20.2 Option H

Option H combines Basin Reserve Option A (bridge near the Basin Reserve) with a tunnel under Memorial Park ending before Taranaki Street as schematically shown in *Figure 20.3* below. *Figure 20.4* shows this option in more detail.

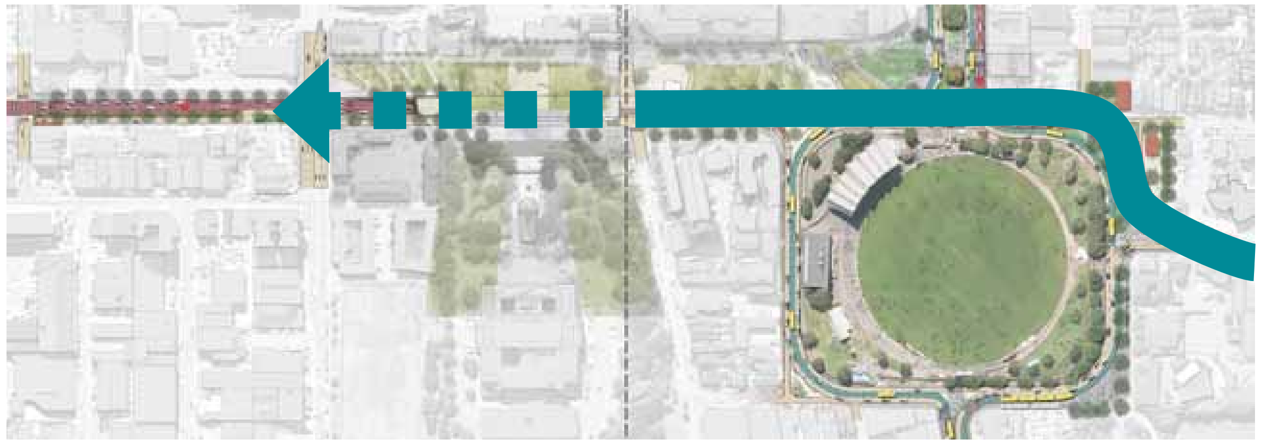


Figure 20.3: Option H Schematic

The key features of Option H are:

- Crèche must be shifted. There is the opportunity to shift it to the corner of Buckle Street and Tory Street to give it a better street frontage and be incorporated into a museums precinct proposed for Buckle Street.
- Affects the buildings on the corner of Kent Terrace and Ellice Street.
- Pedestrian and cyclist path incorporated into the bridge structure.
- Provides improved access to the Basin Reserve with a pedestrian promenade.
- Minimises traffic volumes on Buckle Street therefore improving amenity for Memorial Park users.
- Reduces noise levels within Memorial Park, enabling some park users to use the park for solitary reflection: an activity consistent with the park's purpose.
- Improves the connection between the War Memorial and Memorial Park.
- The trench near Taranaki Street consumes some land that could have been part of the park, reducing the size of the park at this location.
- The pedestrian link between the War Memorial and the City must make a slight deviation to avoid the trench.
- Improved journey times for local and SH1 traffic at Taranaki Street resulting from improvements to the intersection's efficiency.
- Provides improved bus journey times through the intersection of Taranaki Street and Buckle Street as a result of the intersection being more efficient. This supports Wellington City Council's plans to implement bus lanes on Taranaki Street.
- Land between Tory Street and Kent Terrace is intact creating the potential for either park or buildings in this space. If a park is constructed between Tory Street and Kent Terrace, this will improve the connection between the Basin Reserve and Memorial Park.
- Elevated structure may impact on views to / from Kent and Cambridge Terrace and Mount Victoria.
- Constructing a grade separated westbound link in the future requires extending the tunnel past Taranaki Street which will be challenging once Memorial Park is constructed.

