CREATING A SAFE SYSTEM COMPLIANT HIGHWAY NETWORK

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Sub-title – The challenges of implementing a Safe System approach, through the Safer Journeys initiative, in New Zealand

Abstract

The Safer Journey initiative was adopted by New Zealand in 2011 and the first action plan launched. The challenge for road corridor designers is to translate the principles associated with this initiative into tangible features of that corridor that identifiably contribute to reductions in fatal and serious injuries.

Although New Zealand is an active member of the Austroads consortium and the Austroads Guides are our primary source of guidance, there is a strong desire to put guidelines into place that would result in the safe system desired outcomes sooner than would be addressed by the revisions to the Austroads Guides. An immediate concern was the accelerated programme for the Roads of National Significance; a series of corridors around the country that are of strategic importance. It is critical that these roads are constructed and operated to the latest expected levels of safety. Subsequently, the principles are being adapted to be applied to the rural, single lane and often highly constrained contexts.

The technical memorandum used to deliver this advice includes a detailed, 'whole-of-life' benefit assessment as well as background information that helps the designer assess the most appropriate treatments bearing in mind the safety problem that is being addressed.

This paper will detail and discuss the engineering rationale applied and the challenge of translating the safe system principles into such road corridor features and feedback the level of implementation achieved so far.

INTRODUCTION

Safer Journeys

New Zealand's road safety strategy 2010-2020

Safer Journeys is the government's strategy to guide improvements in road safety over the period 2010 to 2020. The strategy's vision is a safe road system increasingly free of death and serious injury and further develops the application of the Safe System approach to New Zealand.

The Safe System recognises that people make mistakes and are vulnerable in a crash. It reduces the price paid for a mistake so crashes don't result in loss of life or limb. Mistakes are inevitable - deaths and serious injuries from road crashes should not be.

As with many OECD countries and others around the world, although the road toll has been falling steadily over the last decade, there has been an increasing intolerance to the level of trauma on our roads. At the same time there has been a snow-balling of evidence in research that quantifies the efficacy of treatment of roadsides relating to crash outcomes and questions the validity of the clear-zone as the panacea to road safety that it has been for the last forty or so years.

Here in New Zealand we have traditionally designed our roadsides with clear-zones that, in order to limit cost and land-take, are traditionally accepted to have an operating efficacy of approximately 80% and a physical limit of 9.0m from the edge of the running lane. With the safe system approach to road trauma, the risk profile associated with mitigating crash severity has shifted away from frequency towards severity. That is to say that we should no longer accept high severity crashes as unavoidable even if the likelihood is very low. However, to do this by applying the clear-zone principle, with its increasing width yielding diminishing returns, would precipitate huge swathes of gently sloped, well-constructed roadsides with little or no landscape features that would still not guarantee 100% success. It should be noted that the normal principles of value for money still apply when prioritising works with a limited (and often shrinking) budget.

Research by Doeke and Woolley (CASR 2010) [1] indicated that severe injury crashes occur at distances much greater than 9.0m. At such distances, the predominant cause of injury was found to be 'vehicle roll', rather than 'object struck'. More recent Austroads research (ARRB 2014) [2] examining different roadside factors that affect crash outcomes, suggested that, while run-off-road casualties decreased with increasing clear zone width, the greatest rate of decrease occurred over the first 4m. More importantly the research found that 30% of all run-off-road casualties occurred in clear zones >13m and that the decrease in 'hit objects' crashes in wide clear zones was accompanied by an increase in roll-over crashes. For medians the equivalent offset is moderated to 3m due largely to the prevailing carriageway cross-fall being away from the median.

The challenge is to provide a solution that attempts to cater for all outcomes in a pragmatic and affordable compromise that has the 'Safe System' balance of severity and exposure (probability).

Crash Reduction and Crash Modification factors

Crash reduction factors (CRFs) have been generally used in Australia and New Zealand to indicate the safety benefits of various corridor treatments; however practice in other key international documents has evolved to use CMFs rather than CRFs. A crash modification factor (CMF) expresses the 'relative change in crash frequency due to a specific change in the road or its immediate environment'. The relationship between CMFs and CRFs is quite simple: CRF = (1.00 - CMF) x 100%.

The advantages of using the term CMF are that it avoids the presumption that crashes will necessarily reduce as a result of a treatment and the awkwardness of negative percentage reduction factors when crashes increase. This change has been reflected in the recent guidance on evaluation of effectiveness of road safety treatments (Austroads 2012a)[3].

By multiplying the CMF's together and applying an appropriate confidence factor (Austroads 2012a)[3] then practitioners can achieve a greater understanding of the efficacy of treatment combinations.

I WOULDN'T START FROM THERE!

As we all know, New Zealand's evolutionary road network is not unique in the world. It has evolved out of necessity, rather than design. The bronze plaque on the monument in Fig 1 below, records the journey of William Rees and Nicholas von Tunzelman, driving their sheep for the first time from Wānaka to Wakatipu; south over the Crown Range, some 1100m above sea level, in 1859. The road remained predominantly unsealed until only a few years ago.

Photo :Bob DeMay

Figure 1
Crown Range monument

Figure 2
SH 47 – Mt Ngarahoe

The impression the country fosters with the rest of the world is one of spectacular outdoor focus, sympathetically combined with the trappings of the finer things associated with a sophisticated and artistic culture. Generally, this is very much the case and the very best of hospitality and entertainment can be found the length and breadth of the country. The universities in New Zealand have the reputations to match much larger and older establishments. An issue for the transport authorities is that the expectation of the road network is naturally high. It could be said that it reflects more on the artistic and entertaining, rather than an effective and efficient means of getting from A (Awanui) to B (Bluff); in this case, a distance of around 1,980 km. As a result, journey times are often unexpectedly higher than anticipated and accordingly there is a risk that speeds increase. As a relatively young country, we are only in the early stages of 'upgrading' our network to meet the aspirations and expectations of our network users.

