60 casualties, 8 fatal and 21 serious; and 21 casualty crashes were reported on Cudlee Creek Road resulting in 1 fatality and 9 serious injuries as detailed in Table 3.

Note the high number of motorcycle crashes per km per annum on these two roads relative to the State average (at least 25 times greater) and the high crash severity ratio (FSI/TC) into guard fence relative to all motorcycle crashes (approx 36% higher than State-wide).

The main crash trends identified for motorcyclists on Gorge Road for the period 2001-10:

- 56 of the 126 total casualty crashes (44%) involved motorcycles
- 52 of the 56 motorcycle casualty crashes occurred in dry conditions
- 52 of the 56 motorcycle casualty crashes occurred in daylight
- 49 of the 56 motorcycle casualty crashes occurred on a horizontal curve
- 19 of the 56 motorcycle casualty crashes (34%) involved guard fence, resulting in 5 fatal and 8 serious injury crashes

The main crash trends identified for motorcyclists on Cudlee Creek Road for 2001-10:

- 19 of the 40 total casualty crashes (48%) involved motorcycles

- All 19 motorcycle casualty crashes occurred in dry conditions and in daylight
- 16 of the 19 motorcycle casualty crashes occurred on a horizontal curve
- 7 of the 19 motorcycle casualty crashes (34%) involved guard fence, resulting in 1 fatal and 5 serious injury crashes

Table 3: Motorcycle casualty crashes - Gorge Rd and Cudlee Creek Rd, 2001-10 (Speed limit ≥ 70 km/h)

Road Section Details	Dist. (km)	Total casualty crashes 2001-10	M/C casualties 2001-10				M/C crashes /km pa	Crash Severity Ratio FSI/TC	Total casualty crashes involving guard fence	M/C casualties 2001-10 involving guard fence				Crash Severity Ratio FSI/TC
			Fatal	Serious injury	Minor injury	Total casualties (TC)				Fatal	Serious injury	Minor injury	Total casualties (TC)	
State-wide M/C crashes on high speed roads	**10500**	**976**	**72**	**421**	**618**	**1111**	**0.01**	**0.44**	**68**	**12**	**32**	**29**	**73**	**0.60**
Gorge Rd all crashes	22.7	126	9	33	120	162								
Gorge Rd M/C crashes		**56**	**8**	**21**	**31**	**60**	**0.25**	**0.48**	**19**	**5**	**8**	**9**	**22**	**0.59**
Cudlee Creek Rd all crashes	7.8	40	1	17	33	51								
Cudlee Creek Rd M/C crashes		**19**	**1**	**9**	**12**	**22**	**0.27**	**0.45**	**7**	**1**	**5**	**3**	**9**	**0.67**

Between 1997 and 2004 these two roads had their 100 km/h speed limits reduced to 80 km/h in three stages. Speed surveys were not available for before and immediately after the speed limit changes to ascertain any effect on speeds. Speed survey information was available for Gorge Road before and after the motorcycle barrier installations, on a relatively straight section of the road (RRD 14.56 km). The 85th percentile speed for motorcycles in 2009 was 119.9 km/h eastbound and 112.3km/h westbound (refer Table 4). In 2012 the 85th percentile speed was lower at 110.5 km/h eastbound but the same at 112.3 km/h westbound. While the 85th percentile speed for motorcycles eastbound showed a drop, these generally high motorcycle speeds compare against the much lower 85th percentile speed of around 90 km/h for all vehicles on this same section of road.

Table 4: Speed survey results for Gorge Road and Cudlee Creek Road

Road	Start RRD (km)	End RRD (km)	Data Year	85th percentile Speed (km/h)		
				All vehicles	m/c EB	m/c WB
Gorge Road	12.0	21.6	2009 2010 2012	88 90 92	119.9 - 110.5	112.3 - 112.3
Gorge Road	22.6	27.3	2009	83		
Cudlee Creek Road	0.6	7.8	2009	80		

RRD = Road Running Distance; m/c = motorcycle; EB = Eastbound; WB = Westbound

4. SAFETY BARRIERS AND TREATMENTS

Motorcycles are especially vulnerable to collisions on bends and curves, where deceleration, leaning and acceleration occurs and the stability of the motorcycle is at stake with loss of friction and control more likely. It was stated in Austroads (1999) that “there is no effective way to ‘soften’ impacts with roadside furniture for motorcyclists”.

