OPUS

NZ Transport Agency

Wellington Urban Motorway

Bridge Safety Barrier Assessment

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Contents

1 Scope

Opus has been commissioned by NZ Transport Agency (the Transport Agency) to carry out a desktop study of the existing road safety barriers on bridge structures along the Wellington Urban Motorway (WUM), south of the Thorndon Overbridge (TOB). The following structures have been included:

- Murphy Street Off-Ramp – Adjacent to SH1 (BSN 10718)
- May Street On-Ramp – Over SH1 (BSN 10720)
- Bowen Street Overpass – SH1 Southbound (BSN 10727)
- Bowen Street Overpass – SH1 Northbound (BSN 10728)
- Tinakori Road Off-Ramp Bridge – Adjacent to SH1 (BSN 10728)
- Shell Gully Overbridge – SH1 Northbound (BSN 10731) & Southbound (BSN 10732)
- Terrace Off-Ramp Bridge – Adjacent to SH1N (BSN 10733)
- Clifton Terrace On-Ramp Bridge – Adjacent to SH1 (BSN 10734)

The location of these structures are shown on the maps in Figures 1.1 and 1.2. Note, TOB is not shown in Figure 1.1 but is further north. The 2014 Annual Average Daily Traffic (AADT) volume associated with each structure is also shown, which are obtained from the 'NZ Transport Agency State Highway Traffic Booklet 2014'.

Figure 1.1: Northern Study Section and 2014 AADT Volumes

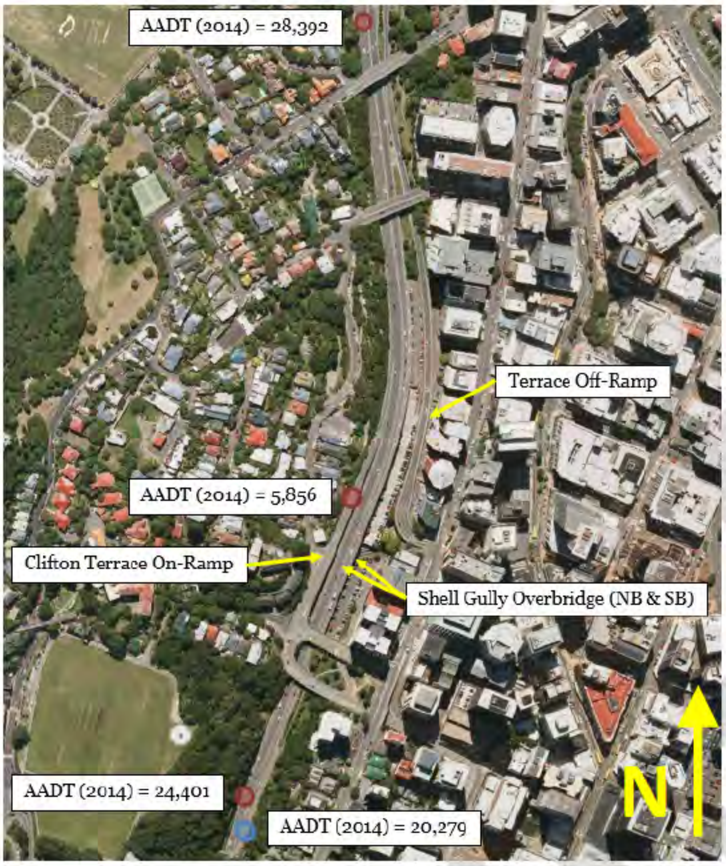


Figure 1.2: Southern Study Section and 2014 AADT Volumes

The purpose of this study is to:

a. Outline the road safety barrier compliance standards in New Zealand (NZ).
b. Identify the existing barrier systems installed on the structures above.
c. Determine the level of containment required by current compliance standards.
d. Discuss the expected performance and condition of the existing barrier systems.
e. Consider possible retrofit options and provide indicative costs.

2 Methodology

The methodology for this study is similar to a previous feasibility barrier assessment carried out for the TOB. This assessment, as attached in Appendix A, lead to the installation of a TL-4 Modified Thrie-beam system in 2010/11. This study draws on the knowledge of the TOB barrier project.

The barrier systems included in this study involve the barriers on the bridge structures mentioned above and the approach barriers either side of the bridge. Barrier systems beneath any highway structures have been excluded from this study.

Note that this is a desktop study and no site visits have been carried out as part of this barrier assessment to confirm the measurements on any construction drawings referred to. Similarly, the condition assessment of the existing barrier systems is based from the Transport Agency's bridge structures inspection programme, covered under NZTA S/6. Therefore, no specific barrier inspection has been carried out to determine the current condition of the barrier systems.

Indicative costs discussed for retrofit options include preliminary and general, temporary traffic management, temporary works/access and deck strengthening (where required); however they exclude any services relocation (eg drainage, telecommunications, etc). Note that these indicative costs are only rough order costs as they substantially depend on the temporary traffic management and temporary works/access associated with the barrier retrofit on each bridge structure. In terms of temporary traffic management, we have outlined our assumptions in regards to the type of closure required and the estimated construction period.

3 Road Safety Barrier Compliance Standards in New Zealand

In NZ, there has been a gradual progression in compliance standards for road safety barriers, with the Transport Agency generally accepting standards used in Australia and the United States (US).

In 1999, the Transport Agency adopted the US National Cooperative Highway Research Program Report 350 (**NCHRP-350**), prepared in 1993 by the Federal HighWays Administration (FHWA), as the performance criteria for approving barrier systems to be installed on the NZ state highway network. This research report involved various road safety barrier hardware being subject to full-scale crash testing in order to verify the barrier system performed satisfactorily in typical crash conditions, and to ensure the expected impact severity on vehicle occupants was not above unacceptable levels. Testing was representative of expected field conditions and the vehicle fleet, with evaluation relating to the containment of crash energy – a function of vehicle mass, speed and angle of impact.

NCHRP-350 established three criteria to evaluate the performance of barrier systems:

- Structural Adequacy – The barrier hardware must contain and redirect the test vehicle, without the vehicle penetrating, under-riding or over-riding the barrier system. Although controlled lateral re-direction of the vehicle is acceptable.
- Occupant Risk – Detached elements, fragment, or other debris from the test vehicle should not penetrate the occupant compartment or present an undue hazard to other traffic.
- Vehicle Response Post Impact – After collision with the barrier system, it is preferable that the trajectory of the vehicle does not intrude into adjacent traffic lanes.

Subsequently, the Transport Agency published Specification M23 'Road Safety Barrier Systems' (NZTA M23) in 1999, which outlined compliance requirements for all road safety barrier systems installed on the state highway network. This document specified NCHRP-350 as the primary performance criteria for acceptance of any road safety hardware system.

In September 2012, the Transport Agency adopted the more recent American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (**MASH**) as the performance criteria for all new road safety hardware systems installed on the state highway network from 1 November 2012. Although, the Transport Agency confirmed a 'grandfathering' clause which allowed all highway safety hardware accepted under NCHRP-350 to remain in place, and continue to be manufactured and installed. However, all new products entering the market (or significant variants of existing systems) shall be tested and evaluated in accordance with the more onerous MASH criteria.

The subsequent upgrade known as MASH, reflects the upsizing of the north-American vehicle fleet since 1993 and makes amendments to remove minor testing inconsistencies from NCHRP-350. The characteristics of the MASH vehicle fleet are generally similar to the New Zealand light vehicle fleet, with the exception of NZ High Productivity Motor Vehicles (HPMVs) with masses above 44 tonnes. This particular issue is discussed later in this report.

Tables 3.1 and 3.2 below provide a summary of NCHRP-350 and MASH criteria. Note, the lighter mass vehicles (820kg small car and 2000kg pickup truck) are used in all tests to ensure that the impact severity conditions are not exceeded for these smaller vehicles.

Table 3.1: NCHRP-350 Summary

Test Level	Test Vehicle Mass	Impact Speed	Impact Angle	Crash Energy
TL-1	Small Car - 820kg Pickup Truck - 2000kg	50kph 50kph	20 25	9kJ 35kJ
TL-2	Small Car - 820kg Pickup Truck - 2000kg	70kph 70kph	20 25	18kJ 68kJ
TL-3	Small Car - 820kg Pickup Truck - 2000kg	100kph 100kph	20 25	37kJ 138kJ
TL-4	Small Car - 820kg Pickup Truck - 2000kg Single Unit Truck - 8000kg	100kph 100kph 80kph	20 25 15	- - 133kJ
TL-5	Small Car - 820kg Pickup Truck - 2000kg Tractor Van Trailer – 36000kg	100kph 100kph 80kph	20 25 15	- - 595kJ
TL-6	Small Car - 820kg Pickup Truck - 2000kg Tractor Tank Trailer – 36000kg	100kph 100kph 80kph	20 25 15	- - 595kJ

Table 3.2: MASH Summary

Test Level	Test Vehicle Mass	Impact Speed	Impact Angle	Crash Energy
TL-1	Small Car - 1100kg Pickup Truck- 2270kg	50kph 50kph	25 25	17kJ 36kJ
TL-2	Small Car - 1100kg Pickup Truck- 2270kg	70kph 70kph	25 25	34kJ 71kJ
TL-3	Small Car - 1100kg Pickup Truck - 2270kg	100kph 100kph	25 25	70kJ 144kJ
TL-4	Small Car - 1100kg Pickup Truck - 2270kg Single Unit Truck - 10000kg	100kph 100kph 90kph	25 25 15	- - 193kJ
TL-5	Small Car - 1100kg Pickup Truck - 2270kg Tractor Van Trailer - 36000kg	100kph 100kph 80kph	25 25 15	- - 548kJ
TL-6	Small Car - 1100kg Pickup Truck - 2270kg Tractor Tank Trailer - 36000kg	100kph 100kph 80kph	25 25 15	- - 548kJ

As can be seen above, the key differences between NCHRP-350 and MASH are:

- Small car - mass increases from 820kg to 1100kg
- Small car - impact angle increases from 20 to 25 degrees
- Pickup truck - mass increases from 2000kg to 2270kg
- Single unit (TL-4) truck - mass increases from 8,000kg to 10,000kg
- Single unit (TL-4) truck - speed increases from 80kph to 90kph.

NZTA M/23 specifies that all barrier systems on state highways are to achieve a minimum performance level of NCHRP-350 TL-3. Therefore, the majority of barrier systems on the NZ state highway network are designed to at least contain vehicles up to 2000kg at 100km/h (assuming an impact angle of 20 degrees). The performance level of barrier systems approved by the Transport Agency are given in Appendix A of NZTA M23.

The requirements for road safety systems installed on state highway bridges however are determined by the barrier selection method given the NZ Transport Agency Bridge Manual 3rd Edition (the Bridge Manual). **A performance level 4 (TL-4) barrier is the minimum standard acceptable for all new state highway structures, unless approval is obtained from the National Manager - Traffic and Safety.** Compliant barrier systems, approved by the Transport Agency, are specified in NZTA M/23: Appendix B.

The Bridge Manual specifies that designers should start with the conditions requiring a TL-5 barrier and then work through to TL-4. A performance level 5 (TL-5) barrier should be provided where one or more of the following conditions exist:

a. More than 2000 heavy/commercial vehicles per day; posted speed limit greater than 60km/h);
b. More than 4000 heavy/commercial vehicles per day; posted speed limit less than 60km/h);
c. Major roads with AADT of 10,000 or more vehicles per day;
d. Roads with AADT of 40,000 or more vehicles per day;
e. Electrified railways, or over goods lines carrying significant quantities of either noxious of flammable substances;
f. High occupancy land such as houses, factories, areas for congregating, etc;
g. The height differential is more than 10 metres;
h. Water depth is greater than 3 metres;
i. The highway crossing the structure is on a horizontal curve with a radius of 600m or less.

The NZTA Bridge Manual specifies that if the requirements for a TL-5 barrier are exceeded then consideration of a TL-6 barrier should be carried out. The following is stated in the Bridge Manual:

"A performance level 6 barrier shall only be provided at specific locations where agreed by the road controlling authority, where there is a high probability of loss of life or serious injury due to a vehicle penetrating the barrier."

Given the requirements by the Transport Agency, the barrier systems on most bridges should be designed to at least contain cars, heavy utilities and light/medium mass commercial vehicles. However, due to New Zealand High Productivity Motor Vehicles (HPMVs) being above 44 tonnes, the mass for the TL-5 (36 tonne Tractor Van Trailer) and TL-6 (36 tonne Tractor Tank Trailer) test regimes are exceeded. Therefore, barrier systems even at these test levels may not provide containment for these larger vehicles.