KEY DISCUSSION POINTS

In the absence of a wider need to provide or maintain corridor width, e.g. for future proofing, quantities balance, or other practical reasons, the most recent research now suggests traversable wide berms, shoulders and medians are not necessarily beneficial and are certainly not the safety panacea they were once considered. At larger distances, 'vehicle roll-over' replaces 'object hit' as the predominant outcome (CASR 2010)[1]. However, when concrete and other semi-rigid barriers are placed at increased distances from the carriageway, the collision angle of an errant vehicle increases. This results in higher perpendicular impact forces, and higher severity crash outcomes, unless they are placed such a distance away that the impact speed is significantly reduced (<30km/h). In such circumstances, a flexible barrier system provides a much more forgiving environment.

Note that, while a Wire Rope Safety Barrier (WRSB) is generally preferred because of its energy absorbing qualities, there are contexts that prohibit its use e.g. low radius curves or sharp sag curves. Although a wire rope will deflect much further than a semi-rigid alternative and still contain a captured vehicle, this remains a preferable outcome compared to complete failure and penetration. Notwithstanding this preference, the actual safety barrier type should be selected using a project specific 'fit for purpose' exercise. In addition there are scenarios where a barrier installation is not an appropriate solution and a designed run-out area can be provided. In such cases, the slope on this run-out area should ideally be limited to a maximum of 1:6 (preferably 1:10) (ARRB 2014)[2] and the surface integrity conducive to a controlled outcome rather than snagging or penetration.

There is also a need to consider the shy-distance to a barrier system. The shy distance is the offset of the system from the running edge of the live traffic lane. This parameter has an influence on driver behaviour, as a vertical roadside feature has varying effect on a driver's behaviour depending on its proximity to the edge line. While a certain amount of normalising occurs with a constant reduced offset, there is a limit to how low a value can be used before it significantly affects either vehicle position in the lane or its speed.

Logically, with reduced offset, there is also an increased risk of 'incidental' strikes. Such strikes are commonly the result of momentary lapses in concentration that would normally be recovered within available shoulder space. Not only do these incidents increase property damage and maintenance liability, if the offset is less than 1.5m then the crash risk actually rises and this increase is significant towards 0.5m. (ARRB 2014). [2]

The selection of cross section and median type (where relevant) in particular, will influence the best value for money on a 'whole-of-life' basis. Note that the 'whole-of-life' cost must take into account predicted crash outcome severity. The cost of maintenance will have a significant impact on 'whole-of-life' and the maintenance of narrow medians may well require more extensive traffic control and lane closures.

Engineering hearts and minds

An important part of the adoption of the safe system guidelines developed for New Zealand has been demonstrating the whole-of-life value for money aspect. Although we have reduced the importance of achieving favourable benefit cost ratios in favour of ‘doing the right thing’ and are moving to incorporating predictive crash rates as well as reactive crash statistics, an essential part of the transition process has been demonstrating that the resulting designs still represent sound investment. The use of crash modification factors are an indicator, however a significant effort has gone into demonstrating the efficacy of the recommended treatments, taking into account the construction and ‘whole-of-life’ maintenance costs. In going through this process, the industry is able to quantify the benefits (the ‘minds’) of a strategy and system that appears to make sense and supports the desire to improve safety (the ‘hearts’)

Using a predictive model, we expect 5 run-off-road injury crashes per 100m Vehicle kilometres travelled on a high standard of dual carriageway road (4.5 Star KiwiRAP rating). (NZTA 2011)[4]. A proportion of these will be a fatal or serious and the remainder will be minor-injury crashes. Different roadside treatments vary in efficacy in mitigating against fatal and serious injury crashes. If a wire rope barrier system is installed as edge protection for example, then the proportion of these run-off-road crashes that will result in death or serious injury is 23% and minor injury crashes will make up the remaining 77%; for a clear-zone, these proportions are 30% and 70% respectively. The social cost of each crash type is then multiplied by the total predicted crashes for a desired period of time (20, 25, 30 years). This gives the benefits of the edge treatment in terms of lives and injuries saved.

On the other side of the ledger are the costs of the installation of the edge treatment and the on-going maintenance costs. With barrier systems, this includes the cost of repair for non-injury crashes into the barrier.

An example of the application of this process, using three sections of the same project that have different characteristics and various lengths of different edge protection types, is given in appendix A of this report.

Dual Carriageways (4-lane divided)

Current design guidelines for dual-carriageways require the left-hand 2.5m shoulder be increased to 3m adjacent to a barrier. This provides the additional space needed for a driver to stop and get out of the vehicle safely. Therefore, there already is a predominance of safety barrier systems positioned 3m from the edge-line and perpetuating this offset under a Safe System philosophy will provide network consistency. As the greatest safety benefit (rate of crash decrease) occurs over the first 4m from the edge-line, a barrier positioned at 3m offset would theoretically be subject to a greater number of strikes than one placed at 4m. However, the construction and maintenance costs associated with the additional 1m offset outweigh the corresponding reduction in cost of barrier repairs, making the 3m offset the better value-for-money option.

A ”towards Safe System compliant” design would be likely to involve a safety barrier system, having considered the energy transfer and absorption qualities as a default treatment. The research indicates that different safety barrier systems have quite different CMF’s (ARRB 2014)[2] that reflect their ability to absorb energy that would otherwise transfer to vehicle occupants. As death and serious injuries reduce, this implies that there would be a corresponding increase ‘property only’ crashes and that this cost could be included in the ‘whole-of-life’ calculation. However, from a Safe System perspective, focussing of deaths and serious injuries, these costs are considered irrelevant. The actual cost of the barrier compared to the additional benefit it provides should be considered on a case by case (location and installation specific) basis.

As dual carriageway roads are principally designed to provide improved travel times and reliability, traffic lanes should generally be available at all times and not subject to closures or speed restrictions during normal median maintenance. As barrier repairs (following a strike) are more likely to require a short term closure or speed restriction then they may be regarded as an exception rather than a routine event; however these are often able to be undertaken at a time of day that minimises traffic delays.