Figure 20.4: Option H


Joins SK2 OPTION

20.3 Option I

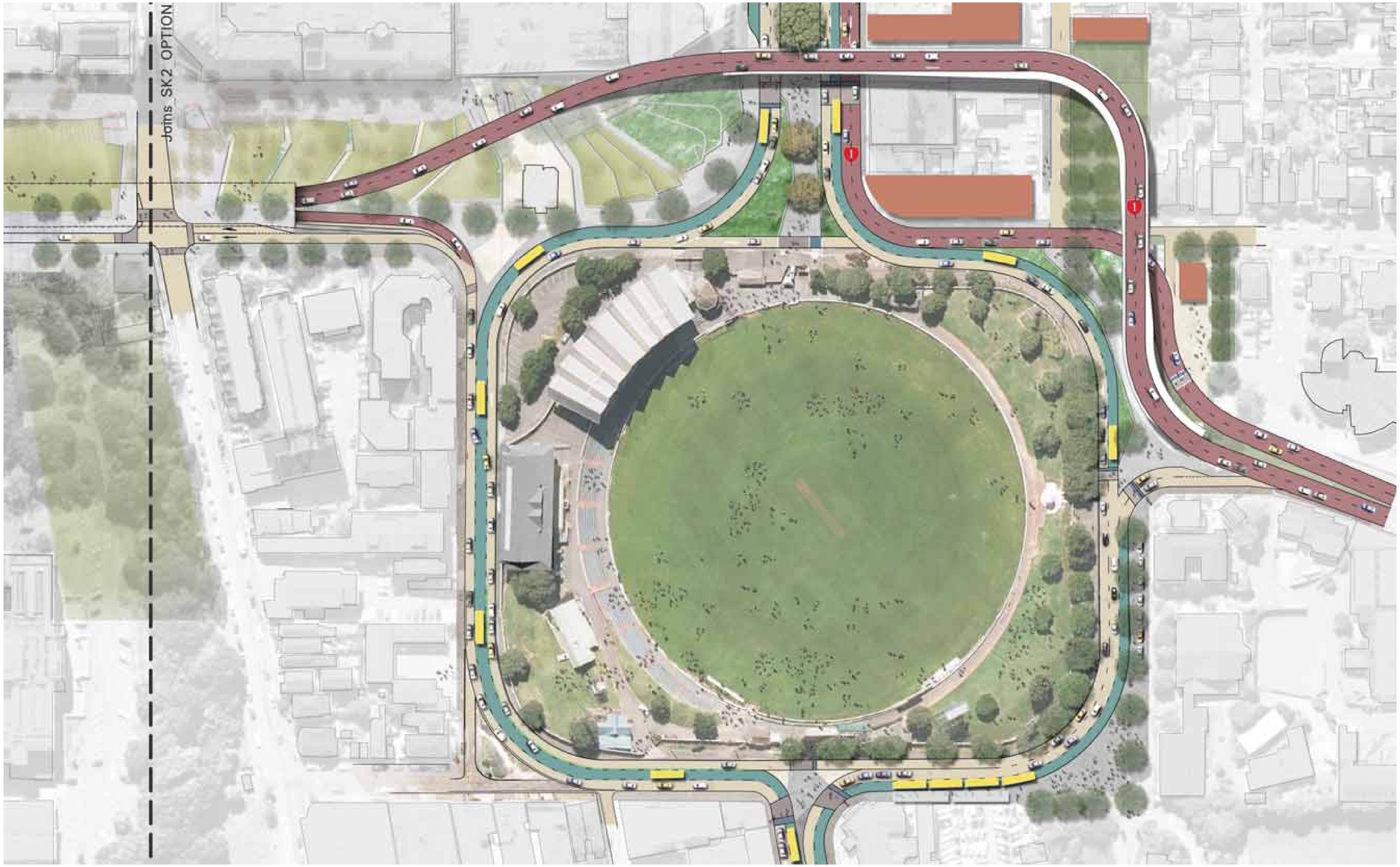
Option I combines Basin Reserve Option B (bridge away from the Basin Reserve) with a tunnel under Memorial Park ending before Taranaki Street as schematically shown in *Figure 20.5* below. *Figure 20.2* shows the option in more detail.