The Bridge Manual specifies a performance level 4 (TL-4) barrier is the minimum standard acceptable on state highway structures. For this reason we will primarily compare the existing barrier systems to a TL-4 (Modifed Thrie-beam) barrier (if a semi-rigid system) or a TL-4 (F-shape) concrete barrier (if a rigid system). Figure 3.3 shows a TL-4 Thrie-beam (with modified blockout) barrier system.

Figure 3.3: TL-4 Thrie-beam (with Modified Blockout) Barrier System

4 Murphy Street Off-Ramp

4.1 Existing Road Safety Barrier System

The road safety barriers on the Murphy Street Off-Ramp (BSN 10718) are shown in Figures 4.1 and 4.2. As shown in Figure 4.1, there is a crash cushion protecting Flag Sign #6 (BSN 10717) located in the median area between the off-ramp and the motorway. Along the off-ramp (on the motorway side), there is a strong post (timber) with w-section guardrail system, as shown in Figure 4.2. This barrier system manages the risk of a potentially errant vehicle falling onto the three-lane motorway below, which carries approximately 24,000 vpd.

Figure 4.1: Murphy Street Off-Ramp – Crash Cushion

Figure 4.2: Murphy Street Off-Ramp – Edge Barrier

4.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 4000 vehicles per day (vpd) with 3% heavy vehicles (i.e. heavier than 3.5 tonnes). Vehicles enter the off-ramp from the motorway which has a posted speed limit of 100km/h, although there is a 50km/h speed sign located approximately 60-70 metres up the off-ramp. Therefore, average operating speeds are predicted to be between the two posted speed limits, at around 70-80km/hr.

Information from the Transport Agency Crash Analysis System (CAS) shows no barrier incidents causing injury have occurred along this location during the 10 year period between 2005 and 2014.

4.3 Level of Containment Required

The off-ramp is not considered to be a bridge structure in the Bridge Manual, therefore a TL-3 barrier is required in accordance with the barrier selection method in NZTA M23.

4.4 Performance of Existing Barrier System

The timber post w-section guardrail barrier system is performance level TL-3 (according to NCHRP-350) and is an approved system as referenced in NZTA Specification M/23. The design principle for w-beam guardrail is that the timber posts rotate in the surrounding soil (breaking off under extreme impact forces), allowing the rail to deflect outwards and resist the impact forces through ribbon tension in the rail. The timber blockouts are located between the posts and rail to prevent the vehicle's wheel from snagging on the post which could lead to the vehicle rolling over. NZTA M/23 specifies a deflection of 800mm (under highest impact severity).

Although this barrier system is approved in M/23, there are a couple of construction defects with the existing system. In accordance with Transport Agency Technical Memorandum (TM-2005), issued December 2011, timber guardrail posts are not permitted to be embedded into hard surfaces such as concrete footpaths (as shown in Figure 4.2). The hard surface limits the performance of the barrier system as the impacted post will not be able to properly rotate backwards before shearing. This issue increases the stiffness of the barrier which could lead to wheel snagging or vehicle pocketing, and ultimately rupture or override of the barrier.

Additionally, the 100-150mm high concrete kerb is essentially in line with the w-section rail therefore, given the rail is designed to deflect up to 800mm, a vehicle could be launched up when hitting the kerb which could lead to override of the barrier or the vehicle rolling over.

The crash cushion is a proprietary product (as shown in Figure 4.1) approved by the Transport Agency.

4.5 Condition Assessment of Existing Barrier System

The timber posts, timber blockouts, steel rail and steel bolts are in satisfactory condition and there are no significant areas of impact damage, as observed during the principal bridge inspection in 2014. Note, some early signs of corrosion is still considered acceptable and will need to be monitored to ensure the performance of the barrier is not severely impaired.

The crash cushion appears to be in a satisfactory condition.

4.6 Retrofit Options and Indicative Costs

Given the existing barrier meets the current compliance standards by the Transport Agency, no retrofit options have been considered.

4.7 Summary

The performance level (TL-3) of the existing barrier meets the current compliance standards by the Transport Agency. Although noting the two issues discussed in Section 4.3, we consider the existing barrier system is adequate for this location and fit for purpose given it is maintained in a satisfactory condition.

5 May Street On-Ramp

5.1 Existing Road Safety Barrier System

The road safety barriers on the May Street On-Ramp (BSN 10720), which was constructed in 1968, are shown in Figures 5.1 to 5.5. The barrier along the on-ramp is an out-dated system consisting of steel channel bridge rail on steel posts which are top mounted to the kerb upstand on the bridge deck (refer to Figure 5.1). There is a top handrail along the entire length and on both sides. The length of the barrier system on the bridge structure is approximately 100m on each side (200m total).

Figure 5.1: May Street On-Ramp – Barrier System

This barrier system manages the risk of a potentially errant vehicle falling onto the six-lane motorway (three in each direction) beneath the structure, which carries approximately 21,000 vpd northbound and 24,000 vpd southbound. Refer to Figure 5.2

Figure 5.2: May Street On-Ramp – Bridge Structure and WUM

Referring to the 1968 construction drawings (see Figure 5.3):

- Steel rail was a 10″×3″ 19lb (8.1mm thick) channel section.
- Steel posts were cut from a 10″×4″ 19lb universal beam. The posts were at a spacing of 2.1m.
- Steel blockout was an 8″×4″ 18 lb 'I' section.
- A 10″×7″×3″ treated pine block between the rail and steel blockout.
- The rail was mounted to each steel blockout using two 3/4″ (19mm) bolts and the posts sections were welded onto an 11″×9″×5/8″ steel baseplate.
- The post baseplates were fixed into the bridge deck using four cast-in sockets with 3/4″ bolts.

- All steel was mild steel in accordance with British Standard 15 (1948) and all welds were 3/16" fillet welds (all around).

The centreline of the rail was 1′-9″ (533mm) from the road surfacing, and the handrail was to be 3′-0″ (914mm) from the road surfacing. Given the bridge would have likely been resurfaced several times over the years, it is reasonable to expect that this height will most likely be less than these values. Additionally, the front face of the rail was 1′-0″ (305mm) from the post face and 2'-0" (610mm) from the back edge of the concrete kerb upstand.

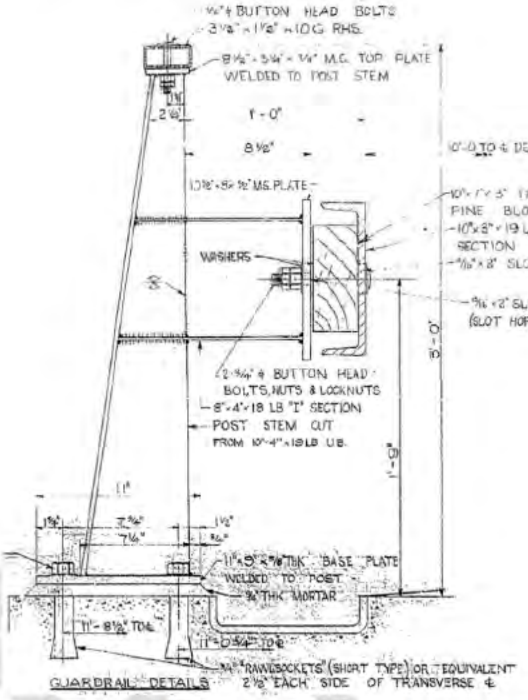


Figure 5.3: Post Detail from Construction Drawings (Designed in 1968)

The rail sections vary between 82 and 109 inches (25-33m) long, typically spanning approximately 12 posts. As shown in Figure 5.4, the rail sections were fixed together at each end with two 1" Macalloy bolts.

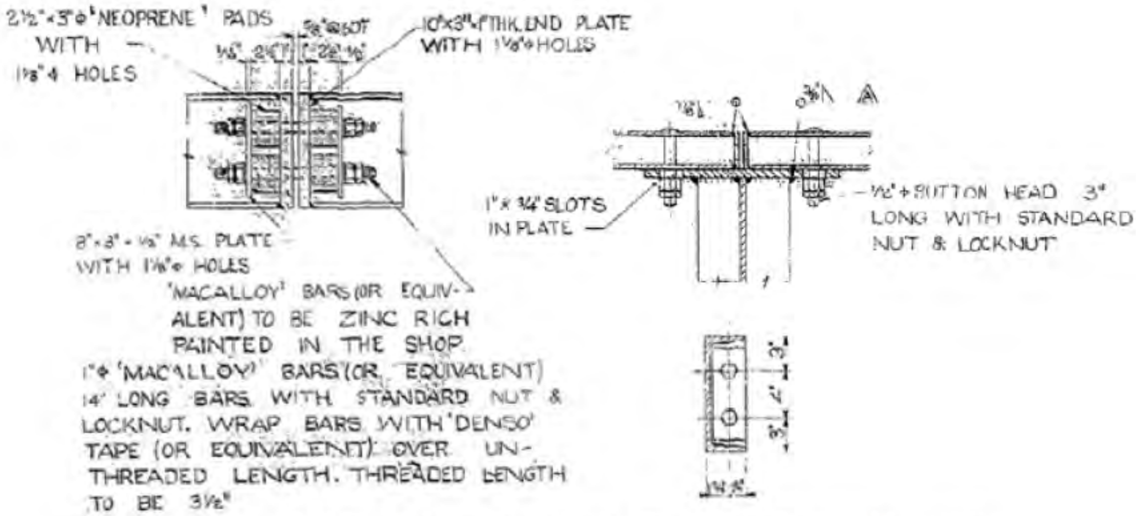


Figure 5.4 Rail Detail from Construction Drawings (Designed in 1968)

At the bottom of the on-ramp, the barrier changes to a strong post (timber post and blockout) system with w-beam guardrail. Refer to Figure 5.5.

Figure 5.5: May Street On-Ramp – Trailing Transition and Barrier System

5.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 4,100 vpd (including 3% heavy). The posted speed limit is 50km/h transitioning to 100km/h at the bottom of the on-ramp. Operating speeds on the on-ramp are restricted by the curvature of the bridge structure, therefore we expect vehicles are likely to be travelling on average in the 60-70km/h range along the on-ramp section above the WUM.

Information from the Transport Agency CAS shows that there were no significant injury barrier incidents along the bridge structure during the 10 year period between 2005 and 2014.

5.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the May Street On-Ramp has the following factors for the consideration of a performance level 5 (TL-5) barrier:

- AADT (2014) = 4,100 vpd (3% heavy) = 123 heavy/commercial vpd
- Speed = 60 - 70 km/h (predicted)
- Drop of approx. 7 metres
- Horizontal curve radius of 63m
- High risk land use underneath the structure (SH1 with AADT of 25,000 to 28,000 vpd in each direction).

As above, the approximate average daily volume of 123 heavy/commercial vehicles is significantly below the threshold of 2000 vpd (for roads with a posted speed limit of 60km/h or more) specified in the Bridge Manual. Additionally, the 2014 AADT of 4,100 vpd is significantly lower than the threshold of 40,000 vpd (or 10,000 vpd per lane) to justify a TL-5 barrier. While there is a drop of approximately 7m and the presence of high risk land beneath the bridge structure (WUM), the risk of a vehicle penetrating (or over-riding) the barrier is reduced by the lower predicted speeds. Therefore, we consider a TL-4 barrier system is required as for the bridge structure.

5.4 Performance of Existing Barrier System

The existing barrier would be considered a semi-rigid barrier system, as the barrier consists of a bridge deck mounted post and continuous rail system, which is typically designed to deform during a vehicle impact in order to absorb energy from the collision. A semi-rigid system relies on two mechanisms for crash energy containment and redirection. These are the ribbon strength and continuity of the rail section, and the lateral stiffness developed through the rotational resistance of the post/baseplate assembly as the system tries to rotate backwards under impact.

Following our investigation of available literature, the existing barrier is a unique system designed specifically for either this bridge or similar bridge structures constructed in New Zealand during the 1960's/70's. During our research we were unable to find any previous barrier assessments evaluating the barrier system on the May Street On-Ramp, or any other bridge structure included in this study. As no documentation can be found confirming whether this barrier system was subject to crash testing, it is difficult to confirm the actual field performance of this barrier system.