An important implication of an increased length in safety barriers along-side our roads is the potential additional maintenance liability. Although this has been taken into account in the 'whole-of-life' cost calculation (Appendix A) this may be mitigated in high fatigue risk areas by using audio tactile profiled markings (rumble strips). These are extremely effective at redirecting drivers who are 'drifting off' the carriageway with the research showing that the great percentage of course correction occurs within 300mm (Finley, M.D. et al, M.A. (Texas Transportation Institute, 2009)[5].

It should be noted that the position of any 'hinge points' (changes in slope) in the roadside or particularly in median is adjusted relative to the offset of the safety barrier system. This is to ensure that he efficacy of the safety barrier system is not adversely affected by the impact of such a hinge point on the trajectory of an errant vehicle. (Austroads 2009)[6]. This may be particularly challenging when the offset of the safety barrier system has to be adjusted to provide sight distance around a curve.

Examples of the recommended median and roadside treatments from that publication are given in Appendix B of this paper (NZTA 2013)[7].

Single Carriageways (2-lane; 2-way)

Figure 3
SH6 Arahura Bridge – multifunctional structure

Figure 4
SH6 Arahura Bridge – Safe System segregated multifunctional structure

The key to transitioning to a Safe System compliant rural corridor for single carriageways lies in the identification of the safety risks, present or future (anticipated), to be addressed. The resolve to move to a predictive, preventative model for road safety is challenged greatly by the issues presented by rural corridors that have evolved in pockets to satisfy local needs over decades, rather than being designed to satisfy a grander plan or strategy.

Aspirations towards consistent standards that directly relate to the road classification are admirable. In reality however, this is practically unachievable as even the shortest length of 'non-conforming' highway will inevitably discredit this whole philosophy. The cost of uniformity would not only be prohibitive, it doesn't represent the best value for money for either network efficiency or, more pertinently, safety. In practical terms therefore, the inevitable compromise is required as it always has been, but now with greater focus on predictability of outcome and emphasis on safety.

The highway classifications do provide a very useful skeleton on which to base the key safe system parameters to make most appropriate use of the corridor width available while focussing on the issues to be resolved and the risks mitigated. In this way, the principles of both safe system and fitness for purpose may be satisfied and hence a strong likelihood of achieving good value for money.

As described previously, the most important parameters in translating the safe system principles into practice are:

- pavement width and treatment (lanes and shoulders; audio tactile markings)
- the roadside treatment (and hazard mitigation)
- separation of opposing traffic (audio tactile markings; wide centrelines and barriers)
- segregation of networks for vulnerable users

The starting point in New Zealand tends to be the capacity of the lane and shoulder widths relating directly to the requirements according to the road classification, but still with safety in mind. Using recent research into making the roadsides safer (ARRB 2014)[2], this classification based cross-section is then modified to maximise the crash modification factors (CMF) that could be expected. This is given effect to primarily by optimising the offset to safety barrier systems, the sealed and un-sealed shoulder widths (total available width) and then considering the separation of opposing traffic.

Figure 5
SH1 Centennial Highway, Wellington narrow median barrier

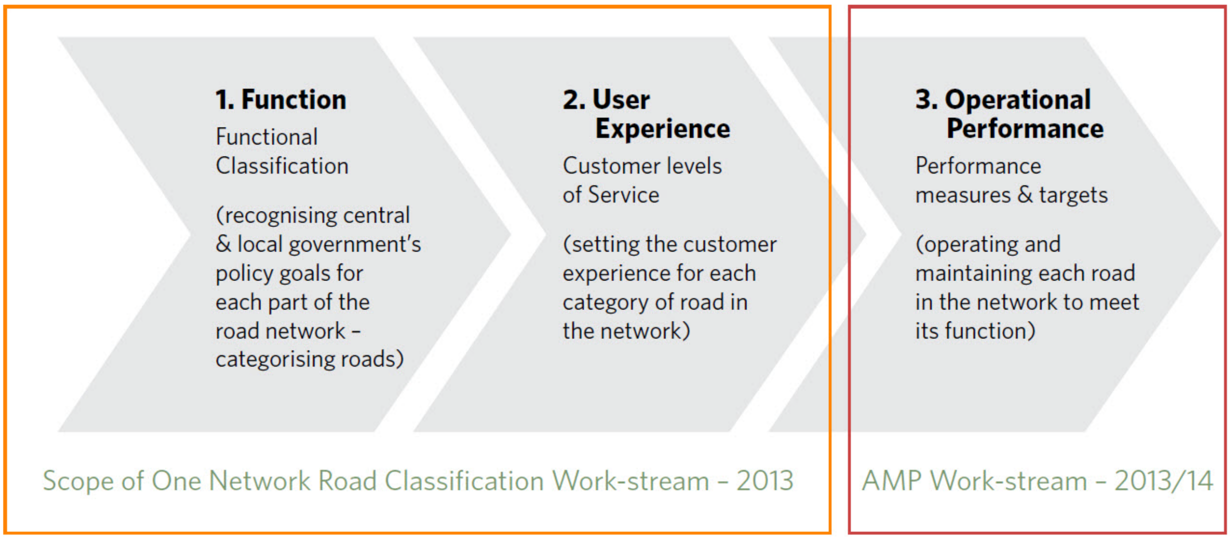
ONE NETWORK ROAD CLASSIFICATION (ONRC)

Our One Network Classification relates directly to the form and function of each category with the appropriate usage factored in. The following table gives a much reduced overview of the categories we use and the rationale behind each one. (NZTA 2013)[8]

The ONRC has three components:

1. A Functional Classification
2. Customer Levels of Service
3. Performance Measures and Targets

Classifying roads involves placing them in categories based on the primary function(s) each perform. This information helps inform decisions about the associated customer level of service that a particular category of road should offer; and in turn, the operational performance the road needs to deliver to meet that level of service for the customer.



