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Report

Muswellbrook Waste Transfer Station

Road Safety Review

Prepared for: Muswellbrook Shire Council
23 June 2022

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1. Introduction

Muswellbrook Shire Council (MSC) is currently assessing a Development Application for 32-36 Glen Munro Rd for a Waste Transfer Facility (DA 2021-55) on behalf of the Regional Planning Panel. Recommendations for the Conditions of Consent (if recommended for approval by Muswellbrook Shire Council) will be made to the Regional Planning Panel for final consideration.

As part of the assessment process, concerns have been raised regarding the intersection of Glen Munro Road and Thomas Mitchell Drive, predominately regarding northbound traffic originating from the New England Highway and heading northbound towards this intersection (and towards Denman Road).

Glen Munro Road forms part of the main industrial area for Muswellbrook and background traffic currently for various industrial sites along this road is made of predominately light traffic and occasional heavy trucks. This development proposes approximately 42 equivalent semi-trailer loads per day in and out of the site (84 total movements) significantly increasing traffic to this road and associated intersection with Thomas Mitchell Drive. The proposed split of traffic has been suggested as 70% southbound traffic from Denman Road and 30% traffic from the New England Highway travelling northbound and crossing southbound traffic at intersection with Glen Munro Road. This projection proposed by the applicant, however, does not include or consider changes in traffic direction associated with the future Muswellbrook Bypass, expected to be delivered around 2025.

MSC is concerned that the intersection is immediately downhill of a reduced sight distance horizontal curve in Thomas Mitchell Drive. If this is the case MSC are then concerned that there would be a risk of rear end-collision with any traffic that may queue to turn right into Glen Munro Road. The current intersection arrangement is T-intersection with only a 2m shoulder and therefore not enough clearance for a vehicle to overtake a queued vehicle. The speed limit in this area changes from 100km/hr to 80km/hr prior to this intersection, and remains 80km/hr through to the intersection with Denman Rd.

1.1 Purpose and Scope of this Report

Muswellbrook Shire Council (MSC) has commissioned SMEC to undertake a Road Safety Review on the intersection of Thomas Mitchell Drive and Glen Munro Road as it relates to the DA 2021-55 (Waste Transfer Station, 32-36 Glen Munro Road, Muswellbrook) and review the road safety documents provided by the applicant.

The report details the findings of a site visit undertaken on 7 June 2022 and a review of safety related issues. The site visit and safety review were conducted by Paul Crowe (Auditor ID: RSA-02-0715).

The project includes the follow:

1. A review of documentation provided by the applicant for DA 2021-55 relating to their Road Safety Assessment.
2. A desktop study and field investigation of all relevant information relating to the geometry, sight distance, hazards, speed zones, linemarking, lighting and traffic impacts for the intersection.
3. An independent review of all relevant road safety issues and identification of potential improvements for the existing conditions and the proposed development (DA 2021-55) including a formal risk assessment.
4. Provide prioritised recommendations of safety improvements that could be implemented by the applicant based on existing risks and because of this proposed development and the development of a conceptual sketch detailing the proposed recommendations.
5. Provide professional advice in accordance with TfNSW Road Safety Audit guidelines, including opinions of the effectiveness of various options.
6. Evaluate the improvements to road safety of all the recommended mitigation measure within the project area.
7. Note any safety improvements that could be implemented at a future stage.
8. As a provisional sum, provide estimations for each safety improvement measure.

1.2 Assessment Location

The Thomas Mitchell Drive and Glen Munro Road intersection is situated in the Muswellbrook LGA, around 5km south of Muswellbrook. The assessment location can be accessed via Thomas Mitchell Drive and either New England Highway (to the south) and Denman Road (to the north). Refer to Figure 1 and Figure 2