The lateral rotational resistance of the post is governed by the particular load which causes the post/baseplate assembly to be frangible. Current compliant deck mounted barrier systems include 'necked' hold down bolts, fixing the post baseplate to the bridge deck, which provide resistance against impact forces. These bolts are weakened to fracture and release the post at a particular design load. For example, the TL-4 Thrie-beam system includes two M20 Class 4.6 hold-down bolts, fixing the post baseplate into the bridge deck, which have a 20mm 'necked' length in alignment with the baseplate in order to fail in tension at a load of 90kN. In comparison, the lateral rotational resistance of the existing barrier would probably be govern by the welded connection between the post and baseplate, given that the ¾" (18mm) diameter hold-down bolts are not 'necked'. Although the failure mechanism of the existing barrier is slightly different to the TL-4 Thrie-beam system, in principal it is the same with the post/baseplate connection expected to be frangible at a comparable loading. Therefore, we predict the existing barrier posts will dislodge from the bridge deck at a loading roughly similar to the modern TL-4 Thrie-beam system, and the barrier system will behave in a similar manner.

The ribbon strength of the rail is dependent on the stiffness/ductility of the steel channel rail and the grade of steel. The steel channel rail has a thickness of 8.1mm, three times the thickness of the TL-4 Thrie-beam guardrail (2.7mm). According to BS15 (1948), the steel grade (yield strength) is 221MPa for all steel in the existing system. This steel grade is considerably less than the modern Thrie-Beam system, where the posts are formed from steel grade HU300 in accordance with AS/NZS 1594 (300 MPa) and the rail is steel grade HA350 (350MPa). Although a lower steel grade, the ribbon strength of the existing system is still expected to be stronger than the TL-4 Thrie-beam system due to the significantly stiffer rail section. Given the stiffness of the rail, the deflections are predicted to be much less than the TL-4 Modified Thrie-beam system (900mm), therefore the performance of the existing barrier is expected to be between a semi-rigid system and rigid system.

In terms of the continuity of the rail, the existing system differs significantly to the modern Thrie-beam system for both the length of rail sections and the connection detail between rail sections. The existing system has much longer lengths of rail, at 25m or greater, compared to the 4m long Thrie-beam guardrail. The rail sections are connected together with two 1" (25.1mm) diameter Macalloy bars (or equivalent), whereas Thrie-beam guardrail sections are connected by eight M16 bolts. The connection detail between the rail and posts is however more similar. The existing barrier involves the rail being fixed to every post with two ½" (12.7mm) bolts, whereas the Thrie-beam guardrail is fixed to every post with one M16 bolt.

Given the 50km/hr speed environment immediately before the on-ramp, we expect speeds to be much less than 100km/h (TL-3) and also less than 80km/h (TL-4 vehicle in NCHRP- 350). Furthermore, due to the high curvature of the bridge, we expect vehicles are likely to be travelling on average in the 50-70km/h range along the on-ramp section above the WUM. Consequently, the impact loads (crash energy) are expected to be much less than the NCHRP-350 testing regimes. Given lower speeds and therefore smaller impact loads than the NCHRP-350 testing, a TL-4 vehicle is not expected to penetrate through the steel channel rail due to the predicted continuity and ribbon strength of the existing rail. Although the post baseplate connection is predicted to be frangible at TL-3 impact loads, the rail system alone is still expected to be able to withstand forces from a TL-4 vehicle due to the lower impact loads.

The height of the existing barrier is however a major concern as there is a high risk that a TL-4 vehicle (higher centre of mass) could over-ride the barrier system. The construction drawings show the rail height to be 533mm to the rail centre, and 660mm to the top of the rail. However due to several resurfacings of the bridge since construction, these heights are now expected to be less. Therefore, the height of the barrier is significantly lower than the TL-4 Thrie-beam system at 610mm (rail centre) and 865mm (top of rail). It should be noted that these heights are even less than a TL-3 W-beam system at 550mm (rail centre) and 710mm (top of rail). Although there is a top handrail at 941mm, the welded connection at the post/baseplate is expected to fracture before the vehicle would engage with the handrail, due to the stiffness of the rail. Therefore the handrail is not expected to provide any resistance to a vehicle over-riding the barrier.

Another issue is related to the stiffness of the steel channel rail and how it deforms when impacted by a TL-3 (or TL-4) vehicle, which relates to the energy absorbed by the barrier and consequently the impact forces on occupants in the vehicle. Due to the strength of the steel channel rail, the deformation of the barrier system is expected to be less than a W-beam or Thrie-beam guardrail system, therefore could potentially lead to greater injuries sustained by vehicle occupants. One significant risk is related to the top handrail creating a 'javelin' hazard, where the handrail could become detached from the barrier and penetrate the vehicle, potentially impaling an occupant. Again due to the low speed environment, we consider this risk to be low (provided the barrier hardware is in good condition) and therefore acceptable.

The strong post (timber) system with w-beam guardrail at the bottom of the on-ramp (refer Figure 4.5) is the same as the barrier system discussed in Section 3. Although the steel channel rail system is expected to be much stiffer than the timber post with w-beam guardrail, pocketing is not considered to be an issue due to the direction of traffic.

5.5 Condition Assessment of Existing Barrier System

As observed during the principal bridge inspection in 2014, there are various stages of corrosion on several parts of the barrier system (posts, rail and bolts). This corrosion is not surprising given the barrier was installed around 40 years ago. Refer to Figure 5.6 for some example of the corrosion observed.

Although early signs of corrosion is not expected to severely weaken the barrier system, critical elements of the barrier (hold-down bolts, rail bolts and welded connections between rail sections) should be regularly checked for corrosion and repaired/replaced if necessary. If the condition of these critical elements is neglected then the performance of the barrier could be compromised.

Figure 5.6: Corrosion on the Steel Channel Rail

The existing barrier does have a few localised areas of impact damage (eg slightly bent rail and/or posts), however theses appear to have been sideswipe collisions given the damage is only minor. As there is no substantial damage (eg tears in rail, deformed posts/blockouts, fractured bolts, etc), we don't expect the performance of the barrier system to have been dangerously impaired.

The strong post (timber) system with w-beam guardrail, at the bottom of the on-ramp, appears to be in a satisfactory condition.

5.6 Retrofit Options and Indicative Costs

5.6.1 Do Nothing

If the existing barrier system is retained, the Transport Agency will need to accept the risk of the non-compliant (and potentially deficient) barrier system. Additionally, ongoing difficulties, and high costs, of maintaining the non-standard barrier system will continue, especially when damaged sections are replaced after a vehicle collision.

5.6.2 TL-4 Modified Thrie-beam Barrier

According to current compliance standards, provision of a Performance Level 4 (TL-4) barrier is required. The total rough order cost of replacing the existing barrier systrem with a TL-4 Modifed Thrie-beam barrier is around $350,000 – $550,000. Note that this cost includes preliminary and general, temporary traffic management and temporary works/access; however relocation of services is excluded. Given the approximate barrier length of 240m (including new leading and trailing transition sections), the cost of this option would be approximately $1,500 - 2,300/m.

Note, this cost assumes the on-ramp structure can be closed every night for around 4-6 weeks (with 6-7 hour shifts). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

5.7 Summary

As there is no crash testing data available, it is difficult to determine in-service performance (under actual field conditions) of this barrier system. The expected performance of this barrier (as discussed in Section 5.4) is only based on readily available literature about modern and historic road safety barrier systems, and can be subjective.

Primarily based on the rail height, the existing barrier system would be considered as non-compliant to TL-3 NCHRP-350 criteria. While the barrier system might be able to resist the impact forces from a NCHRP-350 TL-3 (or TL-4) vehicle, there is a concern that the vehicle will not be redirected in a smooth/controlled manner due to the low height and stiffness of the barrier system. Additionally, there is a high risk that TL-4 or larger vehicles (higher centre of mass) could over-ride the barrier.

According to current compliance standards, provision of a Performance Level 4 (TL-4) barrier is required. However given the lower speed environment, we expect the impact loads (crash energy) from a TL-4 vehicle to be much lower than the NCHRP-350 testing. As such, we expect the existing barrier to be able to withstand the impact loads from a TL-4 vehicle (given the lower speed) due to the predicted continuity and ribbon strength of the stiffer steel channel rail.

Although it is probable that a TL-4 or larger (higher centre of mass) vehicle could over-ride the barrier due to the low height, given the AADT of 4100 vehicles per day (including 123 heavy/commercial vehicles) and expected low speeds of 60-70km/h, we consider the overall risk of TL-4 (or larger) vehicles over-riding the barrier to be low and therefore acceptable. Therefore, while the existing barrier is a noncompliant system according to current standards, we consider the existing barrier (in this location) is likely to withstand the impact loads from a TL-4 vehicle due to the expected lower speeds, and is fit for purpose given it is maintained in a satisfactory condition.

However, if the Transport Agency desired a compliant barrier system by current standards then a TL-4 Modified Thrie-beam system should be installed at a rough order cost of approximately $350,000 - $550,000.

6 Bowen Street Overpass – Southbound

6.1 Existing Road Safety Barrier System

The road safety barriers on the Bowen Street Overpass - Southbound (BSN 10727), constructed in 1972, are shown in Figures 6.1 to 6.6. This is also an out-dated system consisting of steel channel bridge rail mounted on steel posts. The length of the barrier system on the bridge structure is approximately 100m on each side (200m total). Although the rail section (and height) is identical to that on the May Street On-Ramp, the steel post is a 4″×4″×1/4″ rectangular hollow section (RHS), as shown in Figure 6.1.

Figure 6.1: Bowen Street Overpass (Southbound) – Edge Barrier Post

As shown in the construction drawings (refer Figure 6.2), other key characteristics of this system include:

- The height of the top handrail is 4′-0″ (1219mm) from the road surfacing (at construction).
- Post spacing of 7′- 6″ (2.3m).
- Steel posts were positioned at the front edge of the 11″×10″×3/4″ mild steel baseplate.
- The steel post was comprised of two sections. The bottom half was a 4″×4″×0.25″ RHS which was shop butt welded to a 4″×3″×0.192″ RHS above.
- Steel blockout was a 4″×3″×0.192″ RHS and there was a 7″×3″×12″ treated pine block between the rail and steel plate on the blockout.
- Steel was mild steel according to BS15 and welds were 3/16" fillet welds (all around).
- The posts are mounted on a concrete kerb upstand which is 200mm above the surfacing.

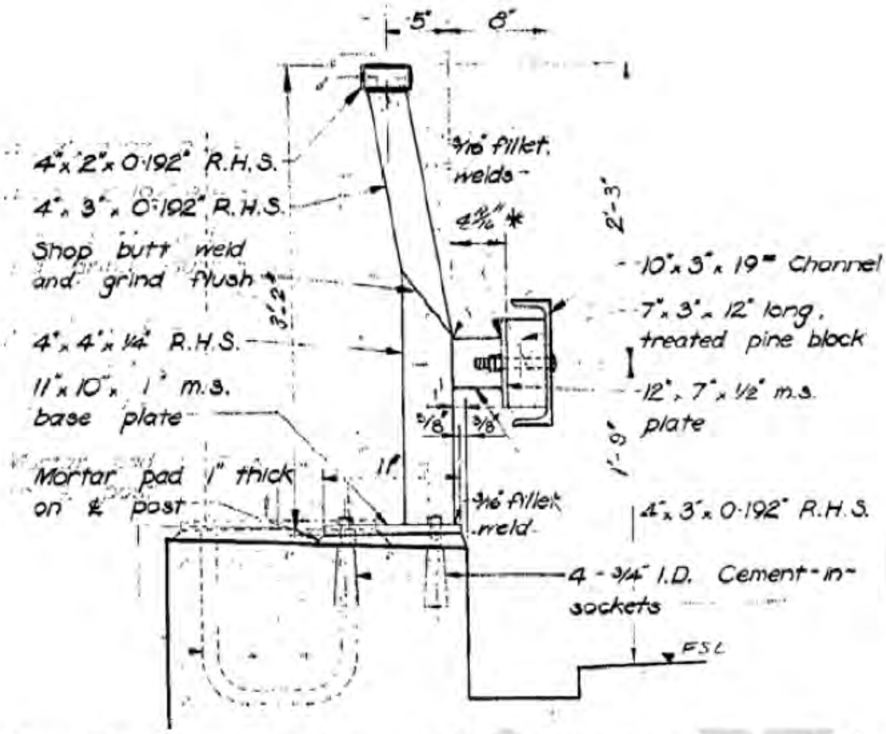


Figure 6.2: Bowen Street Overpass - Barrier Detail from Construction Drawings (Designed in 1971)

Excluding a top handrail, the median barrier is basically the same as the edge barrier apart from the following detailing (refer Figure 6.3 & 6.4):

- Steel posts were positioned behind the front bolts in the 10.5″×10″×3/4″ mild steel baseplate.
- To account for the positioning of the post further back on the baseplate, the blockout is longer to ensure the rail in front of the concrete kerb.