*AMP – Asset Management Plan

Figure 6
Components of the Road Classification Process

Customer levels of service reflect the experience a road user should have, over time, on a particular category of road. In many cases this will be the same as the experience currently offered on these roads today. However, in some cases there may be a gap between what is experienced, what should be experienced or is ‘fit for purpose’ (either more or less). When working out the customer levels of service associated with each category of road, a range of variables need to be considered including road function, traffic movement, the expectations of users, user mode share, safety and speed. In addition, there may be other factors, economic growth initiatives for example, that also affect the investment in the network.

Figure 7 is taken directly from the guidelines published by the Transport Agency (NZTA 2013)[8] for applying the classification. It gives the ranges of values for different parameters as well as the contextual criteria that combine to define the classification of a road corridor.

THE ONRC AND A SAFE SYSTEM

The key to the practical implementation of a safe system to the lower volume, rural corridors is flexibility. We need to be able to apply the principles with sufficient latitude and flexibility that the solutions fit within the available corridor width and still retain the optimum level of safety. It is therefore essential that all the variables are considered and their potentially context sensitive hierarchy clearly explained; ideally in a series of specific examples. This would enable designers to fully appreciate the contribution that each cross-section component makes to safety.

Important documents that assist practitioners in matching appropriate mitigation measures to address specific risks are the High Risk Rural Roads Guide (HRRRG NZTA 2012) and the High Risk Intersection Guide (HRIG NZTA 2013)

Examples of the resulting cross-sections, together with the associated CMF’s are given in Appendix C of this report.

International Best Practice

In general, those concerned with the road network in New Zealand are very outward looking in seeking to replicate best practice from around the world. However, this desire must also be tempered with the aforementioned variations in rules and behaviour, if we are to improve road safety rather than confuse our network users with conflicting or ambiguous messages. We must carefully adapt and adjust the implementation details of all international concepts to incorporate local requirements and expectations.

This is particularly true where we introduce mixed use areas that expect pedestrians, cyclists and motorists to figure priorities out for themselves from intentionally subtle clues. Education has a vital part to play in setting appropriate expectation for all users. Engineers should openly communicate their intentions and expectation of the performance characteristics of their designs; no matter how obvious they may seem, rather than leaving it up to the road users to figure out for themselves. This messaging, using appropriate types of all media, should be adjusted appropriately to ensure that all aspects of the Safe System are adequately addressed.

One network road classification - functional classification

ROAD & STREET CATEGORIES/CRITERIA	FUNCTIONAL CRITERIA AND THRESHOLDS							
	MOVEMENT OF PEOPLE & GOODS				ECONOMIC AND SOCIAL			
	← LINK — PLACE →				← LINK			
	TYPICAL DAILY TRAFFIC (AADT)[1]	**HEAVY COMMERCIAL VECHICLES**[2] (daily flows)	**BUSES** (urban peak)[3]	**ACTIVE MODES**[4]	**LINKING PLACES**	**CONNECTIVITY**	**FREIGHT - INLAND PORTS/PORTS** (per annum)	**AIRPORT PAS NUMBE** (per annu
NATIONAL Meet 3 criteria (incl. at least 1 of Typical Daily Traffic, HCV or Buses & 1 economic or social)	U[7]: > 25,000 R: > 15,000	>800	> 40 buses or 2000 people per hour		>100,000 population[8]		>2 million tonnes (or >$3 billion)[9]	>3 millio
(HIGH VOLUME) Meet at least 1 high volume (Typical Daily Traffic or HCV)	U: > 35,000 R: > 20,000	>1200						
REGIONAL Meet 2 criteria (incl. at least 1 of Typical Daily Traffic, HCV or Buses & 1 economic or social)	U: > 15,000 R: > 10,000	>400	> 40 buses or 2000 people per hour		>30,000 population[11]	Linking remote regions (regional councils) or sole connectivity in urban areas	>1 million tonnes[12]	>500,00
ARTERIAL Meet 2 criteria (incl. at least 1 of Typical Daily Traffic, HCV or Buses)	U: > 5,000 R: > 3,000	>300	> 15 buses or 750 people per hour	Significant numbers of pedestrians and cyclists (urban peak) or part of identified cycling or walking network	>10,000 population[14]	Critical Connectivity (no alternative routes)		>250,00
PRIMARY COLLECTOR Meet 1 criteria (incl. at least 1 of Typical Daily Traffic, HCV or Buses)	U: > 3,000 R: > 1,000	>150	> 6 buses or 300 people per hour		>2,000 population		< 1 million tonnes	<250,0
SECONDARY COLLECTOR Meet 1 criteria (incl. at least 1 of Typical Daily Traffic or HCV)	U: > 1,000 R: > 200	>25			>250 population			
ACCESS All other roads	U: < 1,000 R: < 200	<25			<250 population			
(LOW VOLUME) Meet low volume Typical Daily Traffic	U: < 200 R: < 50							

Functional Classification

There are criteria and thresholds for each category, based on the functions the road performs within the network. To be included in a particular category a road must meet the agreed criteria and thresholds, including at least one of either – typical daily traffic (AADT), heavy commercial vehicles (HCV), or bus (urban peak) as appropriate.

The six functional categories are:

- National: These are roads that make the largest contribution to the social and economic wellbeing of New Zealand by connecting major population centres, major ports or international airports and have high volumes of heavy commercial vehicles or general traffic. They must meet the thresholds for 3 criteria, including at least one of the following movement criteria (Typical Daily Traffic, Heavy Commercial Vehicles or Buses, Urban Peak) and at least one of the economic and social criteria (i.e. 3 in total). To be included in the high volume subset a road must meet one of the high volume criteria for typical daily traffic or HCVs.
- Regional: These roads make a major contribution to the social and economic wellbeing of a region and connect to regionally significant places, industries, ports or airports. They are also major connectors between regions and in urban areas may have substantial passenger transport movements. As well as meeting at least one of the following movement criteria (Typical Daily Traffic, Heavy Commercial Vehicles or Buses, Urban Peak) these roads need to meet at least one of the economic and social criteria (i.e. 2 in total).
- Arterial: These roads make a significant contribution to social and economic wellbeing, link regionally significant places, industries, ports or airports and may be the only route available to some places within the region (i.e. they may perform a significant lifeline function). In urban areas they may have significant passenger transport movements and numbers of cyclists and pedestrians using the road. As well as meeting at least one of the following movement criteria (Typical Daily Traffic, Heavy Commercial Vehicles or Buses Urban Peak) they also need to meet at least 1 other criteria (i.e. 2 in total). The other criteria should then be considered to provide a local 'ground truthing' check, and in some instances by considering these this may result in a road moving up or down a category to reflect the function of the road.
- Primary Collector: These are locally important roads that provide a primary distributor/collector function, linking significant local economic areas or areas of population. They may be the only route available to some places within the region and in urban areas they may have moderate passenger transport movements and numbers of cyclists and pedestrians using the road. These roads need to meet at least one of the movement criteria (Typical Daily Traffic, Heavy Commercial Vehicles or Buses Urban Peak - (i.e. 1 in total). The other criteria are then be considered to provide a local 'ground truthing' check, and in some instance by considering these criteria, this may result in a road moving up or down a category to reflect the function of the road.
- Secondary Collector: These are roads that provide a secondary distributor/collector function, linking local areas of population and economic sites and may be the only route available to some places within this local area. These roads need to meet at least one of the movement criteria (Typical Daily Traffic or Heavy Commercial Vehicles - i.e. 1 in total). The other criteria are then be considered to provide a local 'ground truthing' check, and in some instance by considering these criteria, this may result in a road moving up or down a category to reflect the function of the road.
- Access: These are all other roads. Low volume roads within this category will fall into the low volume subset.

In the Primary/Secondary Collector and Access road categories we propose that the criteria other than the Typical Daily Traffic, Heavy Commercial Vehicles, Bus Urban Peak can be used to move a road up a category on the basis of local knowledge. For example, an Access road may provide critical connectivity or provide access to a regionally or locally significant tourist destination warranting it moving up a category to Secondary Collector even through it does not conform to the movement criteria for that category.

1\. 2\. 3\. 4\. 5\. 6\. 7\. 8\. 9\. 10\. 11\. 12\. 13\. 14\. 15\.

ONE NETWORK ROAD CLASSIFICATION

Figure 7

SUMMARY AND RECOMMENDATION

Designers should use the ONC system to establish the nominal cross-section that is appropriate for a corridor. They should then consider the safety risk(s) for the road user that they need to mitigate and therefore the appropriate treatment(s) that are recommended. Having decided the treatment required, reference should be made to the standard cross-sections (Appendix C) in order to optimise maximise the crash modification factors and also provide consistency of treatments in the way that each of the components are assembled in the final sections.

Discussion Points

In developing a framework and associated guidelines for the practical application of the Safe System principles it is essential that the Transport Agency engages with practitioners so that all are aware of the weight of evidence supporting the recommendations.

Informed debate and discussion of the key issues is essential.

REFERENCES

Research papers

Doeke and Woolley (CASR 2010) - *Effective use of clear zones and barriers in a Safe System's context*

Austroads 2014 – *Improving Roadside Safety – Summary Report*

Austroads 2012a - *An Introductory Guide for Evaluating Effectiveness of Road Safety Treatments*,
NZTA 2011 – *High Risk Rural Roads Guide*

Finley, M.D., Funkhouser, D.S., & Brewer, M.A. (Texas Transportation Institute.2009) – *Studies to Determine the Operation Effects of Shoulder and Centreline Rumble Strips on Two-Lane Undivided Roadways*.

Guidelines

Austroads 2009 – *Guide to Road Design Part 6 – Roadside Safety and Barriers – Commentary 12*

Technical Memoranda (NZ Transport Agency)

NZTA 2013 – TM2503 – *Guidelines for Edge Protection and Medians on Dual Carriageway Roads, incorporating a Safe System Philosophy.*

NZTA 2013 – *Applying the One network Road Classification - Guidelines*

Appendix A

Cost benefit analysis of retrofitting a Wire Rope Barrier System as edge protection on an expressway

SUMMARY OF COST- BENEFIT ANALYSIS OF THE OPTIONS

Safe System Clear Zone vs Barrier Analysis

1	Project Options	Low Clear Zone Severity			Wire Rope Barrier			Low Clear Zone Severity -WRB		
		Section A:	Section B:	Section C:	Section A:	Section B:	Section C:	Section A:	Section B:	Section C:
COSTS:										
2	Capital Costs	-	-	-	0.200	0.624	1.263	0.200	0.624	1.263
3.1	Maintenance Costs 20 Year Analysis Period	-	-	-	0.037	0.116	0.235	0.037	0.116	0.235
3.2	Maintenance Costs 25 Year Analysis Period	-	-	-	0.041	0.126	0.255	0.041	0.126	0.255
3.3	Maintenance Costs 30 Year Analysis Period	-	-	-	0.043	0.133	0.269	0.043	0.133	0.269
4.1	Total Costs (2) + (3.1) 20 Year Analysis Period	-	-	-	0.238	0.740	1.498	0.238	0.740	1.498
4.2	Total Costs (2) + (3.2) 25 Year Analysis Period	-	-	-	0.241	0.750	1.519	0.241	0.750	1.519
4.3	Total Costs (2) + (3.3) 30 Analysis Period	-	-	-	0.243	0.757	1.533	0.243	0.757	1.533
BENEFITS:										
7.1	Accident Costs 20 Year Analysis Period	6.365	16.732	30.862	5.511	14.023	23.9890	0.8540	2.7090	6.8730
7.2	Accident Costs 25 Year Analysis Period	6.920	18.192	33.555	5.991	15.246	26.0830	0.9290	2.9460	7.4720
7.3	Accident Cost 30 Year Analysys Period	7.298	19.185	35.388	6.319	16.079	27.5070	0.9790	3.1060	7.8810
8	Seal Extn/Passing Lane	-	-	-	-	-	-	-	-	-
9	Carbon Dioxide	-	-	-	-	-	-	-	-	-
10	Tangible Benefits (5) to (8)									
11.1	**20 Year Analysis Period Provisional B/C Ratio (7.1)/(4.1)**							**3.6**	**3.7**	**4.6**
11.2	**25 Year Analysis Period Provisional B/C Ratio (7.2)/(4.2)**							**3.9**	**3.9**	**4.9**
11.3	**30 Year Analysis Period Provisional B/C Ratio (7.3)/(4.3)**							**4.0**	**4.1**	**5.1**

