Technical Note 209

Reduced Working Width for Single Slope Concrete Barrier Design

November 2023

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Contents

1 Background

This Technical Note is intended to provide advice on the single slope concrete barrier design to allow for the reduced working width on the Queensland state-controlled road network. While the Normal Design Domain (NDD) and Extended Design Domain (EDD) widths have been covered in the Austroads *Guide to Road Design* (AGRD) Part 6 *Roadside Design, Safety and Barriers* and/or corresponding *Road Planning and Design Manual* (RPDM) Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers*, this Technical Note is specifically focused on the assessment of Design Exceptions (DE) and the implementation of strategies to mitigate potential risks to roadside structures.

The superseded RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers* (Transport and Main Roads, 2014) suggested a working width of 0.9 m (in a 100 km/h speed zone, with a crossfall of 3%). The superseded 2022 version of RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers* (Transport and Main Roads, 2022) accepts the updated minimum working width values as indicated in AGRD Part 6 *Roadside Design, Safety and Barriers* (Austroads, 2022a), which requires a working width of up to 2.4 m, subject to test level and barrier height.

The details of the working widths from the superseded versions of RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers* are listed in Table 1.

Table 1 – Comparison of working widths between superseded RPDM Edition 2, Volume 3, Part 6 Roadside Design, Safety and Barriers 2014 and 2022 versions

<table>
<tr><th colspan="6">RPDM Edition 2, Volume 3 Part 6 (2014) (Superseded)</th></tr>
<tr><th rowspan="2">Speed Zone</th><th colspan="3">Working Width</th><th rowspan="2">Barrier Height</th><th rowspan="2">Design Vehicle</th></tr>
<tr><th colspan="3">Crossfall</th></tr>
<tr><td></td><td>0%</td><td>3%</td><td>7%</td><td rowspan="3">1.1 m</td><td rowspan="3">4.3 m high vehicle</td></tr>
<tr><td>60 km/h</td><td>0.5 m</td><td>0.6 m</td><td>0.8 m</td></tr>
<tr><td>100 km/h</td><td>0.8 m</td><td>0.9 m</td><td>1.1 m</td></tr>
<tr><th colspan="6">RPDM Edition 2, Volume 3 Part 6 (2022) (Superseded) / AGRD Part 6 (2022)</th></tr>
<tr><th>Test Level</th><th colspan="3">Working Width</th><th>Barrier Height</th><th>Design Vehicle</th></tr>
<tr><td>TL-3</td><td colspan="3">0.5 m</td><td>0.915 m</td><td rowspan="5">4.6 m high vehicle</td></tr>
<tr><td rowspan="2">TL-4</td><td colspan="3">2.5 m</td><td>0.915 m</td></tr>
<tr><td colspan="3">2.2 m</td><td>1.070 m</td></tr>
<tr><td rowspan="2">TL-5</td><td colspan="3">2.4 m</td><td>1.070 m</td></tr>
<tr><td colspan="3">1.5 m</td><td>1.370 m</td></tr>
</table>

It should be noted that the superseded working width values specified in the 2014 version of RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers* were adopted directly from the dated Roads and Traffic Authority (RTA) of NSW *Road Design Guide* (RTA, 2000) where the original source of these working widths was not provided and unable to be located or verified.

It is acknowledged that some Transport and Main Roads projects have already been financially approved, funded or commenced based on the 2014 version RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers*. Whilst valid at the time (prior to the version published in

October 2022), a 0.9 m working width does not represent contemporary research findings and recommendations that have been nationally accepted.

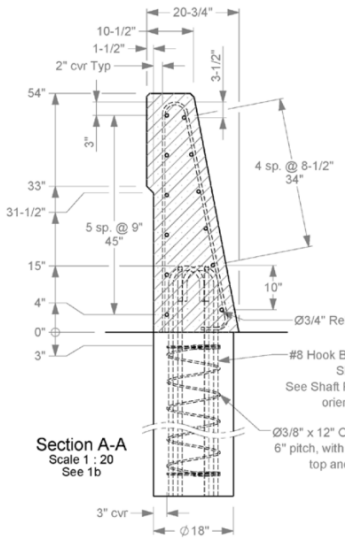
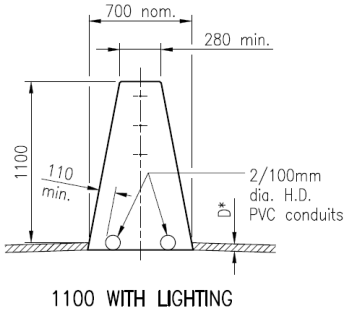
The 2014 version also does not represent the current vehicular features in Queensland. Notwithstanding this, residual risks within the controllable range need to be managed and assessed.