Figure 3: Examples of motorcycle crashes involving guard fence in the absence of a motorcycle protection system

Published international research concluded that hitting a crash barrier was a factor in 8-16 per cent of motorcycle deaths in France and Germany (Brailly, 1998; Domhan, 1987). Riders were 15 times more likely to be killed than a car occupant in this type of collision in the UK (Williams, 2004) and injuries were up to five times more severe than if a rider had hit the rigid object that the barrier was guarding against in Germany and France (Ellmers, 1997; Brailly, 1998).

Crash barriers are designed to turn an uncontrolled high-risk collision into a controlled low-risk event, absorbing impact energy and reducing injury severity. At sites identified through crash records to be high risk to motorcyclists like tight external bends, consideration needs to be given to the form of crash barrier chosen to minimise the risk to this category of road user.

Motorcycle protection systems (MPS) tend either to comprise steel rails, mesh systems or plastic tubes that fit below the existing barrier, preventing riders from sliding under the horizontal beams and offering protection from the steel support posts. The effect of roadway barriers on motorcyclist safety is a developing area of practical research. Roadway barriers are designed to protect road users from hazards on the side of the road (e.g., trees, poles, cliffs, drains) and from oncoming traffic. In Australia three main types of safety barriers are used: concrete barriers, steel beam barriers and wire-rope (cable) systems. Steel barriers fall into the following sub-categories in Australia:

- W-beam comprising steel, concrete (largely superseded) or timber posts supporting a W-profile steel beam
- Steel tubular barriers on bridges
- Wire rope barrier systems

Roadside safety barriers installed along roads in Australia should generally comply with Australian Standard AS/NZS 3845–1999 (which refers to the recommended procedures in US NCHRP 350 (Ross et al 1993), now superseded by MASH (2009)). Identifying the roads most often used by motorcyclists is an important exposure factor in establishing risk, giving a more realistic view of what can be achieved by engineering countermeasures without over-estimating expectations. The standardised protocols used within Road Assessment Programs worldwide are capable of measuring and mapping risk across a network according to crash type and road user mode. Demonstration projects showing the pre and post implementation of motorcycle-friendly devices under real-world conditions should be encouraged and assessed.

4.1 Flexible Mesh MPS

DPTI has installed BASYC motorcycle barriers along Gorge Road and Cudlee Creek Road. BASYC is a product by Cegasa (Spain), a containment mesh designed to absorb human body impact against safety barriers and supplied in Australia by LB International. The barriers installed along Gorge Road and Cudlee Creek Road were the first of their type in South Australia (Figure B, Appendix-A).

The flexible fabric barrier (as shown in Figure 4**)** providing a continuous protection system below the guard rail and in front of the posts, has met European impact safety tests to UNE 135900 for motorcycle riders (86.5 kg dummy, 60 km/h, 30 deg.) and EN 1317 for passenger cars (1.5t, 110 km/h, 20 deg.). The HIC index (Head Injury Criterion) that gauges the risk of head injuries ranged from around 60 at mid span to 470 at the post. The maximum HIC test value is set at 650 for Level-1 (1000 for Level-2). The fabric consists of a fireproof recyclable material with UV protection and performs at ambient temperatures of -20ºC to +80ºC according to product literature.

Approximately $320,000 was programmed for the installation of motorcycle barriers, targeting fatal and serious crashes at high risk locations. The barrier has been installed on Gorge Rd and Cudlee Creek Rd as a demonstration project. There are a number of separate sections installed (14 on Gorge Rd and 3 on Cudlee Creek Road – refer Appendix-A) of various lengths (ranging from about 50m to 200m each) of some 1800m in total length.

(a) Installation (b) Complete

Figure 4: Motorcycle Protection Barrier - BASYC during and after installation

Experience gained from the installation – Flexible mesh

During installation a number of issues were identified:

- Higher steel strength is used in Australia (AASHTO G4 W-beam assembly) compared to Spanish guard fence. This results in difficulty drilling the posts with self drilling screws as the footing had been designed for. The installation technique was modified to use a nail gun (with permission from Spain), using a 19mm nail instead of tek screws after pre-drilling to shorten installation time and was considered strong enough to hold the foot in place.
- The post spacing as specified in AS/NZS 3845:1999 Road Safety Barrier Systems is 2 metres compared to 4 metres in Spain, doubling the number of feet required and almost doubling installation time.
- Guard fence has been installed on three different types of steel posts (between terminals): 'C' posts, 'Charlie' posts and 'cranked' posts. The latest standard posts, 'Charlie' posts as shown in Figure 5, have a different shape to the 'C' post and require a different foot design – the 'Victorian foot' as shown in Figure 6.