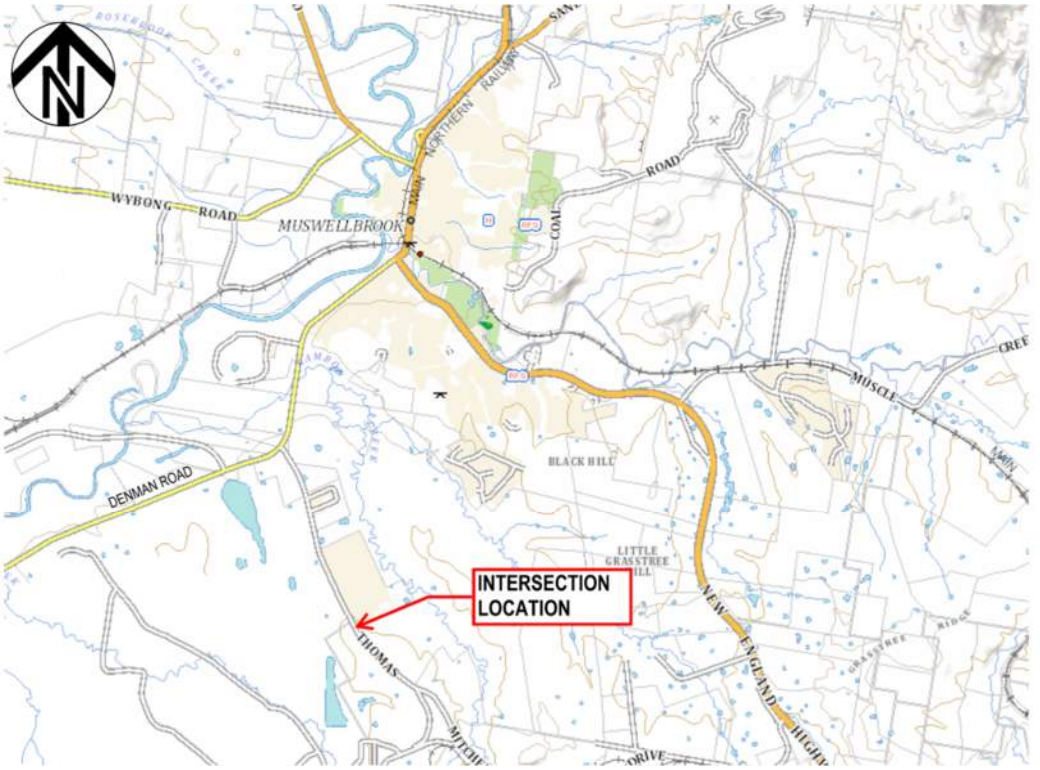


Figure 1: Intersection Location

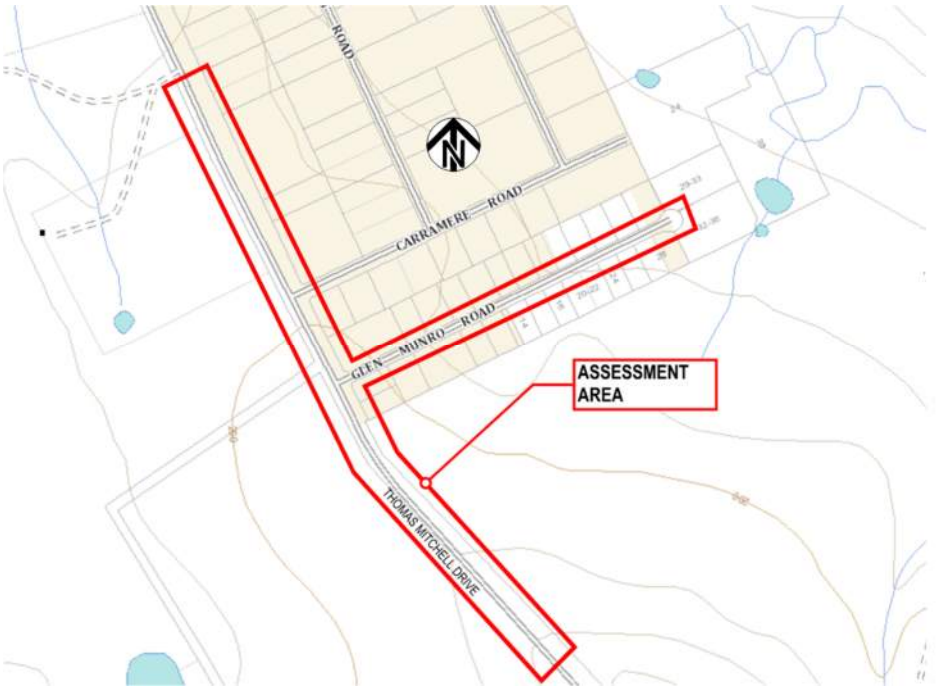


Figure 2: Assessment Area

1.3 Site Inspection and Audit

A site inspection was undertaken as part of this assessment on the 7th June 2022. This site visit was undertaken during daytime and night-time. Weather conditions were fine with some light rain during the night-time visit.

1.4 References and Documentation Audited

The following general standards and guidelines were used as a reference in conducting this Road Safety Review:

- Transport Roads and traffic Authority "Guidelines for Road Safety Audit Practices", 2011.
- Austroads, Guide to Road Safety Series, 2008-2021.
- Austroads, Guide to Road Design Series, 2009-2020.
- Austroads Research Report AP-R509-16, "Safe System Assessment Framework",2016
- Standards Australia "AS 1742 Series 2009: Manual of uniform traffic control devices", 2009.
- Austroads Road Safety Engineering Toolkit

The following reports/documents were provided by Muswellbrook Shire Council:

- DA 2021-55 Road Safety Assessment Brief
- DA 2021-55 Road Safety Assessment Report
- Turning circle diagrams prepared by Muswellbrook Shire Council

2. Details of Assessment Area

2.1 Road Geometry

Glen Munro Road is around 11 m wide and over 600 m long and is a 'no through' road, with access to several industrial businesses. It has an average vertical grade of around 4.5% grading away from Thomas Mitchel Drive. It has a barrier kerb and gutter installed along both sides and has no linemarking, either along its centre line or hold line at the intersection.

Figure 3: Glen Munro Road approaching the intersection with Thomas Mitchell Drive

Thomas Mitchel Drive is approximately 12.8 m wide, with a barrier kerb and gutter installed along the eastern side and a table drain along the western side in the vicinity of the intersection. The northbound lane is around 3.6m wide with a shoulder that varies from 2.1m to 2.3m wide. The southbound lane in the vicinity of the intersection is a 6.6m wide kerbside lane that narrows as it heads south to 3.6m lane with a 2.3m shoulder. There is G4 W-Beam guardrail installed on both sides of the road starting around 65m (western side) and 100m (eastern side) from the tangents points of the curve and extends over its full length discussed below. The terminals are both ET-2000s or similar.

A horizontal curve starts around 80m from the intersection and is around 155m long. The radius of the curve is estimated to be around 530m-550m, with a superelevation of between 2.5% and 3.5%. This provides the curve with a design speed of over 100km/h. This matches the experience on site, where driving this curve at 80km/h was very comfortable. The vertical grade along Thomas Mitchel Drive falls from south to north at an average grade of around 3% with the grade approaching the intersection northbound averaging around 4.5%. There is a sag curve around 1.3km to the north and a crest curve around 750m to the south, both of which will not affect the safety of the intersection.

Figure 4: Location of Give Way sign

The intersection of Glen Munro Road and Thomas Mitchell Drive is a Give Way priority-controlled T-intersection. The Give Way sign is installed 12m back from Thomas Mitchell Drive. It is assumed that this distance is due to the large swept paths of large vehicles and the narrow intersection throat.

The warrant for providing a Stop sign is not met as the sight distance at the intersection exceeds the requirements of AS1742.2 (Figure 2.2). Refer to Section 2.6, the sight distance measured during the site visit exceeds the 80m requirement of AS1742.2 (Figure 2.2).

An old type barrier/sight board sign (G9-209) is installed opposite Glen Munro Road, but it is slightly obscured by long grass, see Figure 5. It is recommended to increase the clearance under the sign and upgrade to the new sign face (2 X D4-2-3).

Figure 5: Existing Barrier Board Obscured by Long Grass

2.2 Pavement Condition

A visual inspection was performed on the existing pavement and similar to what was highlighted in the EMM report, alligator cracking was noted at the intersection. Some other issues were noted in relation to the pavement. The western edge of the pavement showed signs of deterioration, which may be caused by vehicles travelling over this edge as they either overtook a turning vehicle or parked in the verge. The verge also looked slightly eroded but still in relatively good condition. The final issue noted during the site visit was some bleeding of the road surface. This was noted mainly in the wheel paths and could affect the available longitudinal pavement friction and increase the required stopping distance. It is recommended that the road surface is tested to determine the available pavement friction to determine if pavement rehabilitation is required.

Figure 6: Pavement Condition in the Vicinity of the Intersection

2.3 Speed

A speed survey undertaken by EMM along Thomas Mitchell Drive measured the 85th percentile speed as 87km/h northbound and 86km/h southbound. No speed survey was undertaking during this assessment, but these figures seem appropriate from site observations. It is also worth noting that unless there are other traffic calming devices installed it is not uncommon for the 85th percentile travel speed to exceed the posted speed by up to 10km/h.

Glen Munro Road has a 50km/h speed limit. The 80km/h speed zone on Thomas Mitchell Drive starts around 400m south of the intersection and extends to Denman Road. The speed change from 100km/h to 80km/h (400m south of the intersection) is delineated with signage only, with one sign obscured by vegetation. It is noted that during the site drive

through the glare from the sun limited the ability to see these signs effectively. It is recommended that the vegetation is cleared within the sightlines to these signs and that pavement numerals are marked on the pavement to better delineate the change in speed limit.