In situations where redesign of the cross sections is not practical due to site constraints (such as bridge piers, gantries or pre-determined land resumptions), provision of a redesigned single slope concrete barrier is considered as an acceptable alternative solution. A 0.9 m working width in constrained designs can be achieved through a DE, by utilising the concepts and working widths provided in AGRD Part 6 *Roadside Design, Safety and Barriers* (Austroads, 2022a).

2 Development of an alternative design for single slope concrete barriers

The working widths specified in Table 5.5 of AGRD Part 6 *Roadside Design, Safety and Barriers* (Austroads, 2022a) were deduced from data of various crash tests for concrete barriers (including single slope and vertical barriers) with some necessary adjustments applied (Austroads, 2022b). Of the three TL5-12 tests referenced in the Austroads report *Development of Edition 4.0 of the Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads, 2022b), only one test has a near-identical face slope gradient as Transport and Main Roads public domain single slope concrete barrier, as illustrated below.

Table 2(a) – Profiles of the USA Tested Barrier and Transport and Main Roads Public Domain Single Slope Barrier

	USA Tested Single Slope Barrier	**Transport and Main Roads Public Domain Single Slope Barrier**
Diagram		
Height above ground	1.372 m	1.100 m
Base width	0.527 m	0.700 m
Top width	0.267 m	0.280 m
Slope	5.28V:1H	5.25V:1H

Manual for Assessing Safety Hardware (MASH) Test 5-12 of the 1.372 m high barrier conducted in the United States of America (USA) in 2019 (Sheikh et al, 2019) achieved favourable working width

results, however additional barrier height is still required to match working widths closer to the 0.9 m previously assumed in Transport and Main Roads designs. Additional adjustments are also required to account for this standard MASH Test 12 representing a 4.06 m high 36000V truck (vs 4.60 m required) impacting the barrier at the angle of 15° at the speed of 80 km/h. The structural details for this concrete barrier are included Appendix A for reference.

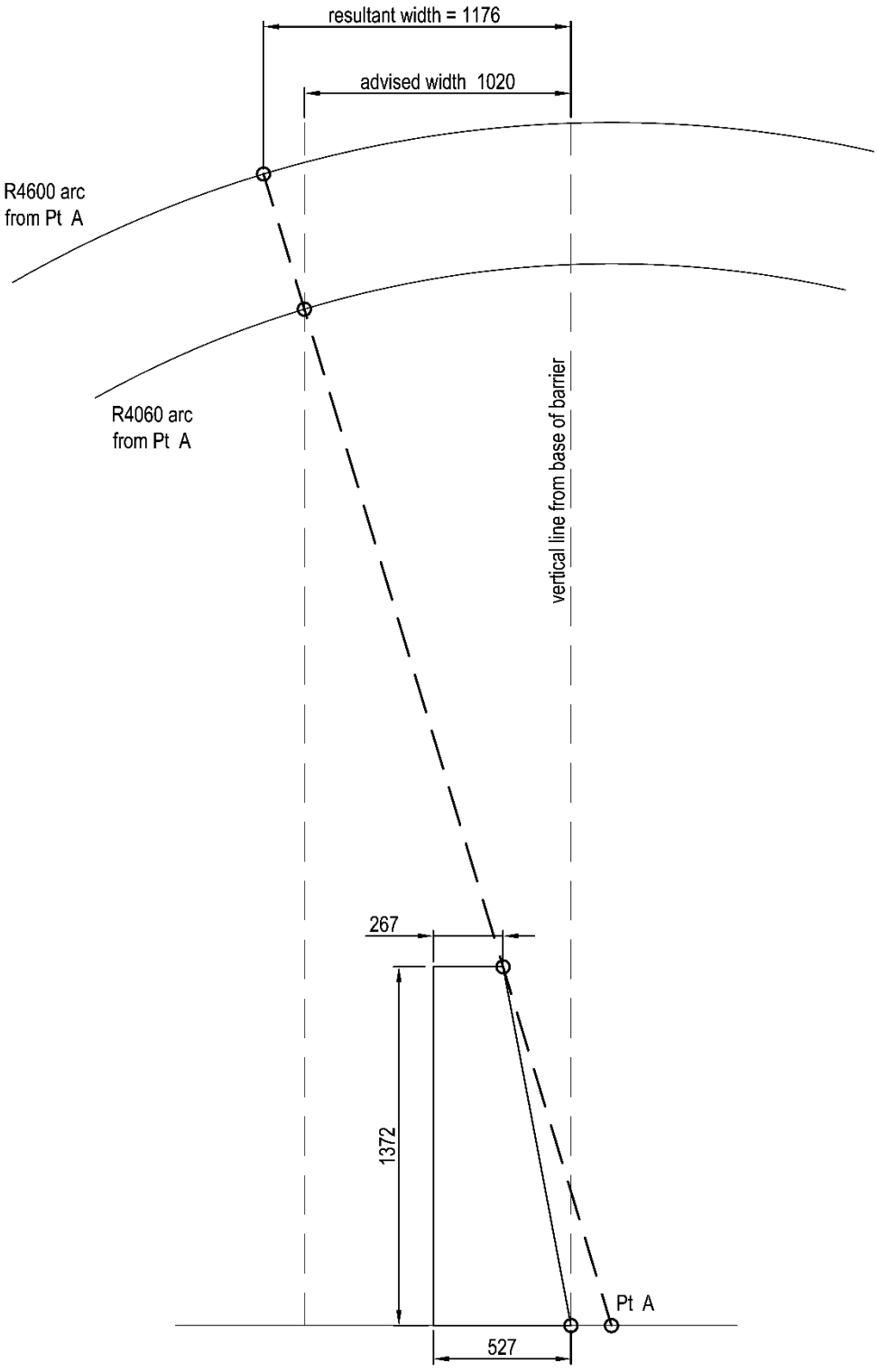
An extrapolation method was employed utilising the MASH Test TL5-12 results to derive a barrier height that would be likely to achieve an equivalent 0.9 m working width for use in Queensland.