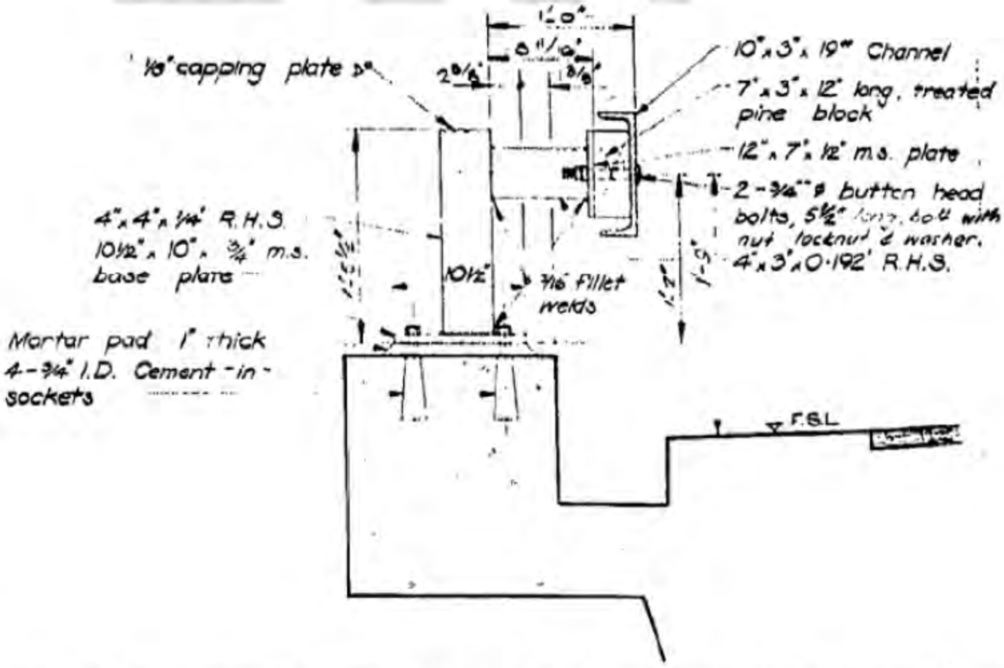


Figure 6.3: Bowen Street Overpass - Barrier Detail from Construction Drawings (Designed in 1971)

Figure 6.4: Bowen Street Overpass (Southbound) – Median Barrier System

The edge barrier system adjacent to the bridge (refer to Figure 6.5), on both the leading and trailing sides, is the same as the median barrier system shown in Figure 6.4. The length of the leading transition barrier is approximately 30m and the length of the trailing transition barrier is approximately 20m.

Figure 6.5: Bowen Street Overpass (Southbound) – Edge Barrier Leading Approach

Additionally, there is a concrete anchor block at each end of the bridge structure where the handrail terminates, as shown in Figure 6.6. This anchor block is 3'-3" (991mm) high, 12" (305mm) thick and 6'-0" (1.83m) long.

Figure 6.6: Bowen Street Overpass (Southbound) – Concrete Anchor Block

The median barrier has different transition systems before and after the bridge. The trailing end involves a TL-4 'New Jersey' concrete (rigid) barrier connecting to the steel channel rail system along the bridge, as shown in Figure 6.7.

Figure 6.7: Bowen Street Overpass (Southbound) – Median Barrier Trailing Transition System

At the leading end, the steel channel rail system on the bridge connects to a TL-3 w-beam guardrail system. Note that there is no appropriate transition section between the two systems to account for the significant increase in stiffness, especially with the rigid concrete anchor block terminal (as mentioned above for the outer edge barrier). Refer to Figure 6.8.

Figure 6.8: Bowen Street Overpass (Southbound) – Median Barrier Leading Transition Approach

6.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 28,400 vpd (including 3% heavy). The posted speed limit on the bridge is typically 100km/h, although the operating speeds can occasionally be less due to congestion during peak periods.

Information from the Transport Agency CAS shows that there were no serious or fatal injury barrier incidents along the bridge structure during the 10 year period between 2005 and 2014. There was one minor injury loss of control crash reported in 2006, which involved a vehicle losing control by avoiding another vehicle and impacting the barrier. One non-injury (loss of control) crash was reported in 2006 and 2013 respectively.

6.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the Bowen Street Overpass (Southbound) has the following factors for the consideration of a performance level 5 (TL-5) barrier system:

- AADT (2014)= 28400 vpd (3% heavy) = 852 heavy/commercial vpd
- Speed = 100 km/h (posted)
- Drop of approx. 8 metres
- High risk land use underneath the structure (Bowen St, carpark)

As above, the approximate average daily volume of 852 heavy/commercial vehicles is below the threshold of 2000 vpd (for roads with a posted speed limit of 60km/h or more). The height differential of around 8m is only slightly below the 10m threshold and the 2014 AADT of 28400 vehicles per day (9,500 vpd/lane) is only marginally below the 10,000 vpd/lane threshold. Furthermore, there is high risk land use below the structure (Bowen Street and car parking area) as well as the WUM being one of the most important roads into Wellington City. Given the factors above meet (or almost meet) the conditions in the Bridge Manual, we consider a TL-5 barrier system is required as for the bridge structure.

Additionally, we note that HPMV and Overweight vehicles (above 44 tonne) are currently not permitted to travel along the WUM, but the Transport Agency is currently considering to remove this restriction. Should the Transport Agency allow HPMV and Overweight vehicle to travel along the WUM then the daily volume of heavy/commercial vehicles could increase to volumes which might justify a TL-6 barrier.

6.4 Performance of Existing Barrier System

During our research we were unable to find any documentation regarding the performance of this barrier system or whether it has been subject to full-scale crash testing, therefore it is difficult to determine the actual field performance of this barrier system.

This out-dated system consisting of steel channel rail mounted on steel posts is similar to the semi-rigid barrier system on the May Street On-Ramp, and therefore we predict the barrier will perform in a similar way. The barrier system is expected to rely on two mechanisms for crash energy containment and redirection of the vehicle. The two mechanisms are the ribbon strength and continuity of the rail as well as the rotational resistance provided by the posts.

The ribbon strength and continuity of the rail is expected to be identical to the May Street On-Ramp, as discussed in Section 5.4. The post spacing of 2.3m is slightly longer than the 2.1 spacing on May Street On-Ramp, however the predicted deflection is expected to be essentially the same due to the identical rail and similar stiffness of the post/blockout configuration.

The rotation resistance of the posts is expected to be governed by the particular design load which causes the post/baseplate assembly to be frangible. Although the post detail is different to May Street On-Ramp, we expect the post/baseplate to be frangible at comparable loading. Therefore, we predict the existing barrier posts will dislodge from the bridge deck at a loading roughly similar to the modern TL-4 Thrie-beam system, and the barrier system will behave in a similar manner.

In contrast to the May Street On-Ramp, vehicles on the Bowen Street Overpass are expected to be traveling 100km/h (or more if speeding) which increases the probability that impact loads (crash energy) will be similar to, or above, the NCHRP-350 testing regimes. Furthermore, given the carriageway width of 15m (kerb to kerb), there is a very high risk that an errant vehicle could strike the barrier at an angle greater than 25 degrees (maximum angle in NCHRP-350 testing), which would also significantly increase the impact loads. Therefore, although the steel channel rail system is identical to May Street On-Ramp, the risk of a TL-4 (or TL-5) vehicle penetrating the barrier is significantly higher due to the larger impact loads associated with greater speeds and the potential for a higher impact angle.

Similarly to the May Street On-Ramp, the height of the barrier was 533mm to rail centre and 660mm to the top of the rail (when constructed), however the current height is likely to be less than these values due to several resurfacings of the bridge deck since 1972. This is a major concern as the barrier height is significantly lower than the TL-4 Thrie-beam system at 610mm (rail centre) and 865mm (top of rail). Furthermore, these heights are even less than a TL-3 w-beam system at 550mm (rail centre) and 710mm (top of rail). It should be noted that although the edge barrier has a top handrail at 1219mm, due to the stiffness of the rail the welded connection at the post/baseplate is expected to fracture before the vehicle would engage with the handrail. Therefore the handrail is predicted to provide very little resistance to a vehicle over-riding the barrier. However, the top handrail would probably help prevent an errant motorcyclist from overtopping the rail.

The strong post (timber) system with w-beam guardrail at the median leading approach to the bridge (refer Figure 6.8) is the same as the barrier system discussed in Section 4.4 (again with the timber posts incorrectly installed in the concrete footpath). Although the timber posts are embedded into the concrete footpath, the deflection of the timber post with w-beam guardrail system is expected to be much greater than the steel channel rail system (especially at the location of the concrete anchor block terminal). Given this differential in stiffness (and deflection) between the two barrier systems, we expect there is potential for vehicle pocketing which is a significant concern. An example of vehicle pocketing is shown in Figure 6.9.

Figure 6.9: Example of Vehicle Pocketing (source – US Department of Transportation)

6.5 Condition Assessment of Existing Barrier System

As observed during the general bridge inspection in 2014, there are various stages of corrosion on several parts of the barrier system (posts, rail and bolts). Refer to Figure 6.10 for some typical examples of the corrosion observed.

Figure 6.10: Corrosion at Welded Connection in the Rail and around Post Baseplate

Although early signs of corrosion is not expected to severely weaken the barrier system, critical elements of the barrier (hold-down bolts, rail bolts and welded connections between rail sections) should be regularly checked for corrosion and repaired/replaced if necessary. Should the condition of these critical elements be neglected then the performance of the barrier could be compromised.

Additionally, the existing barrier does have a few localised areas of impact damage (eg slightly bent rail and/or posts), however theses appear to have been sideswipe collisions given the damage is only minor. As there is no substantial damage (eg tears in rail, deformed posts/blockouts, fractured bolts, etc), we don't expect the performance of the barrier system to have been dangerously impaired. Refer to Figure 6.11 for some examples of barrier damage due to vehicle impacts.

Figure 6.11: Examples of Barrier Damage from Vehicle Impacts

6.6 Retrofit Options and Indicative Costs

6.6.1 Do Nothing

If the existing barrier system is retained, the Transport Agency will need to accept the risk of the non-compliant (and potentially deficient) barrier system. Additionally, ongoing difficulties, and high costs, of maintaining the non-standard barrier system will continue, especially when damaged sections are replaced after a vehicle collision.

6.6.2 TL-5 Rigid Concrete Barrier

According to current compliance standards, provision of a Performance Level 5 (TL-5) barrier is required. The Texas HT-80 system is the preferred TL-5 barrier by the Transport Agency.

Strengthening of the bridge deck will be required to withstand the impact loads transferred from the TL-5 rigid barrier. This will incur significant additional costs and required a substantially longer construction period. Including the deck strengthening, the total rough order cost of replacing the existing barrier systrem with a TL-5 rigid (Texas HT-80) barrier is around $1.0 – 1.5M. Note that this cost includes preliminary and general, temporary traffic management and temporary works/access; however any potential relocation of services (eg drainage, telecomunications, etc) is excluded. Also included in this indicative cost is the replacement of the non-complaint approach barrier systems (60m length) with TL-4 Thrie-beam barrier. Given the total barrier length of approximately 260m (including the non-compliant approach barriers), the total cost of this option would be approximately $5,000 - 7,000/m for the TL-5 system and approximately $1,500 – 2,300/m for the TL-4 approach system.

Note, this cost assumes a lane closure for around 8 - 12 weeks (with 8 hour shifts). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

6.6.3 TL-4 Modified Thrie-beam Barrier

Should the Transport Agency determine a TL-5 barrier is not a cost-effective solution due to the costs associated with the deck strengthening, then a TL-4 Modified Thrie-beam system could be installed, similar to the Thrie-beam system installed on TOB. For comparision purposes, the total rough order cost of installing a TL-4 Modified Thrie-beam system would be around $400,000 - $600,000, at approximately $1,500-2,300/m.