The EMM safety report noted that there is strong merit in reducing the speed limit from 80km/h to 60km/h and refers to TfNSW's speed zoning guidelines. The TfNSW's speed zoning guidelines gives an overview of the typical application of different types of speed limit. For a 60km/h speed zone they suggest it would need to be either a significant urban arterial road, a divided road with high volumes and narrow lanes, or a rural residential road in a village. There are none of these road attributes present. Other attributes that TfNSW look for when considering speed zone are high crash rates, poor road geometry, high number of intersection, centreline marking, quality of pavement, all of which are good with in the current 80km/h section. There are only a few items that are marginal such as, 'do the intersections have marked turning bay' and 'is there sufficient width to pass a vehicle turning into a property access'. Overall, there isn't enough evidence that would suggest that TfNSW would consider a reduced speed limit under their current guidelines.

Figure 7: Thomas Mitchell Drive Northbound Speed Zone Change (100km/h to 80 km/h)

2.4 Traffic

Using the traffic survey undertaken by EMM on the 24th November 2020 (extract shown in Figure 8) and the expansion factor in "*principles and guidelines for economic appraisal of transport investment*" for Rural peak 1 hour (pm) to weekday of 12.10, we get an ADT of **5,046** with a HV% of **7.4**.

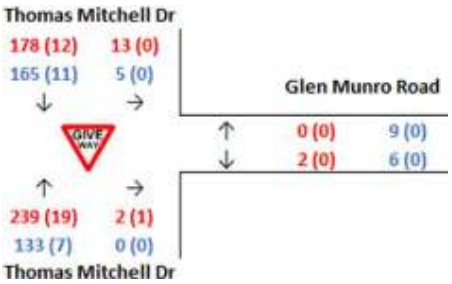
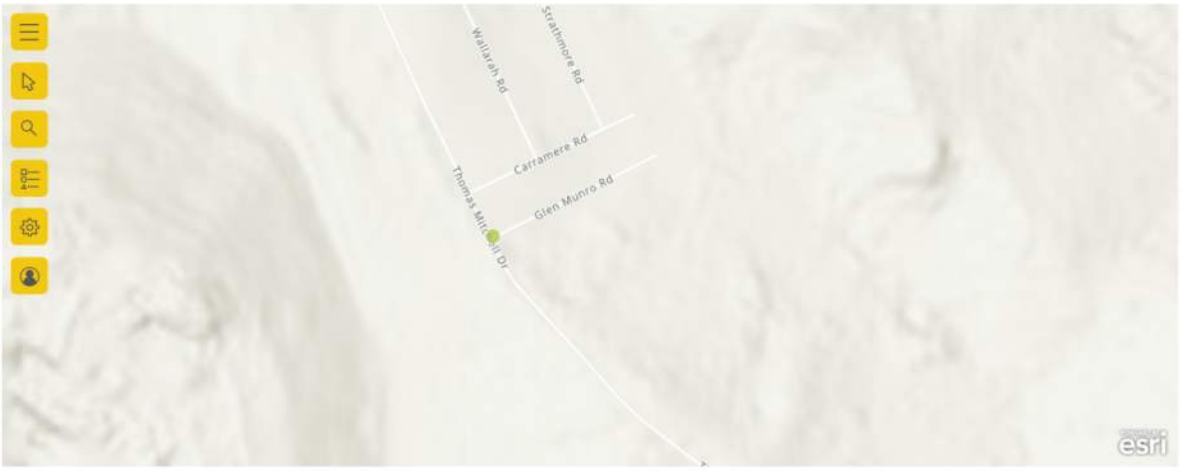


Figure 8: Extract from DA 2021-55 Environmental Impact Assessment Final - PAN-97898 Figure 4.6

It is noted that the additional traffic generated by the development will increase the risk of crashes at the intersection (by increase the likelihood) of Thomas Mitchell Drive and Glen Munro Road.

2.5 Crash History

There has been one crash within the assessment area in the 5-year period between 2016 and 2020. This was a serious injury crash involving a light vehicle that departed the carriageway to the right and hit an object or parked vehicle. This occurred at the intersection of Thomas Mitchell Drive and Glen Munro Road. Based on this information there isn't any crash trends or crash hotspots within the assessment area.



Reporting year	Crash Id	Degree of crash	RUM - code	RUM - description	Type of location	Natural lighting	Longitude	Latitude	Number killed	Number injured
2019	1204331	Serious Injury	73	Off rd rght => obj	T-junction	Daylight	150.880363	-32.314050		1

Figure 9: Crash Map (Source: https://roadsafety.transport.nsw.gov.au/statistics/interactivecrashstats)

2.6 Sight Distance

There are several sight distances that must be provided in the design of all intersections, these include.

- Approach Sight Distance (ASD)
- Safe Intersection Sight Distance (SISD)
- Minimum Gap Sight Distance (MGSD)
- Stopping Sight Distances (SSD)

The minimum requirements and what is achieved on site is documented in Table 2. The figures in brackets are for trucks, where specified in Austroads. The figures are based on an 85th percentile speed of 90km/h, reaction time of 2.5 seconds deceleration coefficient of 0.36 (d) and have been adjusted for a grade of -4% but noting the minor road (Glen Munro Road) approach to the intersection is on a positive grade and in a 50km/h speed zone.

Table 1: Minimum Sight Distance Requirements and Achieved

Sight Distance	Minimum (m)	Achieved (m)
Approach Sight Distance (ASD)	162 (190)	>300
Safe Intersection Sight Distance (SISD)	239 (255*)	North >400, South = 180
Minimum Gap Sight Distance (MGSD)	125**	North >400, South >180
Stopping Sight Distances (SSD)	164 (193)	188

*observation time for truck reduced to 2.5sec and d to 0.29

**Follow up headway excluded from MGSD calculation

Table 2 shows that minimum sight distances are achieved for most legs of the intersection, except SISD to the south and SSD for HVs.

2.6.1 Safe Intersection Sight Distance (SISD)

SISD is recommended so that there is sufficient distance for a driver of a vehicle on the major road (Thomas Mitchell Drive) to observe a vehicle on a minor road (Glen Munro Road) approach moving into a collision situation

(e.g., in the worst case, stalling across the traffic lanes), and to decelerate to a stop before reaching the collision point. It is made up of an observation time of 3 seconds, a reaction time of 2.5sec and the deceleration distance.

SISD was measured on site by setting up a target which was in line with the 5m setback from the lip of the channel along Thomas Mitchell Drive and set at a height of 1.25m. The assessors then positioned themselves at the maximum distance along Thomas Mitchell Drive where they could still see the SISD target while lowering their eye height to 1.1m. At this location a distance was measured to the target and to the centre of the northbound lane, refer to Figure 10.

Figure 10: Photo looking north along Thomas Mitchell Drive at the SISD target

Using this method, a SISD of 180m was measured, which is higher than what was documented in the EMM Road Safety Assessment (140m), but less than what is recommended.