Clear Zone vs Wire Rope Barrier Benefit Cost Ratio Analysis - Section A

Details:

Average AADT 2016-2036 (westbound) =	21166 vpd
Average AADT 2016-2036 (eastbound) =	21300 vpd
Average AADT 2016-2036 (total) =	42466 vpd
Section Length =	1710 m
Length of Clear-zone replaced by Wire Rope Barrier in (both directions)	2020 m
No. of crashes per year	1.33
Crash rate = 5/100 million vehicle kms travelled	

Time Periods:

Base Date =	1/07/2011
Time Zero =	1/07/2014

Costs

Clear Zone Option Social Costs Based on Table 3 in Appendix B

"High" Social Cost per year
$ 957,000.00 (based on NZTA EEM 2006 with Severity Factor of 0.38 and average Ksi $1.877M and minor $0.022M)

"Low" Social Cost per year
$ 827,000.00 (based on reduced Severity Factor of 0.3 to take into account high standard of roadside design on proposed new road)

Following table determines the total High and Low Clear Zone crash Social Costs based on varying periods of analysis

Analysis Period	Uniform Series Present Worth Factor	Single Payment Present Worth Factor	Accident Trend Ajustment	Clear Zone Social Injury Cost		Total Cost over Analysis Period	
				"High"	"Low"	"High"	"Low"
20 years	10.2058	0.7938	0.95	$ 957,000.00	$ 827,000.00	$ 7,365,000.00	$ 6,365,000.00
25 years	11.0963	0.7938	0.95	$ 957,000.00	$ 827,000.00	$ 8,008,000.00	$ 6,920,000.00
30 years	11.7023	0.7938	0.95	$ 957,000.00	$ 827,000.00	$ 8,445,000.00	$ 7,298,000.00

Wire Rope Barrier Option Social Costs Based on Table 4 in Appendix B

$716,000

Following table determines the total Wire Rope Barrier Social Costs for three periods of analysis

Analysis Period	Uniform Series Present Worth Factor	Single Payment Present Worth Factor	Accident Trend Ajustment	WRB Social Cost
20 years	10.2058	0.7938	0.95	$ 5,511,000.00
25 years	11.0963	0.7938	0.95	$ 5,991,000.00
30 years	11.7023	0.7938	0.95	$ 6,319,000.00

Difference between Clear Zone and Wire Rope Option Crash Social Costs

Analysis Period	"High" Clear Zone Social Cost	"Low" Clear Zone Social Cost	WRB Social Cost	Net "High CZ" Social Cost	Net "Low CZ" Social Cost
20 years	$ 7,365,000.00	$ 6,365,000.00	$ 5,511,000.00	$ 1,854,000.00	$ 854,000.00
25 years	$ 8,008,000.00	$ 6,920,000.00	$ 5,991,000.00	$ 2,017,000.00	$ 929,000.00
30 years	$ 8,445,000.00	$ 7,298,000.00	$ 6,319,000.00	$ 2,126,000.00	$ 979,000.00

Costs:
Wire Rope Construction Capital Cost Rate
Based on:

Wire Rope Barrier Including anchor blocks =	= 21,040m (total length) x $75/m	=	$ 1,578,000.00
Contractor Costs + overheads	plus 50%	=	$ 789,000.00
		Total Base Estimate	$ 2,367,000.00
Contingency - assume 7%			$ 165,690.00
		Total Expected Estimate	$ 2,532,690.00
Linear metre rate for 21,040 =		=	$ 120.38
		Approx	**$ 125.00 /m**

Length of Clear-zone replaced by Wire Rope Barrier in (both directions) **2020 m**

Length of WRB in Section A (m)	Wire Rope Construction Cost per m	Single Payment Present Worth Factor	Total Wire Rope Capital Construction Cost
2020	$ 125.00	0.7938	$ 200,400.00

Wire Rope Maintenace Costs:
21.04km length of edge protection wire rope barries being installed - two barrier strikes per week at a repair cost of $2,000/ strike
Annual WRB Maintenance Cost = 2 strikes per month x $2,000/strike x 12 months

$ 48,000.00

Following table determines the total wire rope barrier maintenance costs based on varying periods of analysis

Analysis Period	Length of WRB (m)	Total Length of Edge WRB being Installed (m)	Proportion of Total WRB being installed	Annual WRB Mainteannce Costs	Uniform Series Present Worth Factor	Single Payment Present Worth Factor	Total WRB Maintenance Costs
20 years	2,020	21,040	0.0960	$ 4,600.00	10.2058	0.7938	$ 37,300.00
25 years	2,020	21,040	0.0960	$ 4,600.00	11.0963	0.7938	$ 40,500.00
30 years	2,020	21,040	0.0960	$ 4,600.00	11.7023	0.7938	$ 42,700.00