(a) Top view (b) Side view

Figure 5: Motorcycle Protection Barrier – BASYC on 'Charlie Posts'

(a) Side view (b) Rear view

Figure 6: Motorcycle Protection Barrier – BASYC on C-Posts with Victorian foot

- A significant amount of the guard fence on Gorge Road is on cranked posts, which are not conducive to the installation of BASYC as there is nowhere to attach the foot. The profile of the cranked I-section post (as seen in Figure 7) leaves nowhere for the bracket of the foot to connect to at the required distance away from the mesh to allow the necessary deflection at ground level when impacted. This would be a major modification of the tested article and would require full scale testing. Each foot requires at least 8 screws or nails to hold it in place. Drilling the post flange at the base, i.e. where there is stress concentration, would affect the cranked post strength. Hence the lower foot for the BASYC fitted the 'Charlie' post and the 'C' post but not the cranked post. A different solution was preferred for the cranked posts to dissipate impact forces better around the posts and not require a lower foot.

Figure 7: Cranked Posts on a curve on Gorge Road

- Another concern encountered was the number of screws or nails that were used to hold the BASYC foot in place. In the case of replacement, the same holes may not be reusable in either the post or the rail as they may not provide the same grip. In some cases, post replacement may be necessary.
- At one or two locations total replacement of old standard guard rail on concrete posts with wooden spacers was required as it was found to be unsuitable for the installation.

Vandalism has been a significant issue. The barrier was slashed at a number of locations within a year of installation as shown in Figure 8 and has been the biggest issue for maintenance crews to deal with.

Figure 8: Vandalised motorcycle protection system (BASYC) on Gorge Road

4.2 Steel Rail MPS

This system comprises a continuous galvanised steel flat screen that is attached to the existing barrier by an arm at each post. The MPS steel rail may be curved in the field and is terminated behind posts on both approach and departure (with capping).

The system passed full scale crash tests with crash dummies similar to BASYC in accordance with Spanish Standard UNE 135900 'Performance evaluation for motorcyclist protection safety barriers systems'. The HIC index ranged from 146 mid-span to 170 at the post. In addition to the crash dummy tests, the system also passed full scale car crash testing in compliance with European standard EN 1317-2.

DPTI installed the Motorcycle Protection Steel Rail along Gorge Road and Cudlee Creek Road in 2010/11 (as shown in Figure B, Appendix-A). Approximately $150,000 was programmed for the installation, targeting fatal and serious crashes at high risk locations. The rail system has been installed as a demonstration project. There are a number of separate sections installed totalling 3500 metres of various section lengths (ranging from 50m to 700m each). The "SPM-IS4" Motorcyclist Protection System is a continuous protection system designed for steel road safety barrier and produced by HIASA (Spain) and is available in Australia from Australian Construction Products.

The product was installed as shown in Figure 9 as a part of a trial program to measure the effectiveness of this type of technology. The barriers installed along Gorge Road and Cudlee Creek Road were the first of their type in South Australia. Cranked post locations, which were untouched during the BASYC flexible barrier mesh installation, were all treated using this motorcycle barrier.

The system provides safety for the two main hazards for motorcyclists with steel road safety barriers (similar to flexible barrier):

- The direct impact of the motorcyclist against the post barrier which can cause serious injuries, sometimes fatal.
- The space between two posts could be breached by the motorcyclist leaving them exposed to the hazards the barrier is there to protect.

Figure 9: Steel Rail MPS on Gorge Road and Cudlee Creek Road

Experience gained from the installation – Steel Rail

During the implementation a number of issues were identified:

- Upon installation of the steel rail on the older style W-beam (C-posts) the block out was found to be slightly narrower than the Charlie posts and the steel rail bracket holes didn't match the holes on the block out (as shown in Figure 9). Wider holes were made in the supplied brackets to fit the older style W Beam, after being accepted by structural engineers for trial purposes.
- The Spanish bracket is 130 mm wide compared with 85 mm used for the installed trial bracket with the same thickness of 4 mm such that the stiffness of the trial bracket is around 50% less than the Spanish bracket. The Spanish system has been successfully crash tested, but the modified Australian bracket had not been. Structural calculations estimated that for the 85 mm wide bracket to match the stiffness of the tested 130 mm wide bracket, it would need to be 4.6 mm thick.
- From structural modelling, it was found that the modified bracket under unit load would deflect 90% more than the original HIASA bracket at the rail.
- At some locations there was total replacement of old standard guard rail including old concrete posts, wooden spacers and W-beam to fit the steel rail, which increased the cost pressure (while improving the asset).
- Due to its rigidity, it may not be suitable or possible to install on sharp bends and on end treatments.