Several attributes are required to accurately determine the required SISD, these are shown in Equation 2 below (AGRD04A-17 Guide to Road Design Part4A Unsignalised and Signalised Intersections)

Equation 2 provides the formula for SISD:

$$SISD = \frac{D_T \times V}{3.6} + \frac{V^2}{254 \times (d + 0.01 \times a)}$$

where

SISD	=	safe intersection sight distance (m)
D_T	=	decision time (sec) = observation time (3 sec) + reaction time (sec) – refer to *AGRD Part 3* (Austroads 2016b) for a guide to values
V	=	operating (85th percentile) speed (km/h)
d	=	coefficient of deceleration – refer to Table 3.3 and *AGRD Part 3* for a guide to values
a	=	longitudinal grade in % (in direction of travel: positive for uphill grade, negative for downhill grade)

The observation and reaction times are the same at all locations, but vehicle speed and longitudinal grade will change from site to site. Given the speed survey results at speed of 90km/h is appropriate. A GPS enabled video camera was used during the site visit drive throughs and from the data extract from this device it was determined that the average grade approaching the intersection over the length of the SISD was 4.5%. It is noted the accuracy of the GPS data will be limited however, as we are using the data to measure the grade the accuracy is considered sufficient for this exercise.

The calculated SISD is 226m with a grade correction of 13m, which brings the total recommended SISD to 239m. So 180m would only provide SISD for a design speed of around 74km/h or reduce the observation time/reaction time by around 2 seconds.

It should be noted that the SISD of 226m is for a car (in wet conditions on a flat grade). When considering heavy vehicles, the ability to decelerate is much less and will increase the required time to stop. Austroads does provide guidance on the values to use for truck and suggests reducing the observation time to 2.5sec. Using this guidance, the SISD provided at this intersection will only provide for a truck design speed of around 70km/h (around 71km/h).

There are several safety measures that can be used to mitigate the risks associated with reduced sight distances, which are detailed in the following sections.

2.6.1.1 Remove Sightline Obstructions

SISD is measured from a driver's eye height (1.1m) to the top of the vehicle approaching the intersection (1.25m). Unlike the other types of sight distance, SISD can be achieved over the top of some types of road safety barriers, if the vertical road geometry allows (no crest). At this location there is a standard W-Beam gaudrail road safety barrier with a height of 0.78m and the vertical road geometry does not obscure the sightlines. To achieve SISD to the intersection only vegetation needs to be cleared. Regular maintenance will be required to provide a clear viewing area at all times. There is a TfNSW sign also in this area.

Figure 11: Vegetation Clearing

2.6.1.2 Improve Driver Awareness on Approach to Intersections

Static or dynamic warning of the intersection can help improve an approaching driver's awareness of the intersection and therefore reduce the observation and/or reaction time. As mentioned above if the observation and/or reaction time could be improved from 5.5 seconds to around 3.5 seconds then there would be sufficient distance for the driver to stop before the intersection. It should be noted that although reducing the likely the observation and/or reaction times would improve the safety at the intersection, it would still be considered a departure to the Austroads Guidelines.

Mitigation measures can be implemented to make the driver more aware of the intersection. Advance signage can be installed to warn drivers of the intersection before it is clearly visible. In some situations, flashers installed in conjunction with the sign may further increase driver awareness. At intersections with a high crash history, high traffic volumes, severe sight restrictions, or other concerns, ITS applications may be appropriate strategies. For example, detectors can be placed in the pavement on a minor road approach to a major highway. A flasher on the major highway can be installed to warn drivers that vehicles are at the minor road approach, entering the intersection. There isn't warrant at this location for the installation of an ITS.

2.6.2 Stopping Sight Distance

Stopping Sight Distance (SSD) is the distance to enable a normally alert driver, travelling at the design speed on wet pavement, to perceive, react and brake to a stop before reaching a hazard on the road ahead (AGRD03-16). It is generally measured between the driver's eye (1.1m for cars and 2.4m for trucks) and a 0.2 m high, stationary object on the road. SSD is like SISD except that SSD does not include the observation time (3 seconds). It also cannot be viewed over road safety barriers as the object height is lower than the standard road safety barrier height.

The eastern road safety barrier along Thomas Mitchell Drive restricts the SSD to a vehicle waiting to turn right into Glen Munro Road to 188m. There is therefore a risk a rear-end crash could occur at this location.

To improve SSD the road safety barrier would need to be modified (set-back from the edge of the road). Modifying the location of a road safety barrier can have affect the barriers performance (higher impact angles) and any changes would need to be carefully considered. Note providing adequate SSD does not eliminate the risk of rear-end crashes. Another solution, which would be the preferred, would be to provide space for a vehicle to overtake a waiting vehicle. This mitigation measure would significantly reduce the likelihood of rear-end crashes as it would provide space to a vehicle to manoeuvre around the waiting vehicle if it was late seeing the waiting vehicle. This is in essence a BAR which is discussed in the next section.

Figure 12: Stopping Sight Distance to Vehicle Turning Right into Glen Munro Rd

2.6.2.1 Basic Right-Turn Treatment (BAR)

The basic right-turn treatment (BAR) is the minimum treatment recommended by Austroads for "right-turn movements from a through road to side roads and local access points. This treatment provides sufficient trafficable width for the design through vehicle to pass on the left of a stationary turning vehicle. This is achieved by widening the shoulder to provide a minimum width sufficient to allow vehicles to pass. Substantial speed reduction (half of the design speed) is a feature of this layout. See Figure 13 to see how this would be applied to the Thomas Mitchell Drive and Glen Munro Road intersection.