Figure 20.5: Option I Schematic

The key features of Option I are:

- Less impact on the Crèche than Option H since it does not need to be shifted.
- Provides improved access to the Basin Reserve with a pedestrian promenade.
- Minimises traffic volumes on Buckle Street therefore improving amenity for Memorial Park users.
- Improves the connection between the War Memorial and Memorial Park.
- The trench at Taranaki Street consumes some land that could have been part of the park.
- The pedestrian link between the War Memorial and the City must make a slight deviation to avoid the trench near Taranaki Street.
- Improved journey times for local and SH1 traffic at Taranaki Street resulting from improvements to the intersection's efficiency.
- Provides improved bus journey times through the intersection of Taranaki Street and Buckle Street as a result of the intersection being more efficient. This supports Wellington City Council's plans to implement bus lanes on Taranaki Street.
- Land between Tory Street and Kent Terrace is severed by the bridge structure. This affects the use of the land for buildings and will tend to sever the park, if one is constructed between Tory Street and Kent Terrace.
- Elevated bridge structures may impact views to / from Kent and Cambridge Terrace and Mount Victoria.
- Future proofing requires extending the tunnel past Taranaki Street which will be challenging once Memorial Park is constructed. The bridge structure near the Basin Reserve would need to be constructed in such a way that an eastbound grade separated link could be built in the future.
- Does not affect existing buildings on the corner of Kent Terrace and Ellice Street.

Figure 20.6: Option I


Joins SK2 OPTION

21 Tunnel Ending After Taranaki Street

There are three options which include a tunnel ending after Taranaki Street. These options are described in the following sections.

21.1 Option G

Option G combines a tunnel around the Basin Reserve with a tunnel under Memorial Park ending after Taranaki Street as schematically shown in *Figure 21.1* below. *Figure 21.2* shows the option in more detail.

Figure 21.1: Option G Schematic

The key features of Option G are:

- Almost no impact on the Crèche[1].
- Affects the buildings on the corner of Kent Terrace and Ellice Street.
- Intrusive trench on the northeast side of the Basin Reserve creates severance between the Basin Reserve and Mount Victoria neighbourhood.
- Provides improved access to the Basin Reserve with a pedestrian promenade.
- Minimises traffic volumes on Buckle Street therefore improving amenity for Memorial Park users.
- Reduces noise levels within Memorial Park enabling some park users to use the park for solitary reflection: an activity consistent with the park's purpose.
- Improves the connection between the War Memorial and Memorial Park.
- No severance within Memorial Park. Pedestrians are able to freely cross Buckle Street along its full length between Tory Street and Taranaki Street.
- Improved journey times for local and SH1 traffic at Taranaki Street resulting from improvements to the intersection's efficiency.
- Improves bus journey times through the intersection of Taranaki Street and Buckle Street as a result of the intersection being more efficient. This supports Wellington City Council's plans to implement bus lanes on Taranaki Street.
- Land between Tory Street and Kent Terrace is intact creating the potential for either park or buildings in this space. If a park is constructed between Tory Street and Kent Terrace, this will improve the connection between Memorial Park and the Basin Reserve.
- No elevated structure to impact on views to / from Kent and Cambridge Terrace and Mount Victoria.
- Future proofing is less complicated than some other options since a westbound grade separated link is already constructed from the Mount Victoria Tunnel past Taranaki Street.
- Requires traffic from Buckle Street to travel further to reach the CBD a there is no provision for turning movements at Taranaki Street.

01 Crèche will be lifted up to enable tunnel construction and then will be reinstated in its current location.

Figure 21.2: Option G


Joins_SK2_OPTION

21.2 Option L

Option L combines Basin Reserve Option A (bridge near the Basin Reserve) with a tunnel under Memorial Park ending after Taranaki Street as schematically shown in *Figure 21.3* below. *Figure 21.4* shows the option in more detail.