5. REVIEW AFTER INSTALLATION

5.1 Crash Analysis

After installation of the flexible barrier mesh in June 2010 and the steel barrier in June 2011, the study attempted to review their performance for the first time since installation. A summary of the crashes involved after barrier installation is shown in Table 5. Altogether there were 20 motorcycle crashes reported since installation; out of which 2 crashes were reported to have involved guard fence. One at a treated site was Property Damage Only (PDO), the other was at an untreated site and involved minor injury. No fatal or serious injury has been recorded on both roads involving guard fence.

Table 5: Motorcycle casualty crashes after treatment, June 2010 – March 2012

Road Section Details	Start RRD (km)	End RRD (km)	Dist. (km)	Total crashes	Total m/c casualties					Total m/c crashes involving guard fence	Total m/c casualties involving guard fence			
					Fatal	Serious injury	Minor injury	Property damage only	Total casualties		Fatal	Serious injury	Minor injury	Total casualties
Gorge Rd M/C crashes	4.6	27.3	22.7	10	1	0	5	4	6	2	0	0	1	1
Cudlee Creek Rd M/C crashes	0	7.8	7.8	10	0	0	7	4	7	0	0	0	0	0

In one of the PDO crashes reported on Gorge Road in November 2011, a mature age rider on a Honda Fireblade motorcycle hit the flexible barrier on a tight corner on Gorge Road as identified in Figure 10.

Figure 10: Damaged motorcycle & BASYC barrier after crash on Gorge Road

The rider claimed that an opposing vehicle had been well over the centreline causing him to suddenly change his riding line and lose control. Evidence indicates the rider low-sided into the barrier and the bike's forks were ripped out on the leading barrier post yet the rider walked away with only a reported cut to his right knee. According to reports, the helmet had the graphics worn away by the action of rubbing along the motorcycle barrier.

PDO data for motorcycle crashes can be very informative for crash analysis. If the property damage estimate is less than $3000 then it is not required to be reported in South Australia. A PDO by definition can include untreated injuries. During site investigation it was observed that some crashes might not have been reported but have caused damage to the barrier.

5.2 Maintenance and Operation

Some of the more notable issues after installation are:

- Maintenance is considered a significant issue with both reported and unreported incidents and also due to vandalism. Limited maintenance funds make it more difficult to get crews with material available at all times.
- Loose shoulder material (unsealed shoulders) between the road edge line and the barrier does not assist vehicle drivers/riders to maintain/regain control.
- Residual tree bark, leaves or debris along the road edge make it more slippery for motorcycle riders, which may be exacerbated in the case of flexible mesh where there is very little space left under the mesh for debris to pass through.
- The W-beam terminals were deliberately left untreated with MPS in both cases so as not to interfere with the operation of the terminal in the event of a car crash, as shown in Figure 11. However, it was noted in one case where the terminal is located on a curve due to a road cutting, a motorcycle had struck the post that the flexible mesh is terminated at (refer Figure 10).

Figure 11: End treatment of flexible mesh on Gorge Road

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Although sufficient time has not elapsed for a proper before/after crash evaluation of the treatments, this study has managed to identify that a single crash saving of what turned out to be PDO, which could otherwise have been much worse in the authors' opinion, is enough for any financial justification for this particular installation. Providing treatments at high risk locations, the principle aim to provide roadsides that are more forgiving for motorcycle riders, is consistent with a Safe System. It is evident that both trials with the different products (flexible mesh and steel rail) have been successful so far.

Based on HIC values as a representative indicator of injury, along with other considerations such as initial cost and vandalism, it may be preferable to use the steel rail system more generally and use the flexible mesh system where it is not possible to use steel rail (e.g. sharp bends and terminals) – pending acceptable crash testing of these systems and acceptable in-service performance. The authors consider that the flexible mesh could be continued onto a barrier terminal end treatment located on a trajectory path on a curve, as being of less risk to road users overall (and in-service monitoring if full-scale crash testing is cost-prohibitive).