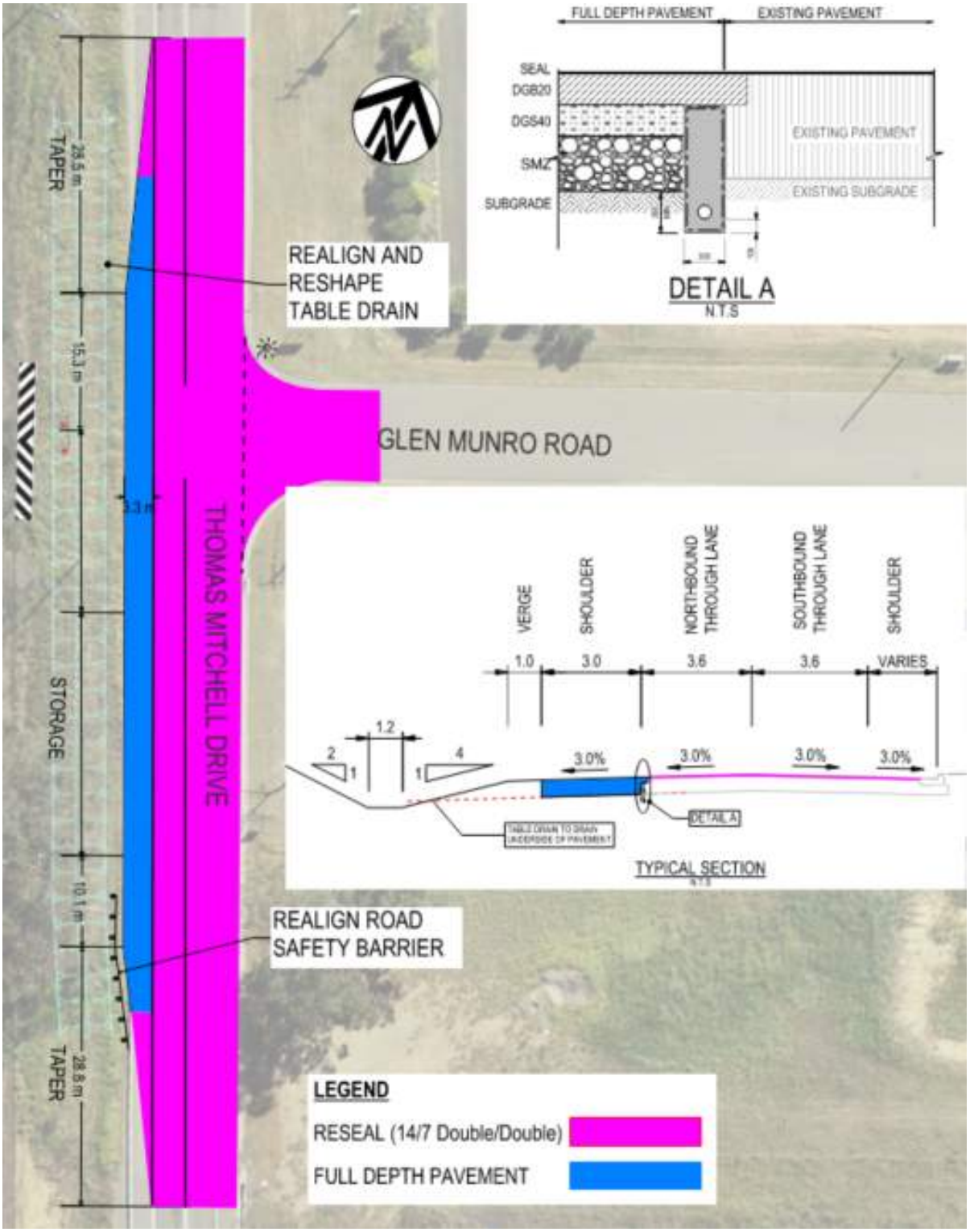


Figure 13: BAR Layout

4. Risk assessment

Identified issues and deficiencies have been rated based on estimated crash frequency, crash severity and level of risk in accordance with the Transport for New South Wales (TfNSW) Safety Matrix, Austroads Guide to Road Safety, Part 6A: Implementing Road Safety Audits (2019). Austroads specifies that this is not a scientific system and professional judgement should be used.

4.1 Crash Frequency

The probable frequency of an incident or crash occurring has been estimated for each issue listed in the Road Safety Audit findings based on the options listed in Table 2.

Table 2: Crash Frequency

Frequency	Likelihood - QUALITATIVE EXPECTATION	Likelihood - QUANTITATIVE FREQUENCY
Almost Certain - L1	Expected to occur frequently during time of activity or project.	10 times or more every year.
Very Likely - L2	Expected to occur occasionally during time of activity or project.	1-10 times every year.
Likely - L3	More likely to occur than not occur during time of activity or project.	Once each year.
Unlikely - L4	More likely not to occur than occur during time of activity or project.	Once every 1 to 10 years.
Very Unlikely - L5	Not expected to occur during the time of activity or project.	Once every 10 to 100 years.
Almost Unprecedented - L6	Not expected to ever occur during time of activity or project.	Less than once every 100 years.

4.2 Crash Severity

The severity of a crash identified in the Road Safety Audit is assessed based on the options listed in Table 3

Table 3: Crash Severity

Severity	Description
Catastrophic – C1	Multiple fatalities or >20 major injuries/permanent disabilities/chronic diseases, or both.
Severe – C2	Single fatality or 10-20 major injuries/permanent disabilities/chronic diseases, or both.
Major – C3	1-10 major injuries requiring hospitalisation and numerous days lost, or medium-term occupational illness.
Moderate – C4	Single recoverable lost time injury or illness, alternate or restricted duties injury or short-term occupational illness.
Minor – C5	Illness or minor injuries requiring medical treatment.
Insignificant – C6	Illness, first aid or injury not requiring medical treatment.

4.4 Level of Risk

Findings are rated for their importance according to a six-tiered system based on the matrix in Table 4 with a suggested treatment approach outlined in Table 5

Table 4: Risk Matrix

	Insignificant - C6	Minor - C5	Moderate - C4	Major - C3	Severe - C2	Catastrophic - C1
Almost Certain - L1	C - Medium - tolerable	B - High - undesirable	B - High - undesirable	A - Very high - generally intolerable	A - Very high - generally intolerable	A - Very high - generally intolerable
Very LikelyL2	C - Medium - tolerable	C - Medium - tolerable	B - High - undesirable	B - High - undesirable	A - Very high - generally intolerable	A - Very high - generally intolerable
Likely - L3	D - Low - broadly acceptable	C - Medium - tolerable	C - Medium - tolerable	B - High - undesirable	B - High - undesirable	A - Very high - generally intolerable
Unlikely - L4	D - Low - broadly acceptable	D - Low - broadly acceptable	C - Medium - tolerable	C - Medium - tolerable	B - High - undesirable	B - High - undesirable
Very Unlikely - L5	D - Low - broadly acceptable	D - Low - broadly acceptable	D - Low - broadly acceptable	C - Medium - tolerable	C - Medium - tolerable	B - High - undesirable
Almost Unprecedented - L6	D - Low - broadly acceptable	D - Low - broadly acceptable	D - Low - broadly acceptable	D - Low - broadly acceptable	C - Medium - tolerable	C - Medium - tolerable

Table 5: Treatment Approach

Risk rating	Suggested treatment approach
A - Very high - generally intolerable	Very high risks are generally intolerable and should be avoided except in extraordinary circumstances. A very high risk would not be acceptable when related to the operation or maintenance of a new or altered asset as the activity would not be permitted. An alternative solution shall be found, and all necessary steps shall be taken to reduce the risk below this level.
B - High - undesirable	High risks are undesirable. It is highly unlikely that an undesirable risk would be accepted when related to the operation or maintenance of a new or altered asset. They can only be tolerated if it is not reasonably practicable to reduce the risk further, that is that SFAIRP is demonstrated, and the risk is agreed as acceptable to TfNSW. High risks are considered to be on the verge of being unacceptable and all credible options to reduce or eliminate the risk shall be explicitly considered.
C - Medium - tolerable	Medium risks are tolerable if it is not reasonably practicable to reduce the risk further. It is essential that where a risk has health, safety or environmental consequences the activity should be reviewed to determine if the risk can be reduced further and whether all reasonable and practicable controls have been considered or applied, or both and a demonstration of SFAIRP is provided. Additional treatment measures should be sought if significant benefit can be demonstrated and/or there is an additional treatment measure which is recognised as good practice in other like environments.
D - Low - broadly acceptable	Low risks are considered to be broadly acceptable. Where the risk has health, safety or environmental consequences control measures should be effective, reliable and subject to appropriate monitoring. If options for further risk reduction exist and costs are proportionate to the benefits, then implementation of such measures should be considered. The risk and its treatments should be subject to appropriate degrees and forms of monitoring to ensure that it remains at this level.