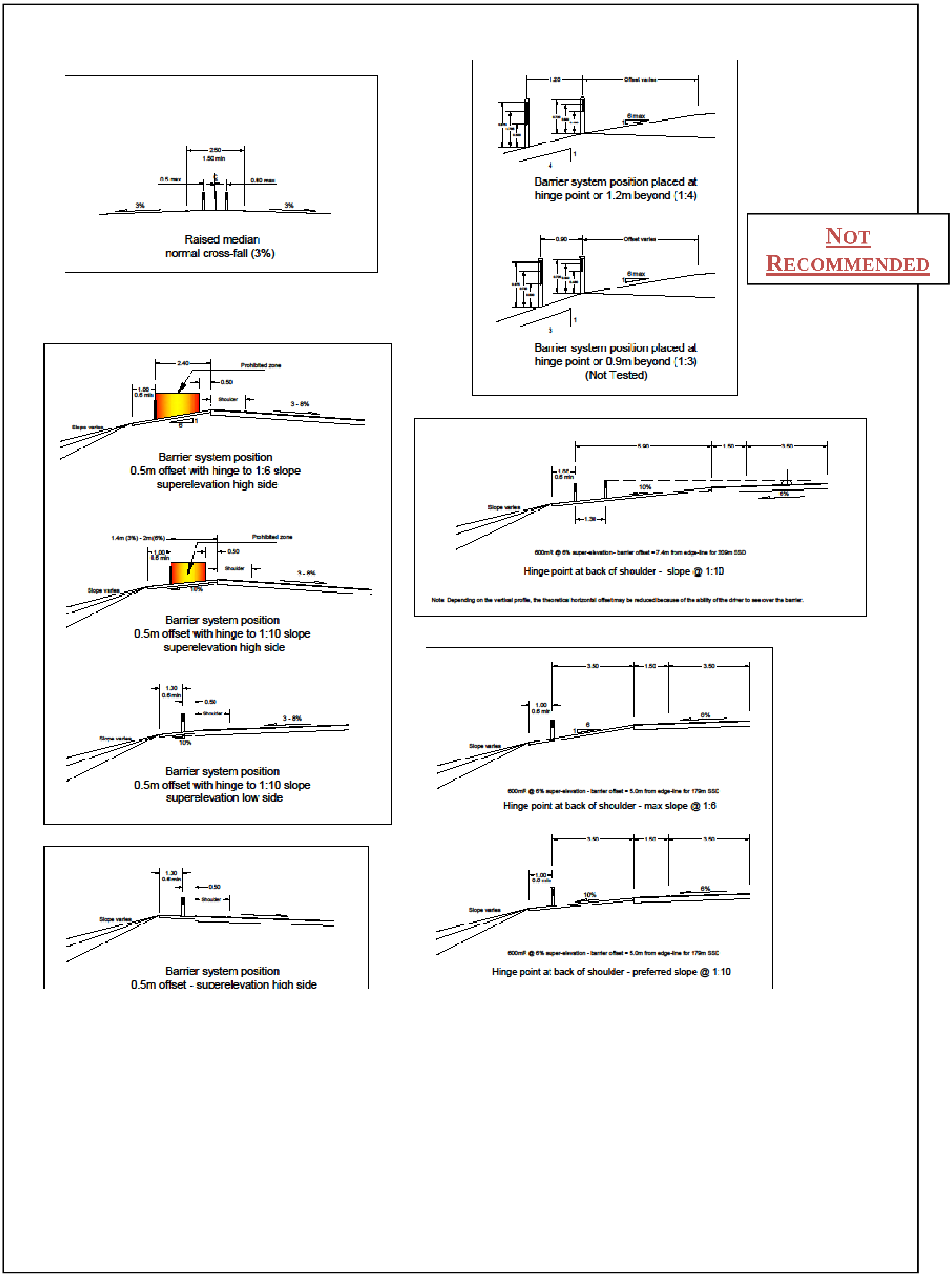
Benefit/Cost Ratio

Following table calculates the benefit/cost ratio for the additional "High" and "Low" Severity costs compared to installing a WRB

Analysis Period	Net "High CZ" Social Cost	Net "Low CZ" Social Cost	Total Wire Rope Capital Construction Cost	Total WRB Maintenance Costs	Total WRB Costs	"High CZ" Benefit Cost Ratio	"Low CZ" Benefit Cost Ratio
20 years	$ 1,854,000.00	$ 854,000.00	$ 200,400.00	$ 37,300.00	$ 237,700.00	7.8	3.6
25 years	$ 2,017,000.00	$ 929,000.00	$ 200,400.00	$ 40,500.00	$ 240,900.00	8.4	3.9
30 years	$ 2,126,000.00	$ 979,000.00	$ 200,400.00	$ 42,700.00	$ 243,100.00	8.7	4.0

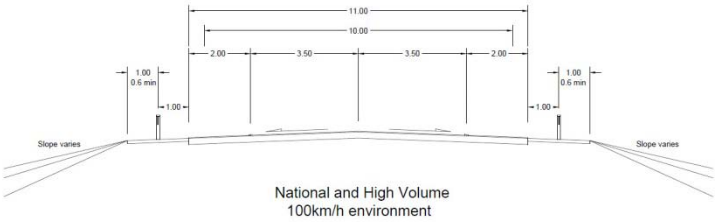
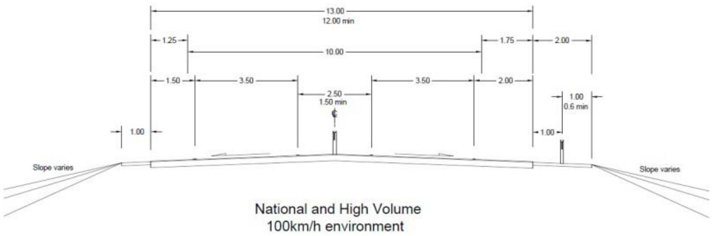
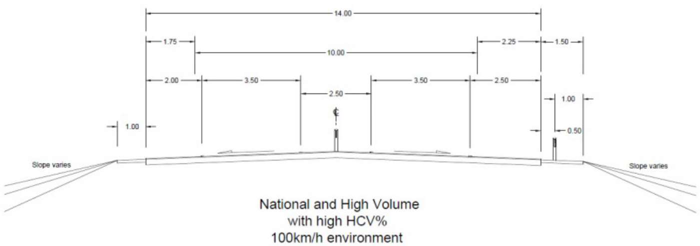
Appendix B