Shoulder sealing between barrier and road edge is considered critical (due to surface friction and level difference) where errant drivers can recover control and is even more critical for motorcycle riders on the outside of the curves.

DPTI will continue to monitor, review and evaluate crashes and performance at the sites, with a view to continuing to invest in motorcycle protection systems and safety at high risk locations.

6.2 Recommendations

The study has identified issues as mentioned above and recommends the following:

- Dedicated funding sources should be identified to continue investing in motorcycle barriers with sealed shoulders at targeted high risk locations to align with the safe system approach.
- Regular inspection and maintenance is required to respond to damage and the cleaning of debris in front of the barrier.
- There may be a case to review the value to road safety research of PDO crashes for motorcyclists, particularly as PDO crashes can include untreated and unreported injuries within the 24-hour reporting window.

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Appendix-A

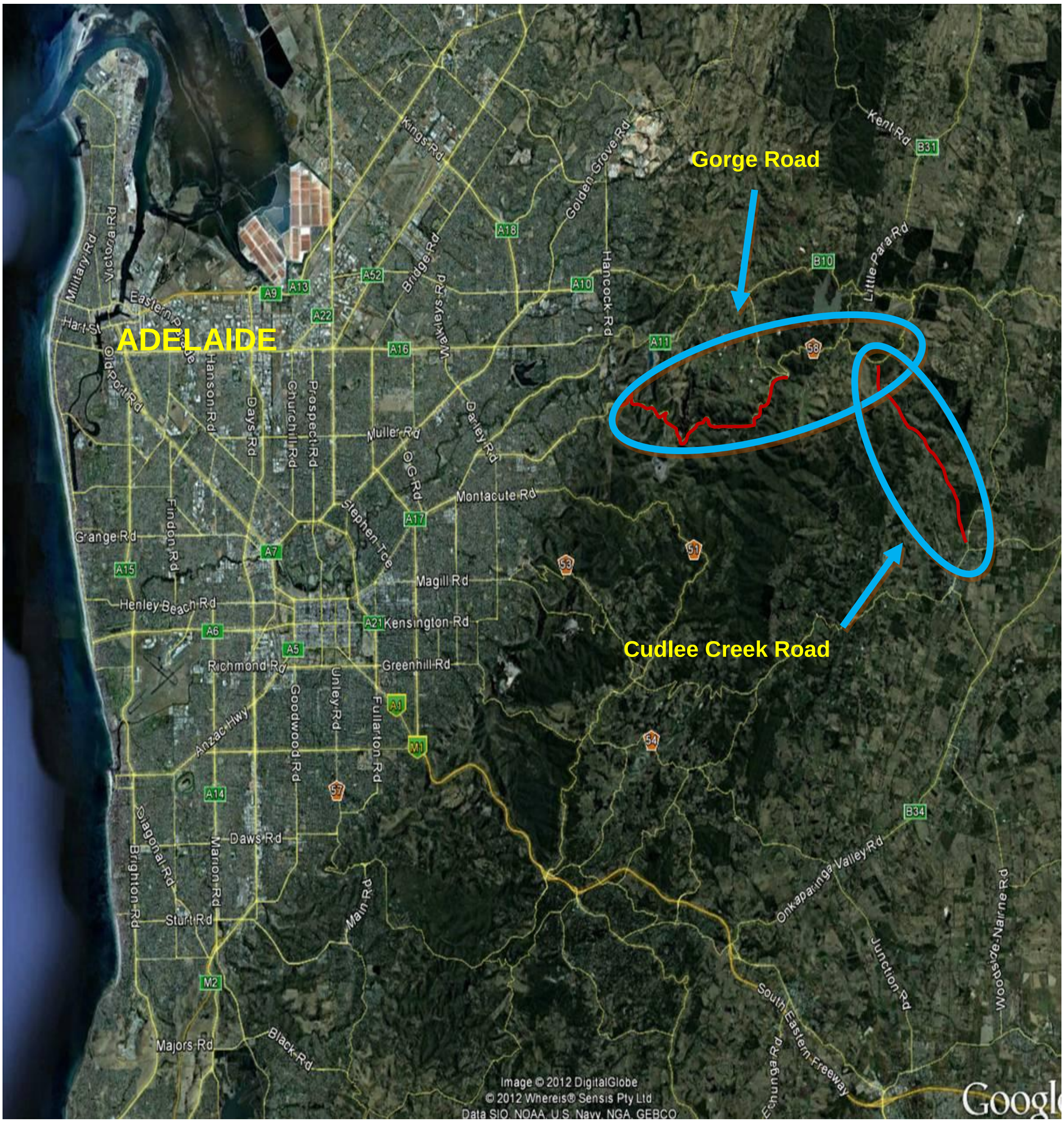

Figure A: Aerial view of Gorge Road and Cudlee Creek Road in relation to Adelaide