4.6 Safe Systems

The "Safe Systems" approach is regarded as international best practice in road safety and provides an outcome whereby death and serious injury are virtually eliminated amongst users of the road system. Safe Systems is the management and design of the road system such that impact energy on the human body is firstly avoided or secondly managed at tolerable levels by manipulating speed, mass and crash angles to reduce crash injury severity. (Austroads 2018b – AP-R560-18).

With the adoption of the Safe Systems approach, it is important that it is integrated into the Road Safety process. There is currently only limited guidance on how this integration should be done and Austroads (Guide to Road safety Part 6, 2019) suggests that 'road safety auditors are given the freedom on how to go about meeting these requirements'. This section describes how the Safe Systems approach has been integrated into this Road Safety Review.

4.6.1 Integration – Severity

One of the suggested ways of integration of the Safe Systems approach in a Road Safety Review is 'relating possible crash forces to tolerable levels of the human body before fatal and serious injury (FSI) occurs (regardless of the likelihood) when identifying and assessing FSI risks' This is covered with the use of the crash severity matrix shown in Table 3, where Catastrophic (C) and Serious (S) highlight the finding that could result in a fatal or serious injury. One minor adjustment with the assessment of severity will be the use of the Safe Systems speed, discussed below.

4.6.2 Integration – Speed

Embedding Safe System principles in road safety practice is a key to integration. Understanding and applying these new principles is something that is strongly encouraged within SMEC and is fundamental to the development of our staff, not only our auditors. To aid the auditors a more quantitative approach to assessing the potential severity of a crash is to use critical speed thresholds to determine if a fatality or serious injury could occur. There is some research done in this area, but Austroads recognise that more needs to be undertaken. Reviewing this research Jurewicz, Sobhani et al. (2015) "Relationships between bullet vehicle impact speed and probability of a MAIS 3+ injury to a target vehicle occupant for different crash configurations" provides a comprehensive approach.

Table 6: Relationship Between Vehicle Impact Speed and Probability of Serious Injury

Austroads 2015 (AP-R498-15 Figure 4.8)			
	10% Severe Injury Risk	50% Severe Injury Risk	100% Severe Injury Risk
Crash Type	Bullet Vehicle Impact Speed		
Car → Pedestrian/Cyclist/Motorcyclist	20	38	75
Car → Tree/Pole	20	38	75
Car → Car (Adjacent Direction)	30	42	75
Car → Car (Opposing – Turning)	30	54	100
Car → Car (Head-On)	30	42	75
Car → Car (Rear-End)	55	83	>100

It must be noted that the speeds referred to are impact speed, which has many contributing factors, such as weather conditions, distance of hazard from travel lane, road geometry etc. It is imperative that the auditor takes all the factors into consideration when determining the impact speed. A separate column is provided in the findings table to assign impact speed where applicable.

4.6.4 Integration – Crash Type

A method used to improve safe System alignment is the adoption of treatments that reduce exposure, likelihood and severity in a compensatory way across key crash types. These crash types are:

- Car / Pedestrian / Cyclist
- Car / Motorcyclist
- Car / Tree / Pole
- Car/ Car (Rear-End)
- Car / Car (Side Impact, Intersection)
- Car / Car (Head On)

By highlighting the review findings that relate to these types of crashes, mitigation measures or recommendations can be aligned with the Safe Systems approach. A separate column is provided in the findings table to assign a crash type where applicable.

Table 7: Road Safety Risk Assessment

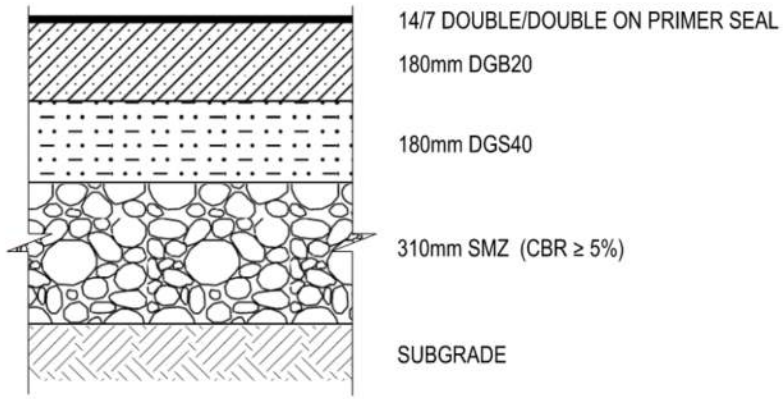
Finding No	Location	Category	Safe Systems		Review Finding	Risk Assessment			Recommendation	Risk Assessment		
			Crash Type	Crash Speed (km/h)		Frequency	Severity	Level of Risk		Frequency	Severity	Level of Risk
001	Thomas Mitchell Drive and Glen Munro Road intersection	Intersections	Car/car (Rear-end)	>70	Reduced sight distance (SSD) to vehicle waiting to turn right in Glen Munro Road leading to a rear-end crash.	Unlikely - L4	Severe - C2	B - High - undesirable	Provide BAR at Thomas Mitchell Drive and Glen Munro Road intersection	Very Unlikely - L5	Severe - C2	C - Medium - tolerable
002	Thomas Mitchell Drive and Glen Munro Road intersection	Intersections	Car/car (side impact, intersection)	>70	Reduced sight distance (SISD) to vehicle in Glen Munro Road turning right leading to side impact crash.	Unlikely - L4	Severe - C2	B - High - undesirable	Clear vegetation with the sightline for SISD, refer to Figure 11	Very Unlikely - L5	Severe - C2	C - Medium - tolerable
003	400m south of Thomas Mitchell Drive and Glen Munro Road intersection	Traffic Signs	Car/car (side impact, intersection)	>70	Drivers heading north along Thomas Mitchell Drive don't see speed zone change and continue towards the intersection above the 80km/h speed limit. This would increase the likelihood of a rear-end or side-impact crash at Thomas Mitchell Drive and Glen Munro Road intersection. It would also increase the likelihood of a run-off crash around the horizontal curve.	Likely - L3	Severe - C2	B - High - undesirable	Clear vegetation in front of speed limits sign and provide '80' pavement numerals in the northbound lanes	Unlikely - L4	Severe - C2	B - High - undesirable