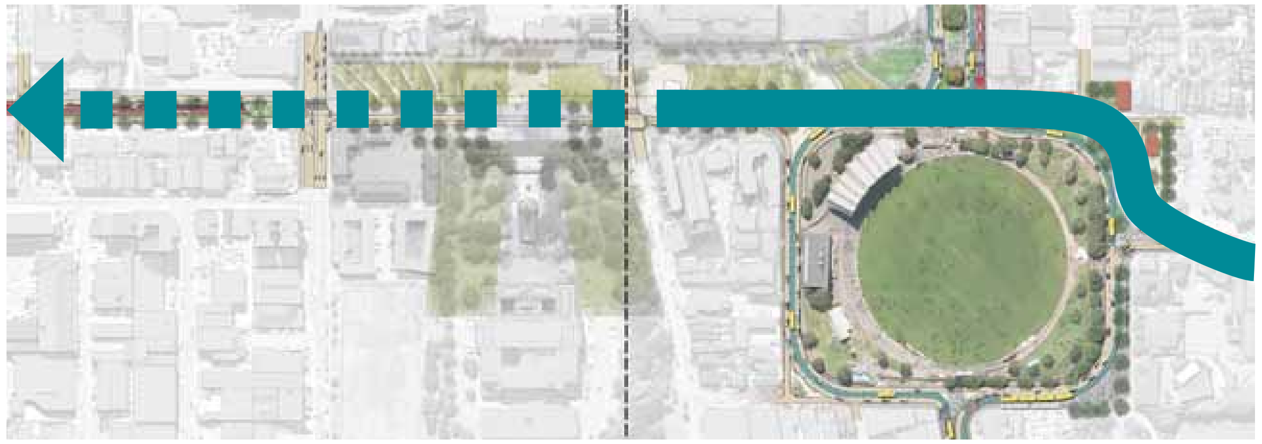
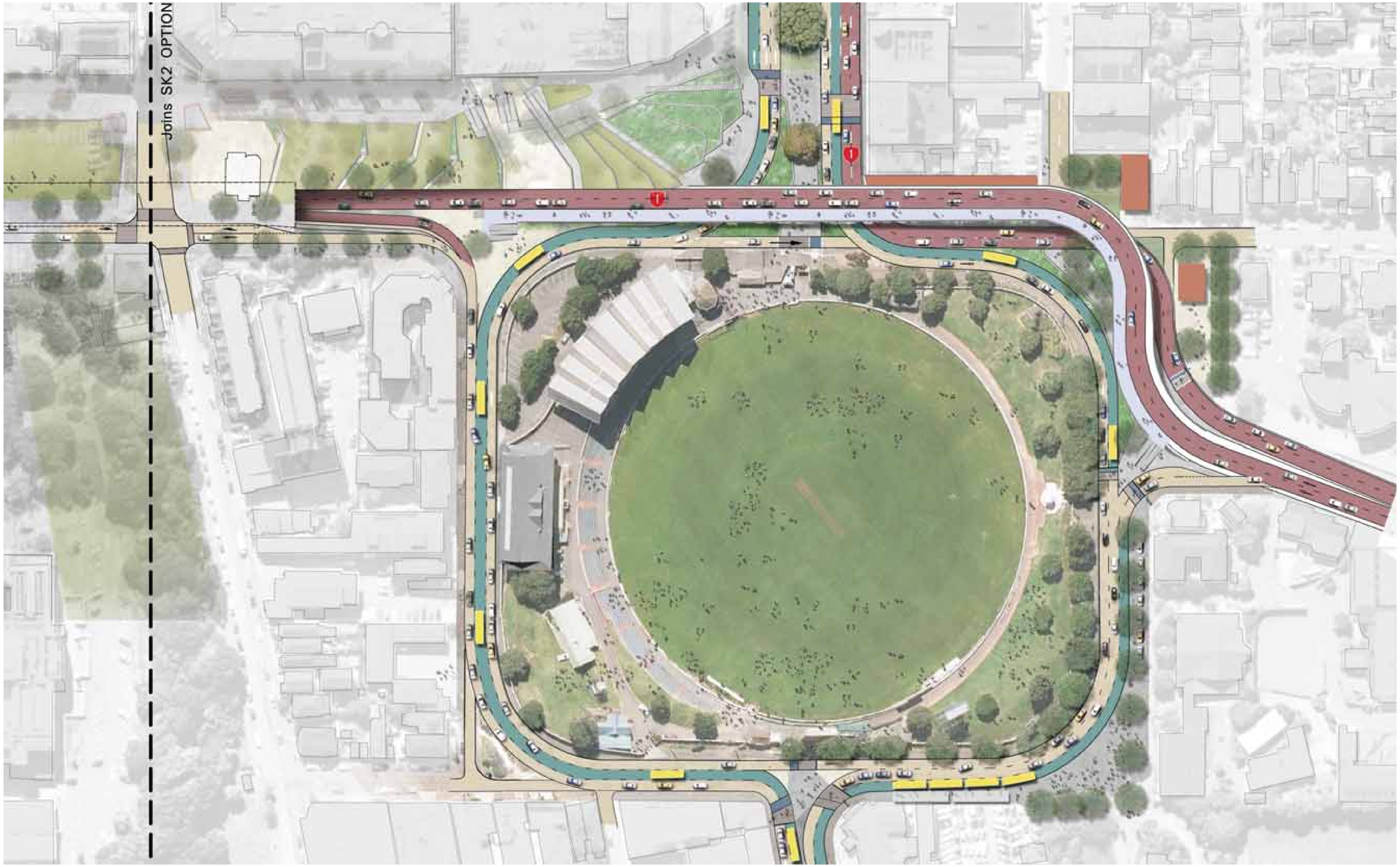