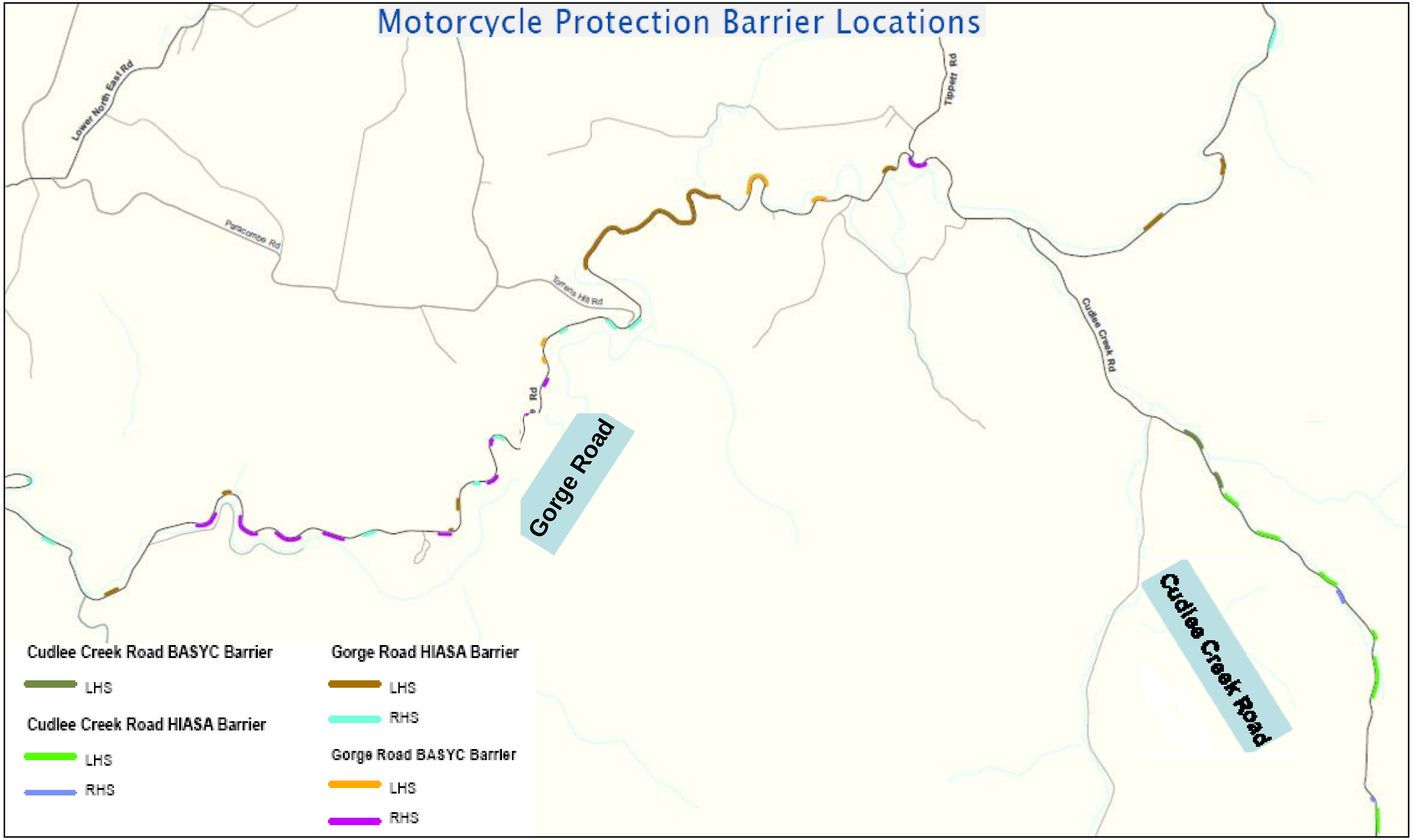

Figure B: Locations of the treated sites on Gorge Road and Cudlee Creek Road