"Point of Contact" Method With Roll Angle Considered

A geometric 'point of contact' method can be applied by extending the 4.06 m long projected vehicle roll line (as recorded in the MASH Test 5-12 for the 1.372 m high barrier) to 4.6 m. The measured roll angle of 16.82° (for the cargo box representing the maximum roll) is assumed to remain same for this method, resulting in a working width of 1.176 m for a 4.6 m high vehicle.

Assuming that the working width is proportional to the vehicle height, the barrier height should be increased to 1.793 m to achieve a 0.9 m working width for a 4.6 m high vehicle. Where a roadside object is a high consequence infrastructure asset or high-risk hazard, such as bridge piers and gantries, a factor of safety should also be applied to the working width to further mitigate the risk of damaging the high risk object. If applying the factor of safety of 1.2, the single slope concrete barrier increases to be 2.151 m high (above the ground surface) to achieve the 0.9 m working width. This method is illustrated in Figure 2 below.

Figure 2 – Working width for 4.6 m high vehicle deduced from recorded value for 4.06 m high vehicle using "point of contact" method with roll angle considered



Note: Due to the increase in mass, height and the centre of gravity, a 4.6 m high vehicle is expected to potentially present a slightly higher roll angle than a 4.06 m high vehicle does. As such, the determined heights have been rounded up to the nearest first decimal place, as per the recommended values below in Table 2(b).

Table 2(b) – Recommended heights of single slope concrete barrier for 0.9 m working width with 4.6 m high vehicles

Test Level	Working Width	Barrier Height	Risk Level*
TL-5	0.9 m	1.8 m	Low
	0.9 m	2.2 m	High

Note:

* This could include structures at risk of collapse and without any alternative load paths if impacted (For example, non-frangible poles and gantry structures). For risk level guidance required at specific sites, consult Transport and Main Roads, Engineering and Technology, Structures Design Review and Standards Unit.
Email: et_structures_review_and_standards@tmr.qld.gov.au.

The longitudinal vertical transition between the various heights for single slope concrete barriers shall not be steeper than 1V: 10H in slope.

3 Design guidance and considerations

The recommended single slope barrier heights presented in Table 2(b) are accepted as a reasonable alternative for adoption on the Transport and Main Roads network where working widths cannot be achieved under latest NDD and EDD requirements. Although Transport and Main Roads has derived these values based on the available evidence and methodologies, they are untested under MASH and are therefore to be considered in the domain of DE, requiring the relevant documentation process.