Note, this cost assumes a lane closure for around 4 - 6 weeks (with 8 hour shifts). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

6.7 Summary

Similar to the May Street On-Ramp, as there is no crash testing data available it is difficult to determine the actual field performance of this barrier system. The expected performance of this barrier (as discussed in Section 6.4) is only based on readily available literature about modern and historic road safety barrier systems, and can be subjective.

Primarily based on the rail height, the existing barrier system would be considered as non-compliant to TL-3 NCHRP-350 criteria. While the barrier system might be able to resist the impact forces from a NCHRP-350 TL-3 (or TL-4) vehicle, there is a concern that the vehicle will not be redirected in a smooth/controlled manner due to the low height and stiffness of the barrier system. Additionally, there is a high risk that TL-4 or larger vehicles (higher centre of mass) could over-ride the barrier.

Given the expected speeds of 100km/h, we consider the impact loads (crash energy) to be similar, or more due to a higher impact angle, to the NCHRP-350 testing. Consequently, due to the AADT of 28,400 vehicles per day (including 852 heavy/commercial vehicles) and predicted impact loads, we expect there to be a significant risk of a TL-4 or larger vehicle over-riding the existing barrier, therefore we consider the existing barrier system to be deficient.

Furthermore, there is a high risk that an errant motorcyclist could overtop the median barrier due to the low height of the steel channel rail and absence of a top handrail. Given the drop of approximately 8m, a potential fall from this height would most likely lead to serious, if not fatal, injuries.

In order to meet current complinace standards, the existing barrier should be replaced with a TL-5 rigid (Texas HT-80) barrier at total rough order cost of approximately $1.0 - 1.5M. This retrofit cost is much more than new construction cost due to the deck strengthening required to withstand the impact loads from the TL-5 rigid barrier. However, should the Transport Agency consider that this option is not a cost-effective solution then a TL-4 Modified Thrie-beam system could be installed at a rough order cost of approximately $400,000 - $600,000.

7 Bowen Street Overpass - Northbound

7.1 Existing Road Safety Barrier System

The road safety barriers on the Bowen Street Overpass - Northbound (BSN 10728), constructed in 1972, are shown in Figures 7.1 to 7.5. The barriers are identical to those on the Bowen Street (Southbound) Overbridge, with a top handrail on the outer edge barrier but no handrail on the median barrier. The length of the barrier system on the bridge structure is approximately 100m on each side (200m total).

Figure 7.1: Bowen Street Overpass (Northbound) – Barrier System

Figure 7.2: Bowen Street Overpass (Northbound) – Top Handrail

The approach barrier systems immediately before the bridge, on both sides, are concrete (New Jersey Type) barriers. Given this is a desktop study, we are unable to confirm whether the concrete units are fixed to the pavement, therefore this concrete barrier might not actually be a rigid system. If the system was fixed to the pavement then it would be reasonable to expect mortar filled holes along the sloped base where dowels have been installed to fix the barrier to the pavement.

However, this detail can’t be seen from the photos. The transition from the steel channel bridge rail system on the bridge to the rigid barrier is shown Figures 7.3 - 7.4.

Figure 7.3: Bowen Street Overpass (Northbound) – Median Barrier Leading Approach

Figure 7.4: Bowen Street Overpass (Northbound) – Edge Barrier Leading Approach

The trailing end terminal of the edge barrier system is shown in Figure 7.5. The trailing approach system for the median barrier was shown previously in Figure 6.6.

Figure 7.5: Bowen Street Overpass (Northbound) – Barrier System Trailing Terminal

7.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 24,900 vpd (including 3% heavy). The posted speed limit over the bridge is 100km/h. The expected operating speeds are likely to be 100km/h.

Information from the Transport Agency CAS shows that no serious or fatal injury barrier incidents have occurred at this location during the 10 year period between 2005 and 2014. There was one reported non-injury loss of control crash in 2006 and 2013 respectively.

7.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the Bowen Street Overpass (Northbound) has the following factors for the consideration of a performance level 5 (TL-5) barrier system:

- AADT (2014)= 24,900 vpd (3% heavy) = 747 heavy/commercial vpd
- Speed = 100 km/h (posted)
- Drop of approx. 8 metres
- High risk land use underneath the structure (Bowen St, carpark)

Given the above (and generally identical to the discussion in Section 6.3), we consider a TL-5 barrier system is required as for the southbound structure.

7.4 Performance of Existing Barrier System

The expected performance and issues with the existing barrier system along the bridge is identical to the Bowen Street Overpass (Southbound) structure, as discussed in Section 6.4.

Unlike the northbound structure, the issue with vehicle pocketing is not a concern at the trailing transition, as the critical stiffness differential is in the opposite direction to traffic. However, this transition section (10m length) would still require replacement if the barrier system on the bridge structure is upgraded.

7.5 Condition Assessment of Existing Barrier System

Similar to Bowen Street Overpass (Southbound), there various stages of corrosion on several parts of the barrier system (posts, rail and bolts), as observed during bridge inspection (principal) in 2014. Refer Figure 7.6 and 7.7 for typical examples of corrosion on the barrier system.

Figure 7.6: Examples of Corrosion on Baseplate Hold-down Bolts and Rail

Figure 7.7: Corrosion on the Underside of the Top Handrail

The extensive corrosion on the underside of the top handrail is a major concern as this could present a possible hazard during a vehicle impact. Reason being, a corroded handrail section could detach and become a projectile, with the potential to penetrate the occupant compartment, especially given the handrail is at a similar height to the windows of a car.

Additionally, there are signs of a few sideswipe collisions, but given the barrier damage is only minor we don't expect the performance of the barrier system to have been dangerously compromised.

7.6 Retrofit Options and Indicative Costs

7.6.1 Do Nothing

This option is generally identical to the Bowen Street Overpass (Southbound) structure, as discussed in Section 6.6.1.

7.6.2 TL-5 Rigid Concrete Barrier

This option is generally identical to the Bowen Street Overpass (Southbound) structure, as discussed in Section 6.6.2.

Although less approach barrier requires replacement, the total rough order cost of this option would be approximately $1.0 – 1.5M.

7.6.3 TL-4 Modified Thrie-beam Barrier

This option is generally identical to the Bowen Street Overpass (Southbound) structure, as discussed in Section 6.6.3.

Although less approach barrier requires replacement, the total rough order cost of this option would be approximately $400,000 – 600,000.

7.7 Summary

Generally the same as Bowen Street Overpass (Southbound). Refer to Section 6.7.

In order to meet current complinace standards, the existing barrier should be replaced with a TL-5 rigid (Texas HT-80) barrier at total indicate cost approximately $1.0 – 1.5M. This retrofit cost is much more than new construction cost due to the deck strengthening required to withstand the impact loads from the TL-5 rigid barrier. However, should the Transport Agency consider that this option is not a cost-effective solution then a TL-4 Modified Thrie-beam system could be installed at a rough order cost of approximately $400,000 - $600,000.

8 Tinakori Road Off-Ramp

8.1 Existing Road Safety Barrier System

The road safety barriers on the Tinakori Road Off-Ramp (BSN 10728), constructed in 1972, are shown in Figures 8.1 - 8.4. As shown in Figure 8.1, the characteristics of the existing barrier systems are generally identical to those on the Bowen Street Overpass structures, as outlined in Section 6.1. The length of the barrier system on the bridge structure is approximately 100m on each side (200m total).

Figure 8.1: Tinakori Road Off-Ramp Bridge – Barrier Systems

The only difference is that the barrier on the motorway side has the top handrail along the entire length, but on the Tinakori Road side the handrail only extends along two-thirds of the off-ramp. The section without the top handrail is above Bowen Street, whereas the section with the handrail is above a carpark, as shown in Figure 8.2.

Figure 8.2: Tinakori Road Off-Ramp Bridge – Top Handrail Section

The leading approach barrier on the western side is a strong post (timber) with steel channel rail system, which originates approximately 80m before the bridge. Whereas the approach barrier on the motorway side is a TL-4 rigid concrete system. Refer to Figure 8.3.

Figure 8.3: Tinakori Road Off-Ramp Bridge – Leading Approach Barriers

The trailing approach barrier, on the western side, is the same steel channel rail system as on the bridge but without the top handrail. This approach barrier extends approximately 20m past the bridge and has no appropriate end terminal. On the motorway side there is no barrier system after the bridge, as shown in Figure 8.4.

Figure 8.4: Tinakori Road Off-Ramp Bridge – Trailing Approach Barriers and End Terminals

8.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 7000 vpd (including 3% heavy). The posted speed limit is 100km/h on the off-ramp, however operating speeds are expected to be marginally lower due to the narrowing road width compared to the motorway.

Information from the Transport Agency CAS shows that there were no fatal or serious injury barrier incidents along the bridge structure during the 10 year period between 2005 and 2014.

8.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the Tinakori Road Off-Ramp Bridge has the following factors for the consideration of a performance level 5 (TL-5) barrier:

- AADT (2014) = 7,000 vpd (3% heavy) = 210 heavy/commercial vpd
- Speed = 80-90 km/h (predicted)
- Drop of approx. 8 metres
- High risk land use underneath the structure (Bowen St, carpark)

As above, the approximate average daily volume of 210 heavy/commercial vehicles is significantly below the threshold of 2000 vpd (for roads with a posted speed limit of 60km/h or more) and the 2014 AADT of 7,000 vpd is below the 10,000 vpd/lane threshold. However, the height differential of around 8m is only slightly below the 10m threshold and there is high risk land use below the structure (Bowen Street and car parking area). Given the factors above meet (or almost meet) the conditions in the Bridge Manual, we consider a TL-5 barrier system is required as for the bridge structure.

8.4 Performance of Existing Barrier System

The expected performance and issues with the existing barrier system along the bridge are identical to the Bowen Street Overpass (Southbound) structure, as discussed in Section 6.4.

As mentioned above, we expect the operating speed of vehicles will be 80-90km/h, marginally lower than the 100km/h speed limit which is due to the narrowing road width after leaving the motorway. Additionally, the carriageway width is only 6m (kerb to kerb), which decreases the risk that vehicles would strike the barrier at a greater impact angle than the NCHRP-350 testing. Given these two factors, there is a high probability that impact loads (crash energy) will be similar to, if not below, NCHRP-350.

The height of the existing barrier is again a major concern as there is a high risk that a TL-4 vehicle (higher centre of mass) could over-ride the low steel channel rail. Furthermore, due to the omission of a top handrail along part of the bridge structure, there is a high risk that an errant motorcyclist could overtop the barrier. Given the drop of approximately 8m, a potential fall from this height would most likely lead to serious, if not fatal, injuries.

The leading approach barrier system consisting of steel channel rail on timber posts is also a non-compliant system. The performance of this barrier system is expected to be similar to the barrier system along the bridge structure due to the identical steel channel rail. Given this continuous rail, the stiffness of the two systems is predicted to be similar and therefore vehicle pocketing is not expected to be a concern.

However, this leading and trailing approach barrier systems (approximately 100m long) would still require replacement if the barrier system on the bridge structure is upgraded.

8.5 Condition Assessment of Existing Barrier System

As with Bowen Street Overbridge, there are early signs of corrosion on various parts of the barrier system (posts, rail and bolts), as observed during the bridge inspection (general) in 2014. Refer to Figure 8.5. The issues with this corrosion and the maintenance of the barrier hardware was discussed in Section 6.5.

Figure 8.5: Corrosion of Baseplate Hold-down Bolts

Additionally, there are signs of a few sideswipe (minor) collisions, but given the barrier damage is minor we don't expect the performance of the barrier system to have been dangerously compromised.

8.6 Retrofit Options and Indicative Costs

8.6.1 Do Nothing

If the existing barrier system is retained, the Transport Agency will need to accept the risk of the deficient barrier system. Additionally, ongoing difficulties (and high costs) of maintaining the non-standard barrier system will continue, especially the replacement of damaged sections after a vehicle impact.

8.6.2 TL-5 Rigid Concrete Barrier

According to current compliance standards, provision of a Performance Level 5 (TL-5) barrier is required. The Texas HT-80 system is the preferred TL-5 barrier by the Transport Agency.

Strengthening of the bridge deck will be required to withstand the impact loads transferred from the TL-5 rigid barrier. This will incur significant additional costs and required a substantially longer construction period. Including the deck strengthening, the total rough order cost of replacing the existing barrier systrem with a TL-5 rigid (Texas HT-80) barrier is around $1.2 - 1.8M. Note that this cost includes preliminary and general, temporary traffic management and temporary works/access; however any potential relocation of services (eg drainage, telecomunications, etc) is excluded. Also included in this indicative cost is the replacement of the non-complaint approach barrier systems (total of 100m) with TL-4 Thrie-beam barrier. Given the total approximate barrier length of 300m (200m for the TL-5 system and 100m for the TL-4 system), the indicative cost for this option is approximately $5,000-7,000/m for the TL-5 system and $1,500 – 2,300/m for the TL-4 system.