Finding No	Location	Category	Safe Systems		Review Finding	Risk Assessment			Recommendation	Risk Assessment		
			Crash Type	Crash Speed (km/h)		Frequency	Severity	Level of Risk		Frequency	Severity	Level of Risk
004	For around 70m on the approach to Thomas Mitchell Drive and Glen Munro Road intersection	Road Pavement	Car/car (side impact, intersection)	>70	There is bleeding of the pavement wearing course that could affect the skid resistance on the approach to the intersection. In wet conditions this could affect the ability for a vehicle to stop behind a vehicle waiting to turn into Glen Munro Road or to stop before a vehicle stalled across the intersection.	Likely - L3	Severe - C2	B - High - undesirable	Improve the skid resistance of the pavement wearing course (such as milling and resheeting).	Unlikely - L4	Severe - C2	B - High - undesirable
005	Opposite the Thomas Mitchell Drive and Glen Munro Road intersection	Roadside Hazards	Vehicle Roll	>70	There is a table drain running along the western side of Thomas Mitchell Drive that has an untraversable profile. This table drain is with the clear zone for 80km/h. If an errant vehicle leaves the road at this location the table drain profile may cause the vehicle to roll.	Unlikely - L4	Severe - C2	B - High - undesirable	Provide a complying table drain profile in accordance with Austroads (AGRD03-16, Section 4.6.1)	Very Unlikely - L5	Severe - C2	C - Medium - tolerable
006	Glen Munro Road approaching intersection	Traffic Signs	Car/car (side impact, intersection)	>70	The exiting sight board opposite Glen Munro Road is obscured by vegetation. This sign is the primary indicator of the intersection as you approach from Glen Munro Road. In wet night-time conditions, a driver unfamiliar with the road network might overshoot the hold point and enter Thomas Mitchell Drive and be impacted by a passing vehicle.	Unlikely - L4	Severe - C2	B - High - undesirable	Upgrade sign and increase the clearance to the ground.	Very Unlikely - L5	Severe - C2	C - Medium - tolerable

5. Estimate of Recommendation

Table 8 details the cost of the road safety recommendations. For this estimate several assumptions have been made, which are as follows;

- All work will be done under one contract and so there will be efficiencies in areas such as traffic management.
- The project duration will 30days, with no wet weather allowance.
- The pavement will consist of 14/7 double/double seal, on 180mm of DGB 20, on 180mm of DGS 40, on 310mm of SMZ. An interface drain has been allowed for between the new and existing pavement. Note for estimation purposed the subgrade is assumed to be <2%.



FULL DEPTH PAVEMENT

- Utility relocations have been excluded from the estimate.
- No allowance for new or adjusted stormwater drainage has been allowed.
- Given this is only a strategic estimate a contingency of 40% has been applied until more detail can be obtained.

Table 8: Schedule of Rate

Pay Item	Description of Work	Quantity	Unit	Rate	Amount	Comments
DELIEVRY READINESS						
1	Project Management	1	lump sum	$26,830.00	$26,830.00	
2	Detail Design & Documentation	1	lump sum	$53,660.00	$53,660.00	
				Sub-total:	**$80,490.00**	
DELIEVRY						
1	Project Management	1	lump sum	$29,520.00	$29,520.00	
				Sub-total:	**$29,520.00**	
JOB SPECIFIC REQUIREMENTS		NONE				
GENERAL REQUIREMENTS						
1	Primary Testing, Subcontract (Provisional Sum)	NONE				
2	WAE Drawings	NONE				
3	Wet Weather Delay Costs	NONE				
PRINCIPAL'S PROJECT ACCOMMODATION		NONE				
UTILITY ADJUSTMENT		NONE				
1	Streetlighting					
1.1	Supply and replace luminaires	2	each	$350.00	$700.00	
1.2	Supply and install outreach om existing poles	2	each	$1,000.00	$2,000.00	
				Sub-total:	**$2,700.00**	
TRAFFIC MANAGEMENT						
	Traffic Management	1	lump sum		$0.00	
	Maintenance of Traffic Control Measures	30	day	$1,500	$45,000.00	This is for the combination of all works
	Routine Maintenance of Existing Roadways	1	lump sum		$0.00	
				Sub-total:	**$45,000.00**	
ENVIRONMENTAL PROTECTION		NONE				
SOIL AND WATER MANAGEMENT						

Pay Item	Description of Work	Quantity	Unit	Rate	Amount	Comments
	Soil and Water Management Control Measures					
	Establishment of Soil and Water Management Control Measures	1	lump sum	$2,000.00	$2,000.00	
	Maintenance of Soil and Water Management Control Measures	30	day	$300.00	$9,000.00	
	Site Water Quality Monitoring	1	lump sum		$0.00	
				Sub-total:	**$11,000.00**	
CLEARING AND GRUBBING						
1	Clearing and Grubbing	3	day	$6,500.00	$19,500.00	Approximately 5 Trees to be Removed, 1200 Light clearing
				Sub-total:	**$19,500.00**	
CONSTRUCTION SURVEYS		NONE				
R15 – KERBS AND CHANNELS (GUTTERS)		NONE				
R33 – TRENCH DRAINS						
5	Trench drain, Rate including for excavation, 100mm Dia Corrugated Perforated Plastic Drainage Pipe, supply and installation of Geotextile, filter materiel and flush points	110	m	$420.00	$46,200.00	
				Sub-total:	**$46,200.00**	
R44 – EARTHWORKS						
1	Topsoil					
1.1	Removal and Stockpiling of Non-contaminated Topsoil (Stockpile Volumes)	10	m^3	$37.00	$370.00	
2	General Earthworks (Cut/Fill)	300	m^3	$57.50	$17,250.00	
3	Unsuitable Material (Item with provisional quantity) replace with DGB 20 (Assumes material classified as VENM/ENM)	10	m^3	$223.30	$2,233.00	
4	Selected Material Zone and Verge					
4.1	Selected Material Zone – Imported Material		m^3	$86.00	$7,998.00	
4.2	Verge - Imported Material	50	m^3	$110.00	$5,500.00	
5	Disposal Off Site of Non-contaminated Spoil (other than Topsoil) (Assumes material classified as VENM/ENM)	300	m^3	$57.50	$17,250.00	

Pay Item	Description of Work	Quantity	Unit	Rate	Amount	Comments
6	Foundation Treatments					
6.1	Treatment Type C1 – Loosen and Recompact	190	m^2	$4.10	$779.00	
7	Removal of Existing Pavement Material					
7.1	Flexible Pavement (Item with Provisional Quantity)	150	m^3	$31.00	$4,650.00	
				Sub-total:	**$56,030.00**	
GENERAL CONCRETE PAVING		NONE				
CONSTRUCTION OF UNBOUND AND MODIFIED PAVEMENT COURSE						
1	Supply and Place Base and Subbase					
1.1	Supply and place 180mm DGS 40 at site including levelling and compacting	150	m^3	$145.00	$21,750.00	
1.2	Supply and place 180mm DGB 20 at site including levelling and compacting	130	m^3	$150.00	$19,500.00	
				Sub-total:	**$41,250.00**	
SPRAYED BITUMINOUS SURFACING (WITH CUTBACK BITUMEN)						
	14/7 mm Aggregate Double /Double Sprayed bituminous surfacing (with cutback bitumen) (Rate including Supply, Precoat, Apply, Incorporate and Sweep Aggregate)	1800	m^2	$7.70	$13,860.00	
				Sub-total:	**$13,860.00**	
SAFETY BARRIER SYSTEMS						
1	Removal of Safety Barriers	30	m	$50.00	$1,500.00	
2	Removal of Terminals and Transitions	1	each	$500.00	$500.00	
3	Construction of Post and Rail Safety Barriers					
3.1	W Beam	30	m	$140.00	$4,200.00	
4	Construction of Terminals					
4.1	Approach Terminal TL4	1	each	$6,700.00	$6,700.00	
				Sub-total:	**$12,900.00**	
RETROREFLECTIVE RAISED PAVEMENT MARKERS		NONE				
SIGNPOSTING						