The methodology adopted in this Technical Note may be utilised by road design practitioners to derive alternative heights for a single slope concrete barrier, departing from NDD and EDD values as specified in RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers* (Transport and Main Roads, November 2023). However, it is important to limit this extended application to single slope concrete barriers with a height of 1.8 m or greater. This limitation is based on the fact that the centre of gravity of the cargo box of the 4.06 m high vehicle in the USA crash test is approximately 1.8 m above the ground surface. An increase in barrier height from 1.372 m tends to reduce the potential for rollover. Considering the elevated centre of gravity of a 4.6 m design vehicle, it is possible that the roll angle may increase. However, this effect could potentially be offset to some degree by increasing the barrier height to 1.8 m or higher. It is important to note that the specific effects of this offset are challenging to quantify due to a lack of adequate data available.

The design considerations when adopting the recommended single slope concrete barrier to achieve a reduced 0.9 m working width, include:

- Scope of Application – The recommended design solution advised in this Technical Note should be restricted to application in the following scenarios:
  - Transport and Main Roads projects that have already been financially approved, funded or commenced prior to RPDM Edition 2, Volume 3, Part 6 *Roadside Design, Safety and Barriers* published in October 2022, or
  - Brownfield sites with existing constraints where practitioners have exhausted all NDD or EDD design options.

- Design Domain – The recommended barrier heights in Table 2(b) constitute a DE. This Technical Note may however allow consolidation of multiple sites within a single DE on a project and assist by provision of recommended values for greater ongoing consistency on the Transport and Main Roads network.
- Level of Risk – Two height values of the concrete barrier have been provided for low and high risk structures respectively. The risk defined here is specific to the potential damage to roadside structures that may be caused by errant vehicles. Additionally, it is important to consider potential risks to vehicle occupants, such as those arising from debris or spearing hazards resulting from an impact. The level of risk associated with roadside structures is dependent upon whether it is deemed acceptable to allow a structure to be struck or glanced. Such variables need to be accounted for the risk assessment. In practice, practitioners may conduct preliminary assessments to determine the risk level of a roadside structure at their discretion based on the RPDM principals and engineering judgement. Practitioners are then recommended to consult Transport and Main Roads, Engineering and Technology, Structures Design Review and Standards Unit (et_structures_review_and_standards@tmr.qld.gov.au) for guidance on individual projects and specific sites. Less significant structures may be allowed to be placed within the working width of concrete barriers at constrained locations, subject to a site specific risk assessment. Some examples of less significant structures may include:
  - non-frangible pole for lighting / traffic signal / utility
  - ordinary road sign support structure
  - boundary / corridor security / fauna fencing, and
  - noise barrier.

  Table 3 provides additional remarks on design requirements for the aforementioned less significant structures.

Table 3 – Design requirements for less significant structures

Less Significant Structures	Design Requirements for a Structure Within the Working Width
Non-frangible poles for lighting / traffic signal / utility	Impacts with the cabin of trucks could result in injuries to the occupants. These should not be in the EDD working width unless the impacts are more unlikely due to road characteristics. A risk assessment for the site is required. Impacts with these poles, being unshielded, are likely to result in serious injuries for passenger cars. The occupants of heavy vehicles are less likely to be injured, but this has not been quantified.
Ordinary road sign support structure	The stiffness of the sign supporting structure should be evaluated as it significantly affects the outcome from an impact. Lightweight posts may be suitable. Signs with horizontal elements should be avoided. Stiffer sign supports should be outside the working width. A lightweight sign support may be installed in the working width, although the risk must be evaluated.

Less Significant Structures	Design Requirements for a Structure Within the Working Width
Boundary / corridor security / fauna fencing	If these fences are frangible, the EDD or DE working width may be applied with an appropriate risk assessment.
Noise barrier	If the noise barrier is frangible, the EDD or DE working width may be applied with an appropriate risk assessment.