Note, this cost assumes the off-ramp can be closed during nights for around 8 - 12 weeks (with 6-7 hour shifts). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

8.6.3 TL-4 Modified Thrie-beam Barrier

Should the Transport Agency determine a TL-5 barrier is not a cost-effective solution due to the costs associated with the deck strengthening, then a TL-4 Modified Thrie-beam system could be installed, similar to the Thrie-beam system installed on TOB. For comparision purposes, the total rough order cost of installing a TL-4 Modified Thrie-beam system would be around $500,000 - $750,000, at approximately $1,700-2,500/m.

Note, this cost assumes that the off-ramp can be closed during nights for around 4 - 6 weeks (with working hours of 8 hours each night). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

8.7 Summary

Similar to the Bowen Street Overpass (Southbound), as there is no crash testing data available it is difficult to determine the actual performance of this barrier system. The expected performance of this barrier (as discussed in Section 8.4) is only based on readily available literature about modern and historic road safety barrier systems, and can be subjective.

Primarily based on the rail height, the existing barrier system would be considered as non-compliant to TL-3 NCHRP-350 criteria. While the barrier system might be able to resist the impact forces from a NCHRP-350 TL-3 (or TL-4) vehicle, there is a concern that the vehicle will not be redirected in a smooth/controlled manner due to the low height and stiffness of the barrier system. Additionally, there is a high risk that TL-4 or larger vehicles (higher centre of mass) could over-ride the barrier.

Furthermore, there is a high risk that an errant motorcyclist could overtop the median barrier due to the low height of the steel channel rail and absence of a top handrail. Given the drop of approximately 8m, a potential fall from this height would most likely lead to serious, if not fatal, injuries.

In order to meet current complinace standards, the existing barrier should be replaced with a TL-5 rigid (Texas HT-80) barrier at total indicative cost of approximately $1.2 - 1.8M. This retrofit cost is much more than new construction costs due to the strengthening of the bridge deck to withstand the impact loads from the TL-5 rigid barrier. However, should the Transport Agency consider that this option is not a cost-effective solution then a TL-4 Modified Thrie-beam system could be installed at a rough order cost of approximately $500,000 - $750,000.

9 Shell Gully Overbridge – Northbound & Southbound

9.1 Existing Road Safety Barrier System

The road safety barriers on the Shell Gully Overbridge - Northbound (BSN 10731) and Southbound (BSN 10732), constructed in 1980, are shown in Figures 9.1 - 9.6. The length of the barrier system on the bridge structure is approximately 370m on each side and 370 along the median (1,100m total).

Figure 9.1: Shell Gully Overbridge – Edge Barrier and Median Barrier

The outer edge barriers, along both structures, are essentially identical to the edge barrier (with the top handrail) on Bowen Street Overpass (Southbound) structure. The key characteristics of this system include:

- 10″×3″ 19lb (8.1mm thick) steel channel section rail.
- Rail sections of 30’-0” (9.1m) long and mounted to the blockout using two 3/4″ (19mm) bolts.
- The centre of the rail was 1’-8” (508mm) above the surfacing when constructed and the top handrail was 3′-3″ (991mm) from the road surfacing.
- The steel post was comprised of two sections. The bottom half was a 4″×4″×0.25″ RHS which was shop butt welded to a 4″×3″×0.192″ RHS above.
- Steel blockout was a 4″×3″×0.192″ RHS and there was a 7″×3″×12″ treated pine block between the rail and steel plate on the blockout.
- Post spacing of 7′- 6″ (2.3m).
- Posts were welded onto a 1’-1″×10″×3/4″ steel baseplate which was fixed into the bridge deck using four cast-in sockets with 3/4″ bolts.
- The posts were mounted on the bridge deck which was level with the surfacing, with the front face of the rail approximately (800mm) from the deck edge.
- All steel was mild steel according to BS15 and welds were 3/16” fillet welds (all around).

However, one key difference was the anchoring of the rail to the bridge deck, as shown in Figure 9.2 and 9.3. The rail was anchored at spacings of no more than 200'-0" (61m).

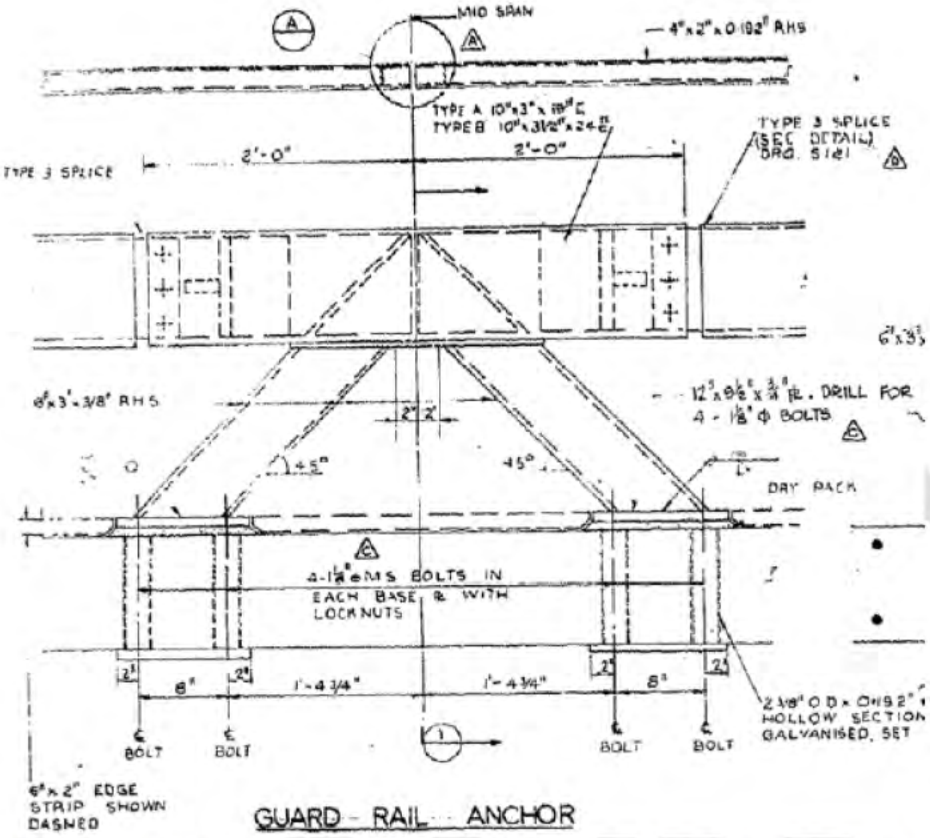
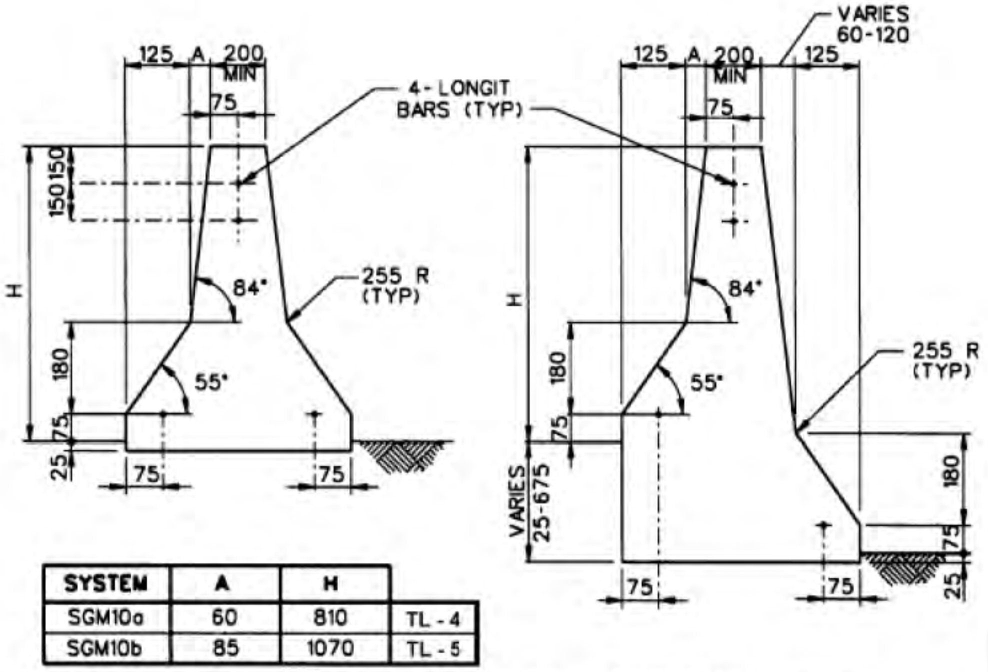


Figure 9.2: Shell Gully Overbridge - Anchorage Detail from Construction Drawings (Designed in 1974)

Figure 9.3: Shell Gully Overbridge – Rail Anchorage to Bridge Deck

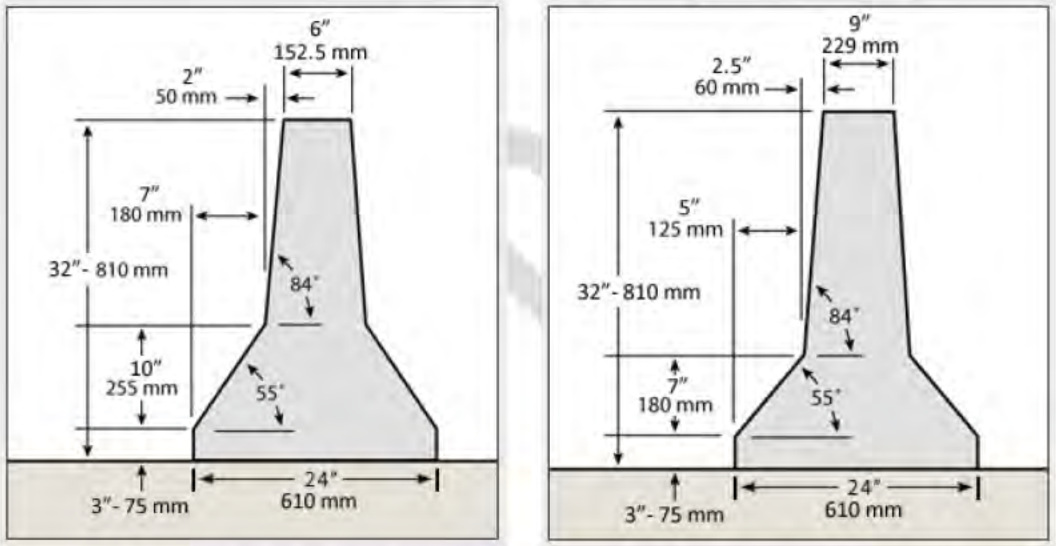
The median barrier along the entire length of the bridge is a concrete (New Jersey Type) barrier, consisting of 6m long segmental units. The height of the concrete barrier seems to be approximately 800mm, which according to the Transport Agency Specification M23 (Specification for Road Safety Barrier Systems), corresponds to a TL-4 level of protection. Figure 9.4 is the F-Shape concrete barrier detail from Section 1.2 in Appendix A of NZTA M23. The F-Shape barrier is the preferred system by the Transport Agency for a TL-4 concrete (rigid) barrier.



SYSTEM	A	H	
SGM10a	60	810	TL - 4
SGM10b	85	1070	TL - 5

Figure 9.4: F-Shape Concrete Barrier Detail from NZTA M23A

The New Jersey shape median barrier is similar to the F-Shape (specified in NZTA M23) but the breakpoint, distance from the ground level to the slope deviation point, is 3″ or 75mm higher. This profile difference is illustrated in Figure 9.5.



New Jersey Barrier Profile Dimensions

F Shape Barrier Profile Dimensions

Figure 9.5: New Jersey Type Concrete Barrier v F-Shape Concrete Barrier

The F-Shape profile is considered to be superior to the New Jersey shape following a research study by the US Federal Highway Administration in the 1970s which analysed the performance of various concrete (rigid) barrier profiles. In the study, barrier configurations were labelled A through F, and F was considered to be the best performing (safer) design. Full-scale crash tests confirmed that the lower sloped face of the F-Shape profile reduces vehicle lift which reduces the potential for small vehicles to rollover upon impact. The F-Shape therefore promoted better vehicle stability and redirection. Additionally, this shape minimises damage when redirecting vehicles under low-impact conditions.