Pay Item	Description of Work	Quantity	Unit	Rate	Amount	Comments
1	Removal, Modification and Relocation of Existing Signs					
1.1	Removal of Existing Signs					
1.1(i)	Sign No: G9-209	1	each	$400.00	$400.00	
1.2	Relocate Existing Signs				$0.00	
1.2(i)	TfNSW Sign and 'Bretts Maintenance & Welding' sign	2	each	$450.00	$900.00	
2	Supply and Installation of New Signs				$0.00	
2.1	New Signs with Standard CHS Post Support Structure				$0.00	
2.1(i)	Sign No: D4-2-3	2	each	$550.00	$1,100.00	
				Sub-total:	**$2,400.00**	
PAVEMENT MARKING (PERFORMANCE BASED)						
1	Longitudinal Lines					
1.1	Using Non-profile Thermoplastic Material, as Specified					
1.1(i)	BB Line	80	m	$15.00	$1,200.00	
1.1(ii)	C1 Line	30	m	$7.00	$210.00	
1.1(iii)	E1 Line	200	m	$8.00	$1,600.00	
2	Transverse Lines and Other Markings					
2	Using Non-profile Thermoplastic Material					
2.1(i)	Speed Zone "80" Numerals	2	m^2	$135.00	$270.00	
				Sub-total:	**$3,280.00**	
VEGETATION						
1	Spraying Weeds with Herbicide	2000	m^2	$0.20	$400.00	
2	Topsoiling Using Site Material Including Surface Preparation					
2.1	Areas with a slope of 5 to 1 or flatter	400	m^2	$11.00	$4,400.00	
3	Topsoiling Open Drains Using Imported Material Including Surface Preparation	300	m^2	$7.30	$2,190.00	For realigned table drain
4	Hydroseeding of Open Drains	150	m^2	$1.20	$180.00	Split 50/50

Pay Item	Description of Work	Quantity	Unit	Rate	Amount	Comments
5	Lining Open Drains with Organic Fibre Mat	150	m^2	$6.30	$945.00	Split 50/50
6	Turfing				$0.00	
6.1	Areas with gradient 5 to 1 or flatter	300	m^2	$15.00	$4,500.00	Area disturbed by construction works
7	Watering (Item with provisional quantity)	5	kilolitre	$300.00	$1,500.00	
				Sub-total:	**$14,115.00**	
LANDSCAPE PLANTING		NONE				
FENCING		NONE				
PROPERTY ADJUSTMENTS		NONE				
	TOTAL AMOUNT (Excluding GST)				**$378,267.00**	
	CONTINGENCY	**40%**			**$151,306.80**	
	TOTAL AMOUNT (Excluding GST) INCLUDING CONTINGENCY				**$529,573.80**	
	Add GST				**$52,957.38**	
	TOTAL AMOUNT including contingency (Excluding GST)				**$582,531.18**	

6. Future Safety Improvements

There are several other safety improvements that would further improve the road safety outcomes at Thomas Mitchell Drive and Glen Munro Road intersection. These are listed below;

- Provide kerb returns that would allow a vehicle to hold closer to the intersection while allowing a truck to turn right or left into Glen Munro Road, see Figure 4. Note that while increasing kerb return radii will improve the heavy vehicles entering Glen Munro Road clear of vehicles waiting to depart the intersection, there is a risk that smaller vehicles will enter a low speed environment from Thomas Mitchell Drive at a higher speed. Careful consideration of the intersection layout will be required in subsequent design stages to maintain safety for all aspects and users of the intersection.

Figure 14: Realign Kerb Return

- The existing streetlighting is flag light and although it highlights the location of the intersection it does not illuminate all the possible conflict points. If the streetlight was upgraded to provide V3 lighting at all the conflict points it would improve the safety of the intersection.
- The BAR turn treatment on a two-lane rural road as shown in Figure 13 has limited applications. It is mainly applicable at the junction of side roads and rural arterial roads with lower traffic volumes. Such turn treatments can record high crash rates, especially in high-speed areas. If in the future traffic volumes especially HV turning volumes increase a more desirable treatment would be a CHR(S) turn treatment discussed in Section A.16 of

AGRD Part 4 and as show below in Figure 15

Figure A 29: Channelised right-turn treatment with a short turn slot [CHR(S)] two-lane rural road

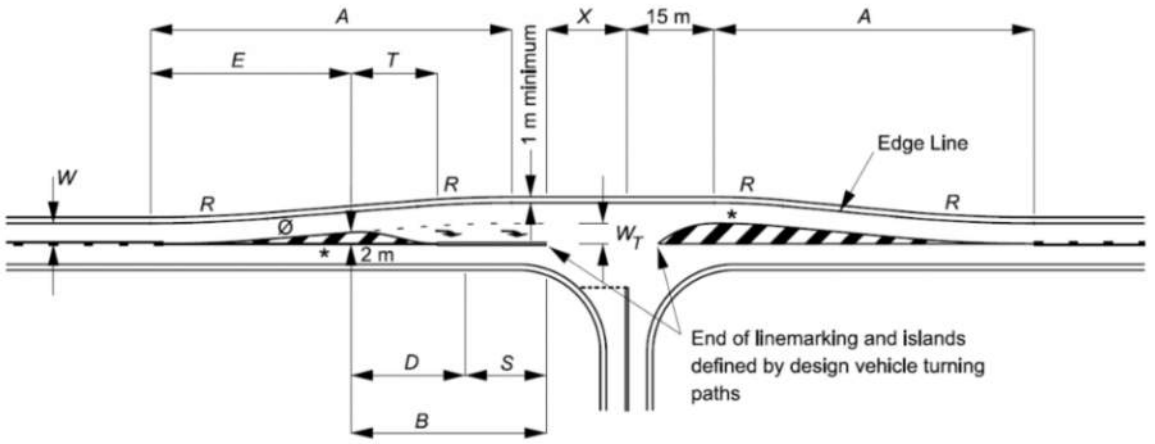


Figure 15: Channelised right-turn treatment with short turn slot [CHR(S)]