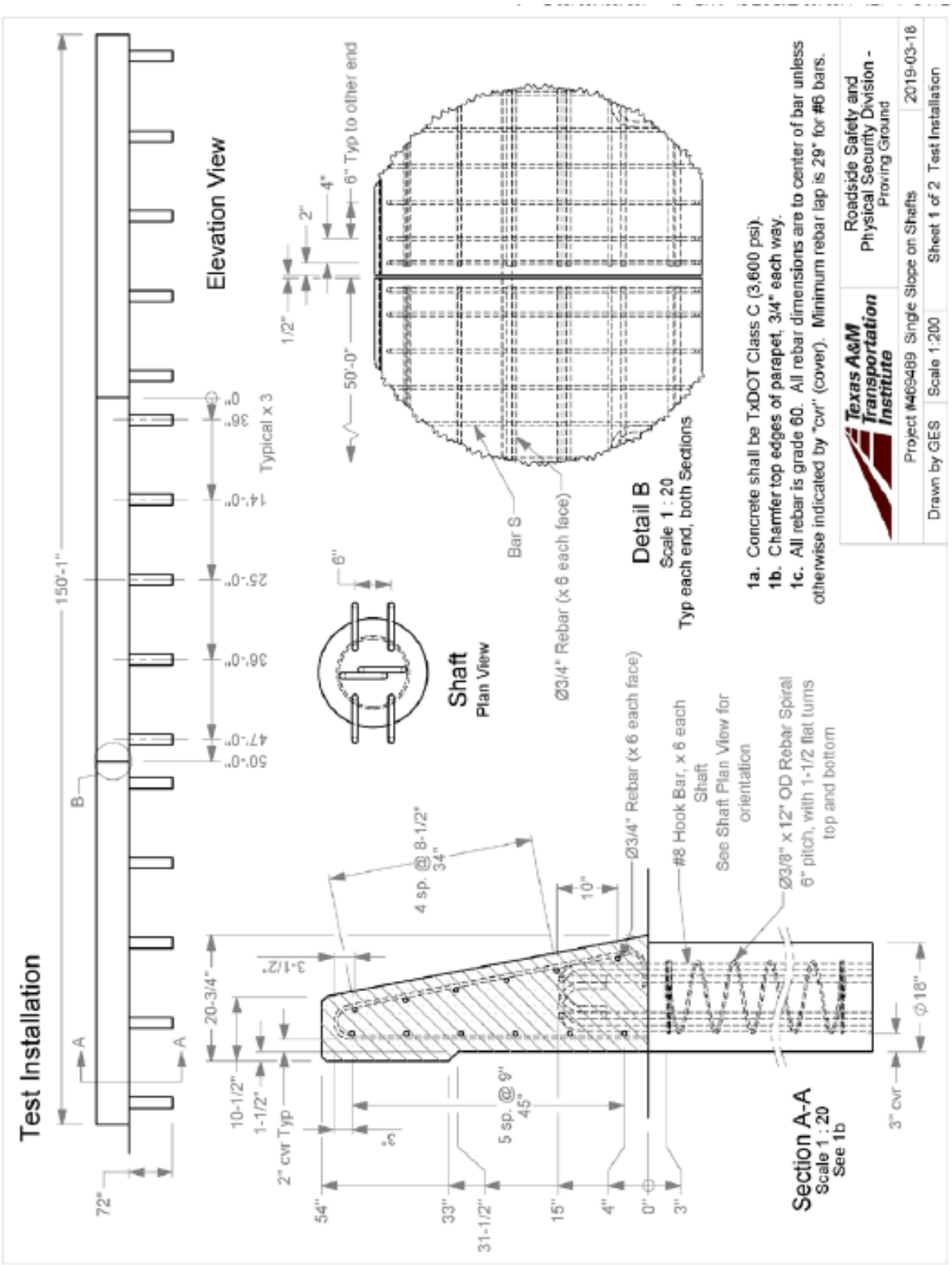
Significant structures are subjected to the guidelines indicated in this Technical Note. Some examples of significant structures may include:

- bridge pier
- retaining wall, and
- sign / ITS device cantilever support or gantry.

- Structural Design – For all structural design considerations for affected infrastructure elements, reference should be made to the latest Transport and Main Roads *Design Criteria for Bridges and Other Structures*. If there is risk of impact to infrastructure assets due to an established working width from this Technical Note a Matters for Resolution shall be presented to Transport and Main Roads detailing the following:
  - Locations of where likely impact could occur, and
  - Proposed modifications to the impacted structure to reduce road safety as low as reasonably practicable (ALARP) and improve structural integrity.

It is recommended that structural design advice is sought from Transport and Main Roads, Engineering and Technology, Structures Design Review and Standards Unit (et_structures_review_and_standards@tmr.qld.gov.au), if further clarification is required.

Appendix A – USA tested concrete barrier design



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