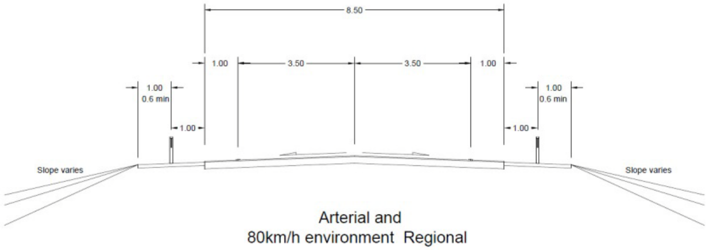
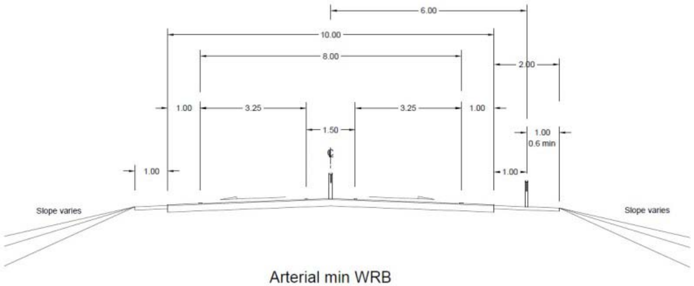
Position of safety barrier systems relative to carriageway hinge-points (TM2503)

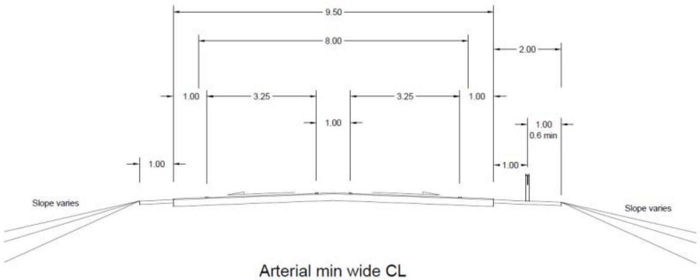
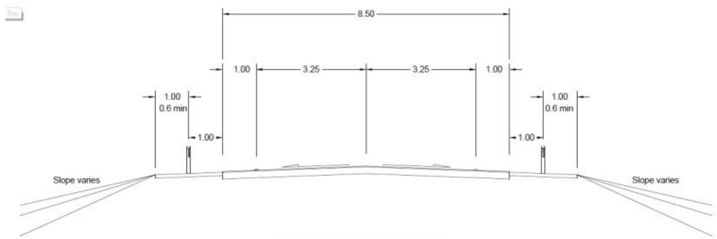


Appendix C

Safe System typical cross-sections based on NZTA 'One Network Classification'

	Typical Section	Classification	Construction details	Key Safety Factors
1		National: >15k v/d (R): >25k v/d (U) >800 HCV/d High Volume >20k v/d (R): >35k v/d (U)	10m + 1m full construction + 2m unsealed No median 3.0m shoulders – with and without barriers • 2.0m sealed • 1.0m unsealed	Edge Only No median 3.0m shoulder width • 2.0m sealed • 1.0m unsealed (cmf=0.56)
2		National: >15k v/d (R): >25k v/d (U) >800 HCV/d High Volume >20k v/d (R): >35k v/d (U)	10m + 3m full construction + 2m unsealed 2.5m median (1.5m min) Median barrier 3.0m barrier shoulders • 2.0m sealed • 1.0m unsealed 2.5m shoulder • 1.5m sealed • 1.0m unsealed	Median and Edge 1.5 – 2.5m median with barrier Edge barrier as required 3.0m shoulder with barrier • 1.0m unsealed (cmf=0.56) 2.5m shoulder without barrier • 1.0m unsealed (cmf=0.63)
3		National: >15k v/d (R): >25k v/d (U) >800 HCV/d High Volume >20k v/d (R): >35k v/d (U) >1200 HCV/d	10m + 4m full construction + 1.5m unsealed 2.5m median Median barrier 3.0m barrier shoulder • 2.5m sealed • 0.5m unsealed 3.0m shoulder	Median and Edge 2.5m median with barrier Edge barrier as required 3.0m shoulder widths: • 0.5m unsealed with barrier – reduce nuisance strikes • 1.0m unsealed (cmf=0.56)

			• 2.0m sealed • 1.0m unsealed	
7		Arterial: >3k v/d (R): >5k v/d (U) >300 HCV/d 80 kph Regional: >10k v/d (R): >15k v/d (U) >400 HCV/d	10m + 1.0 full construction or 9.0m full construction + 2m unsealed No Median 2.0m shoulder with and without barrier • 1.0m sealed • 1.0m unsealed	Edge Only No median Edge barrier as required 2.0m shoulder with or without barrier • 1.0m sealed • 1.0m unsealed (cmf=0.61)
8		Arterial: >3k v/d (R): >5k v/d (U) >300 HCV/d	10m full construction + 2m unsealed 1.5m median Median barrier 2.0m shoulder with or without barrier • 1.0m sealed • 1.0m unsealed Sealed shoulder widths may increase with higher HCV volume	Median and Edge 1.5m median with barrier Edge barrier as required 2.0m shoulder with or without barrier • 1.0m sealed • 1.0m unsealed (cmf=0.61)

9	 Arterial min wide CL	Arterial: >3k v/d (R): >5k v/d (U) >300 HCV/d	9.5m (10m)* full construction + 2m unsealed 1.0m median (1.5m)* Wide centreline ATPM 2.0m shoulder with or without barrier • 1.0m sealed** • 1.0m unsealed *wide centreline width may be future-proofed for barrier **sealed shoulder widths may increase with higher HCV volume	Median and Edge 1.0m (1.5m) wide centreline median ATPM Edge barrier as required 2.0m shoulder with or without barrier • 1.0m sealed • 1.0m unsealed (cmf=0.61)
13	 Minimum - 1m shoulder	General, all-purpose classification where width is restricted.	8.5m full construction +2m unsealed No median separation 3.25 lanes 2.0m shoulder with or without barrier • 1.0m sealed • 1.0m unsealed Sealed shoulders width may increase with higher HCV volume	Edge treatment only 2.0m shoulder with or without barrier • 1.0m sealed • 1.0m unsealed (cmf=0.61) Unsealed 1.5m with barrier - reduce nuisance hits; cmf=0.4