On either approach to the bridge, at the outer edge, there is this same 'New Jersey' concrete barrier which then connects into the steel channel rail barrier on the bridge structure (refer Figure 9.6).

Figure 9.6: Shell Gully Overbridge (Northbound) – Leading Approach Barriers

As the bridge meets the Clifton Terrace On-ramp structure, there is a concrete end terminal. Refer to Figure 9.7.

Figure 9.7: Shell Gully Overbridge (Northbound) – Edge Barrier Trailing End Terminal

9.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 24,400 vpd (including 3% heavy) northbound and 20300 vpd (including 3% heavy) southbound. The posted speed limit is 100km/h and the operating speeds are expected to be similar, except along the southbound structure which speeds can be considerably less due to congestion caused by vehicles merging from three lanes to one prior to the bridge.

Information from the Transport Agency CAS shows there was one serious injury barrier incident along the bridge structure during the 10 year period between 2005 and 2014. This serious injury crash (reported in 2011) involved a motorcyclist losing control while avoiding another vehicle near the exiting from the Clifton Terrace On-Ramp, in slippery conditions, and impacting the barrier. Also, there was one non-injury loss of control crash reported in 2006 and 2014 respectively.

9.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the Shell Gully Overbridge has the following factors for the consideration of a performance level 5 (TL-5) barrier system:

- Northbound AADT (2014) = 24,400 vpd (3% heavy) = 732 heavy/commercial vpd
- Southbound AADT (2014) = 20,300 vpd (3% heavy) = 609 heavy/commercial vpd
- Speed = 100 km/h (posted)
- Drop of approx. 12-15m (southbound) and 5-10m (northbound).
- High risk land use underneath the structure (car parking area)

As above, the approximate average daily volume of 732 heavy/commercial vehicles is below the threshold of 2000 vpd (for roads with a posted speed limit of 60km/h or more) and the 2014 AADT of 24,400 vehicles per day (8,100 vpd/lane) is only slightly below the 10,000 vpd/lane threshold. The height differential of around 12-15m (southbound) and 5-10m (northbound) is above or around the 10m threshold. Furthermore, there is high risk land use below the structure (car parking area) as well as the WUM being one of the most important roads into Wellington City. Given the factors above meet (or almost meet) the conditions in the Bridge Manual, we consider a TL-5 barrier system is required as for the bridge structure.

9.4 Performance of Existing Barrier System

The expected performance and issues with the existing outer barrier system along the bridge is identical to the Bowen Street Overpass (Southbound) structure, as discussed in Section 6.4. However, the rail anchorage is expected to provide some additional capacity to the barrier, especially near the anchorage locations. The anchorages are predicted to improve the continuity/stiffness of the rail and therefore further reduce the deflection of the system.

Furthermore, the carriageway width is 9m (kerb to kerb), with two lanes, so there is a high risk that vehicles could potentially strike the outer barrier at an impact angle of greater than 25 degrees (maximum angle in NCHRP-350 testing).

Following discussions with Engineers from the former Ministry of Works who were involved with the installation of the 'New Jersey' concrete (rigid) median barrier, the 6m long concrete units were not pinned together, which nowadays is current practice for permanent rigid barriers. Although, the concrete units are to some extent held together with steel plate clamp, as shown in Figure 8.7.

Figure 8.7: Shell Gully Overbridge (Northbound) – Median Concrete Barrier

Additionally, the concrete units are not fixed to the pavement or bridge deck, therefore the barrier does not meet the criteria for a NCHRP-350 TL-4 system. Given the absence of a fixing detail to the bridge deck, the concrete median barrier can be displaced up to 1.5m during a vehicle impact. The only resistance provided against the impact loadings is the self-weight of the 6m long concrete units. This deflection of the concrete barrier is a major concern as concrete units could be displaced into the path of an oncoming vehicle travelling at 100km/h.

9.5 Condition Assessment of Existing Barrier System

Similar to the bridge structures mentioned earlier, there are various stages of corrosion on several parts of the barrier system (posts, rail and bolts), as observed during principal bridge inspection in 2014. Figure 8.5 shows some typical corrosion around the hold-down bolts in the baseplate.

Figure 8.5: Corrosion of Baseplate Hold-down Bolts

The issues with this corrosion and the maintenance of the barrier hardware was discussed previously in Section 6.5.

Additionally, there are signs of a few sideswipe (minor) collisions, but given the barrier damage is minor we don't expect the performance of the barrier system to have been dangerously impaired.

9.6 Retrofit Options and Indicative Costs

9.6.1 Do Nothing

If the existing barrier system is retained, the Transport Agency will need to accept the risk of the deficient barrier system. Additionally, ongoing difficulties (and high costs) of maintaining the non-standard barrier system will continue, especially the replacement of damaged sections after a vehicle impact.

9.6.2 TL-5 Rigid Concrete Barrier

According to current compliance standards, provision of a Performance Level 5 (TL-5) barrier is required. The Texas HT-80 system is the preferred TL-5 barrier by the Transport Agency.

Strengthening of the bridge deck will be required to withstand the impact loads transferred from the TL-5 rigid barrier. This will incur significant additional costs and required a substantially longer construction period. Including the deck strengthening, the total rough order cost of replacing the existing barrier systrem with a TL-5 rigid (Texas HT-80) barrier is around $5.5 – 8.0M. Note that this cost includes preliminary and general, temporary traffic management and temporary works/access; however any potential relocation of services (eg drainage, telecomunications, etc) is excluded. Given the approximate barrier length of 1100m, the cost of this option would be approximately $5,000 - 7,000/m.

Note, this cost assumes for the outer barriers that there is a shoulder closure on the southbound structure for around 10 - 15 weeks (8 hour shifts) and a lane closure on the northbound structure for 10 - 15 weeks (8 hour shifts). Additionally for the replacement of the median barrier, the carriageway width will be reprioritised in a similar manner to the Ngauranga to Aotea project, with concrete barriers eitehr side of the work area. Replacement of the median barrier is expected to take a further 6 - 9 weeks (8 hour shifts). Should the Transport Agency not allow these temporary closures then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

9.6.3 TL-4 Modified Thrie-beam Barrier

Should the Transport Agency determine a TL-5 barrier is not a cost-effective solution due to the costs associated with the deck strengthening, then a TL-4 Modified Thrie-beam system could be installed along the outer edge, similar to the Thrie-beam system installed on TOB.

Additionally, the concrete median barrier could be replaced with either a TL-4 wire rope safety barrier or a TL-4 rigid barrier, depending on the allowable deflection accepted by the Transport Agnecy. The wire rope safety barrier is significantly cheaper so has been used in the indicative costing below. For comparision purposes, the total rough order cost of this option would be around $1.5 – 2.3M, at approximately $1,500 – 2,500/m for the TL-4 Thrie-beam system (740m) and approximately $1,000 – 1,500/m for the TL-4 wire rope safety barrier system (370m).

Note, this cost assumes for the outer barriers that there is a shoulder closure on the southbound structure for around 6 - 9 weeks (8 hour shifts) and a lane closure on the northbound structure for 6 - 9 weeks (8 hour shifts). Additionally, for the replacement of the median barrier the carriageway width will be reprioritised in a similar manner to the Ngauranga to Aotea project, with concrete barriers either side of the work area. Replacement of the median barrier is expected to take a further 3 - 5 weeks (8 hour shifts). Should the Transport Agency not allow these temporary closures then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

9.7 Summary

Similar to the Bowen Street Overpass (Southbound) structure, as there is no crash testing data available it is difficult to determine the actual performance of this barrier system. The expected performance of this barrier (as discussed in Section 9.4) is only based on readily available literature about modern and historical road safety barrier systems, and can be subjective.

Primarily based on the rail height, the existing barrier system would be considered as non-compliant to NCHRP-350 TL-3 criteria. While the barrier system might be able to resist the impact forces from a NCHRP-350 TL-3 (or TL-4) vehicle, there is a concern that the vehicle will not be redirected in a smooth/controlled manner due to the low height and stiffness of the barrier system. Additionally, there is a high risk that TL-4 or larger vehicles (higher centre of mass) could over-ride the barrier.

Given the expected speeds of 100km/h, we consider the impact loads (crash energy) to be similar, if not more due to a higher impact angle, to the NCHRP-350 testing. Consequently, due to the AADT of 24400 vpd (including 732 heavy/commercial vehicles) and predicted impact loads, we expect there to be a significant risk of a TL-4 or larger vehicle over-riding the existing barrier, therefore we consider the existing barrier system to be deficient.

In order to meet current compliance standards, the existing barrier should be replaced with a TL-5 rigid (Texas HT-80) barrier at total indicative cost of approximately $5.5 – 8.0M. This retrofit cost is much more than new construction costs due to the strengthening of the bridge deck to withstand the impact loads from the TL-5 rigid barrier. However, should the Transport Agency consider that this option is not a cost-effective solution then a TL-4 Modified Thrie-beam system could be installed along the oute edge and a TL-4 wire rope safety barrier along the median, at a rough order cost of approximately $1.5 – 2.3M.

10 Terrace Off-Ramp Bridge

10.1 Existing Road Safety Barrier System

The road safety barriers on the Terrace Off-Ramp Bridge (BSN 10733), constructed in 1980, are shown in Figures 10.1 - 10.3. The barrier system is generally identical to the outer edge barrier on Shell Gully Overbridge, as discussed in Section 9.1. The length of the barrier is approximately 260m on each side (520m total).

Figure 10.1: Terrace Off-Ramp Bridge – Barrier Post and Rail

Figure 10.2: Terrace Off-Ramp Bridge – Barrier System

Figure 10.1 and 10.2 show the trailing terminals at the end of the bridge near the Terrace.

Figure 10.3: Terrace Off-Ramp Bridge – Trailing End Barrier Terminals

10.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 8,100 vpd (note that this is an interpolated estimate as no traffic monitoring devices are located on this structure). The posted speed limit is 100km/h but reducing to 50km/h around half way along the off-ramp. Therefore, the expected operating speeds are likely to be around 70-80km/h.

Information from the Transport Agency CAS shows that no fatal or serious injury barrier incidents have occurred at this location during the 10 year period between 2005 and 2014. There was one reported non-injury loss of control crash in 2010.

10.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the Terrace Off-Ramp Bridge has the following factors for the consideration of a performance level 5 (TL-5) barrier system:

- AADT (2014) = Approx. 8,100 vpd (interpolated estimate) with 3% heavy
- Speed = 80 - 90 km/h (predicted)
- Drop of approx. 8 - 10 metres
- High risk land use underneath the structure (carpark areas, buildings)

As above, the estimated average daily volume of approximately 243 heavy/commercial vehicles is below the threshold of 2000 vpd (for roads with a posted speed limit of 60km/h or more) and the 2014 AADT of 8,100 vehicles per day (4,050 vpd/lane) is only below the 10,000 vpd/lane threshold. The height differential of around 8-10m around the 10m threshold and there is high risk land use below the structure (car parking area). Given the factors above meet (or almost meet) the conditions in the Bridge Manual, we consider a TL-5 barrier system is required as for the bridge structure.

10.4 Performance of Existing Barrier System

The expected performance and issues with the existing barrier system along the bridge are the same as the Shell Gully Overbridge structure, as discussed in Section 9.4.

As with Tinakori Road Off-Ramp Bridge, we anticipate that vehicle would be travelling at typically 80 - 90km/h along this structure, as vehicles are expected to be slowing down after leaving the motorway. Although the steel channel rail barrier is identical to the Shell Gully Overbridge structure, the risk of a TL-4 vehicle penetrating (or over-riding) the barrier is significantly less due to the lower speed and the consequently lower crash energy than in NCHRP-350.

The carriageway width is 7.5m (kerb to kerb), with two lanes, so there is a risk that that vehicles could potentially strike the barrier at an impact angle of greater than 25 degrees (maximum angle in NCHRP-350 testing). However, this risk is considered to be low (given the lower speeds) and therefore acceptable.

10.5 Condition Assessment of Existing Barrier System

Similar to the bridge structures mentioned earlier, there are various stages of corrosion on several parts of the barrier system (posts, rail and bolts), as observed during general bridge inspection in 2014. Refer to Figure 10.4 showing corroded hold-down bolts, which are able to be pulled out by hand. This is a major concern as if this issue is widespread then the performance of the barrier system could be compromised. The issues with this corrosion and the maintenance of the barrier hardware was discussed previously in Section 6.5.

Figure 10.4: Corroded Hold-down Bolts

Additionally, there are signs of a few sideswipe (minor) collisions, but given the barrier damage is minor we don't expect the performance of the barrier system to have been dangerously impaired. Refer to Figure 10.5 showing some barrier damage from a vehicle impact.

Figure 10.5: Misaligned Rail due to a Vehicle Impact

10.6 Retrofit Options and Indicative Costs

10.6.1 Do Nothing

If the existing barrier system is retained, the Transport Agency will need to accept the risk of the deficient barrier system. Additionally, ongoing difficulties (and high costs) of maintaining the non-standard barrier system will continue, especially the replacement of damaged sections after a vehicle impact.

10.6.2 TL-5 Rigid Concrete Barrier

According to current compliance standards, provision of a Performance Level 5 (TL-5) barrier is required. The Texas HT-80 system is the preferred TL-5 barrier by the Transport Agency.

Strengthening of the bridge deck will be required to withstand the impact loads transferred from the TL-5 rigid barrier. This will incur significant additional costs and required a substantially longer construction period. Including the deck strengthening, the rough order cost of replacing the existing barrier systrem with a TL-5 rigid (Texas HT-80) barrier is around $2.5 - 3.5M. Note that this cost includes preliminary and general, temporary traffic management and temporary works/access; however any potential relocation of services (eg drainage, telecomunications, etc) is excluded. Given the approximate barrier length of 520m, the cost of this option would be approximately $5000 – 7000/m.

Note, this cost assumes a lane closure for around 15 - 20 weeks (8 hour shifts). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

10.6.3 TL-4 Modified Thrie-beam Barrier

Should the Transport Agency determine a TL-5 barrier is not a cost-effective solution due to the costs associated with the deck strengthening, then a TL-4 Modified Thrie-beam system could be installed, similar to the Thrie-beam system installed on TOB. For comparision purposes, the total rough order cost of installing a TL-4 Modified Thrie-beam system would be around $0.8 – 1.2M, at approximately $1,500-2,300/m.

Note, this cost assumes that the southbound structure can be closed every night for around 8 - 12 weeks (6-7 hours each night). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

10.7 Summary

Similar to Shell Gully Overbridge, as there is no crash testing data available it is difficult to determine the actual field performance of this barrier system. The expected performance of this barrier (as discussed in Section 10.4) is only based on readily available literature about modern and historic road safety barrier systems, and can be subjective.

Primarily based on the rail height, the existing barrier system would be considered as non-compliant to TL-3 NCHRP-350 criteria. While the barrier system might be able to resist the impact forces from a TL-3 NCHRP-350 (or TL-4) vehicle, there is a concern that the vehicle will not be redirected in a smooth/controlled manner due to the low height and stiffness of the barrier system. Additionally, there is a high risk that TL-4 or larger vehicles (higher centre of mass) could over-ride the barrier. Therefore, we consider the existing barrier system to be deficient.

In order to meet current compliance standards, the existing barrier should be replaced with a TL-5 rigid (Texas HT-80) barrier at total indicative cost of approximately $2.5 – 3.5M. This retrofit cost is much more than new construction costs due to the strengthening of the bridge deck to withstand the impact loads from the TL-5 rigid barrier. However, should the Transport Agency consider that this option is not a cost-effective solution then a TL-4 Modified Thrie-beam system could be installed at a rough order cost of approximately $0.8 – 1.2M.

11 Clifton Terrace On-Ramp

11.1 Existing Road Safety Barrier System

The road safety barriers on the Clifton Terrace On-Ramp (BSN 10734), constructed in 1980, are shown in Figures 11.1 - 11.3. The barrier system along the bridge structure is generally identical to the outer edge barrier system on the Shell Gully Overbridge, as discussed in Section 9.1. The length of the barrier is approximately 140m on each side (280m total).

The leading approach barriers, on either side, are pedestrian barriers due to the 50km/hr speed environment before the on-ramp. Refer to Figure 11.1.

Figure 11.1: Clifton Terrace On-Ramp Bridge – Leading Approach Barriers

The barrier along the on-ramp is identical to the steel channel rail system on Shell Gully Overbridge, as shown in Figure 11.2.

Figure 11.2: Clifton Terrace On-Ramp Bridge – Steel Channel Rail Barrier System

At the bottom of the on-ramp, at the outer edge, the steel channel rail system connects to a TL-4 rigid concrete barrier (see Figure 11.3). Additionally, there is a non-compliant concrete end terminal where the on-ramp merges with the motorway, as shown previously in Figure 9.7.

Figure 11.3: Clifton Terrace On-Ramp Bridge – Edge Barrier Trailing Approach

11.2 Traffic Volumes and Crash Data

At this location the 2014 AADT was approximately 5,900 vpd (including 3% heavy). The posted speed limit is 100km/hr, with a sign located approximately 20m along the on-ramp. However, we anticipate operating speeds to be approximately 70-80km/h along the majority of bridge structure as vehicles approach the on-ramp from a 50km/h speed environment.

Information from the Transport Agency CAS shows that no fatal or serioud injury barrier incidents have occurred at this location during the 10 year period between 2005 and 2014.

11.3 Level of Containment Required

Following the barrier selection method in the Bridge Manual, the Clifton Terrace On-Ramp has the following factors for the consideration of a performance level 5 (TL-5) barrier system:

- AADT (2014) = Approx. 5,900 vpd (with 3% heavy) = 177 heavy/commercial vpd
- Speed = 70 - 80 km/h (predicted)
- Drop of approx. 5 - 8 metres
- High risk land use underneath the structure (carpark, WUM, residential buildings)

As above, the approximate average daily volume of 177 heavy/commercial vehicles is significantly below the threshold of 2000 vpd (for roads with a posted speed limit of 60km/h or more), Additionally, the 2014 AADT of 5,900 vpd is significantly lower than the threshold of 40,000 vpd (or 10,000 vpd per lane) to justify a TL-5 barrier. While there is a drop of approximately 5-8m and the presence of high risk land beneath the bridge structure (WUM), the risk of a vehicle penetrating (or over-riding) the barrier is reduced by the lower predicted speeds. Therefore, we consider a TL-4 barrier system is required as for the bridge structure.

11.4 Performance of Existing Barrier System

The expected performance and issues with the existing barrier system along the bridge are the same as the Shell Gully Overbridge structure, as discussed in Section 9.4.

As with the May Street On-Ramp, we anticipate that operating speeds along the structure will be 70-80km/h as vehicles are expected to be transitioning from a 50km/h speed environment to

100km/h on the motorway. Although the steel channel rail barrier is identical to the Shell Gully Overbridge structure, the risk of a TL-4 vehicle penetrating (or over-riding) the barrier is significantly less due to the operating speeds (and therefore lower crash energy) being less than NCHRP-350 TL-3.

The carriageway width is 7.5m (kerb to kerb), with one lane, so there is a minor risk that that vehicles could potentially strike the barrier at an impact angle of greater than 25 degrees (maximum angle in NCHRP-350 testing). However, this risk is considered to be low (given the lower speeds) and therefore acceptable.

11.5 Condition Assessment of Existing Barrier System

Similar to the bridge structures mentioned earlier, there are various stages of corrosion on several parts of the barrier system (posts, rail and bolts), as observed during general bridge inspection in 2014. The issues with this corrosion and the maintenance of the barrier hardware was discussed previously in Section 6.5.

Additionally, there are signs of a few sideswipe (minor) collisions, but given the barrier damage is minor we don't expect the performance of the barrier system to have been dangerously impaired.

11.6 Retrofit Options and Indicative Costs

11.6.1 Do Nothing

If the existing barrier system is retained, the Transport Agency will need to accept the risk of the deficient barrier system. Additionally, ongoing difficulties (and high costs) of maintaining the non-standard barrier system will continue, especially the replacement of damaged sections after a vehicle impact.

11.6.2 TL-4 Modified Thrie-beam Barrier

According to current compliance standards, provision of a Performance Level 4 (TL-4) barrier is required. The total rough order cost of replacing the existing barrier systrem with a TL-4 Modifed Thrie-beam barrier is around $450,000 – $700,000. Note that this cost includes preliminary and general, temporary traffic management and temporary works/access; however relocation of services is excluded. Given the approximate barrier length of 280m, the cost of this option would be approximately $1,600 - 2,500/m.

Note, this cost assumes the on-ramp structure can be closed every night for around 5-8 weeks (with working hours of 6-7 hours each night). Should the Transport Agency not allow this temporary closure then costs could be significantly greater due to programme ineffeciency as well as increased temporary works or the provision of scaffolding.

11.7 Summary

Similar to Shell Gully Overbridge, as there is no crash testing data available it is difficult to determine the actual field performance of this barrier system. The expected performance of this barrier (as discussed in Section 11.4) is only based on readily available literature about modern and historic road safety barrier systems, and can be subjective.

Primarily based on the rail height, the existing barrier system would be considered as non-compliant to TL-3 NCHRP-350 criteria. While the barrier system might be able to resist the impact forces from a NCHRP-350 TL-3 (or TL-4) vehicle, there is a concern that the vehicle will not be redirected in a smooth/controlled manner due to the low height and stiffness of the barrier system. Additionally, there is a high risk that TL-4 or larger vehicles (higher centre of mass) could over-ride the barrier.

According to current compliance standards, provision of a Performance Level 4 (TL-4) barrier is required. However given the lower speed environment, we expect the impact loads (crash energy) from a TL-4 vehicle to be much lower than the NCHRP-350 testing. As such, we expect the existing barrier to be able to withstand the impact loads from a TL-4 vehicle (given the lower speed) due to the predicted continuity and ribbon strength of the stiffer steel channel rail.

Although it is probable that a TL-4 or larger (higher centre of mass) vehicle could over-ride the barrier due to the low height, given the AADT of 5,900 vehicles per day (including 177 heavy/commercial vehicles) and expected low speeds of 70-80km/h, we consider the overall risk of TL-4 (or larger) vehicles over-riding the barrier to be low and therefore acceptable. Therefore, while the existing barrier is a noncompliant system according to current standards, we predict the existing barrier (in this location) is likely to withstand the impact loads from a TL-4 vehicle due to the expected lower speeds, and is fit for purpose given it is maintained in a satisfactory condition.

However, if the Transport Agency desired a compliant barrier system by current standards then a TL-4 Modified Thrie-beam system should be installed at a rough order cost of approximately $450,000 - $700,000.

12 Conclusion

This barrier assessment desktop study concludes that the existing road safety barriers along the majority of the bridge structures along the WUM are below current compliance standards. The costs for upgrading the existing barrier systems to either a TL-5 Texas HT-80 rigid concrete barrier or TL-4 Modified Thrie-beam barrier could vary significantly due to the deck strengthening required for a TL-5 system as well as the provision for temporary traffic management and temporary works/access. Table 12.1 below provides a summary of the conclusions from this study.

Table 12.1: Summary of Existing Barrier Systems and Retrofit Options

Structure	Predicted Test Level	Compliant Test Level	Barrier Length	ROC for TL-4 Replacement	ROC for TL-5 Replacement
Murphy Street Off-Ramp	TL-3	TL-3	-	-	-
May Street On-Ramp	TL-3*	TL-4	240m	$350 - 550k	-
Bowen Street Overpass (SB)	TL-3*	TL- 5 (Texas HT)	260m	$400 - 600k	$1.0- 1.5M
Bowen Street Overpass (NB)	TL-3*	TL- 5 (Texas HT)	210m	$400 - 600k	$1.0- 1.5M
Tinakori Road Off-Ramp Bridge	TL-3*	TL- 5 (Texas HT)	300m	$500 – 750k	$1.2- 1.8M
Shell Gully Overbridge	TL-3*	TL- 5 (Texas HT)	1100m	$1.5 – 2.3M	$5.5 – 8.0M
Terrace Off-Ramp Bridge	TL-3*	TL- 5 (Texas HT)	520m	$0.8 – 1.2M	$2.5 - 3.5M
Clifton Terrace On-Ramp Bridge	TL-3*	TL-4	280m	$450 - 700k	-

*NCHRP-350 TL-3 has been assumed however no crash testing data is available to confirm this.

Appendix A

Thorndon Overbridge Barrier Replacement Feasibility Study

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