Figure 21.3: Option L Schematic

The key features of Option L are:

- Crèche must be shifted. There is the opportunity to shift it to the corner of Buckle Street and Tory Street to give it a better street frontage and be incorporated into a museums precinct proposed for Buckle Street.
- Affects the buildings on the corner of Kent Terrace and Ellice Street.
- Pedestrian and cyclist path incorporated into the bridge structure.
- Provides improved access to the Basin Reserve and a pedestrian promenade.
- Minimises traffic volumes on Buckle Street therefore improving amenity for Memorial Park users.
- Improves the connection between the War Memorial and Memorial Park.
- No severance within Memorial Park. Pedestrians are able to freely cross the full length of Buckle Street between Tory Street and Taranaki Street.
- Improved journey times for local and SH1 traffic at Taranaki Street resulting from improvements to the intersection's efficiency.
- Improves bus journey times through the intersection of Taranaki Street and Buckle Street as a result of the intersection being more efficient. This supports Wellington City Council's plans to implement bus lanes on Taranaki Street.
- Land between Tory Street and Kent Terrace is intact creating the potential for either park or buildings in this space.
- Elevated structure may impact on views to / from Kent and Cambridge Terrace and Mount Victoria.
- Future proofing is less complicated than some other options since a westbound grade separated link is already constructed from the Mount Victoria Tunnel past Taranaki Street.
- Requires traffic from Buckle Street to travel further to reach the CBD since there is no provision for turning movements at Taranaki Street.

Figure 21.4: Option L


Joins SK2 OPTION

21.3 Option M

Option M combines Basin Reserve Option B (bridge away from the Basin Reserve) with a tunnel under Memorial Park ending after Taranaki Street as schematically shown in *Figure 21.5* below. *Figure 21.6* is a full size plan of the Option.

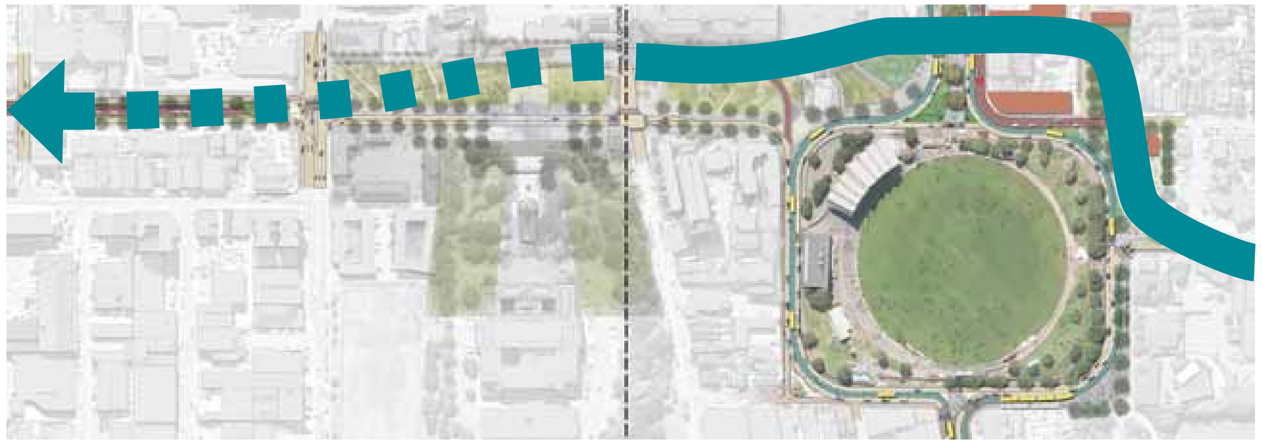
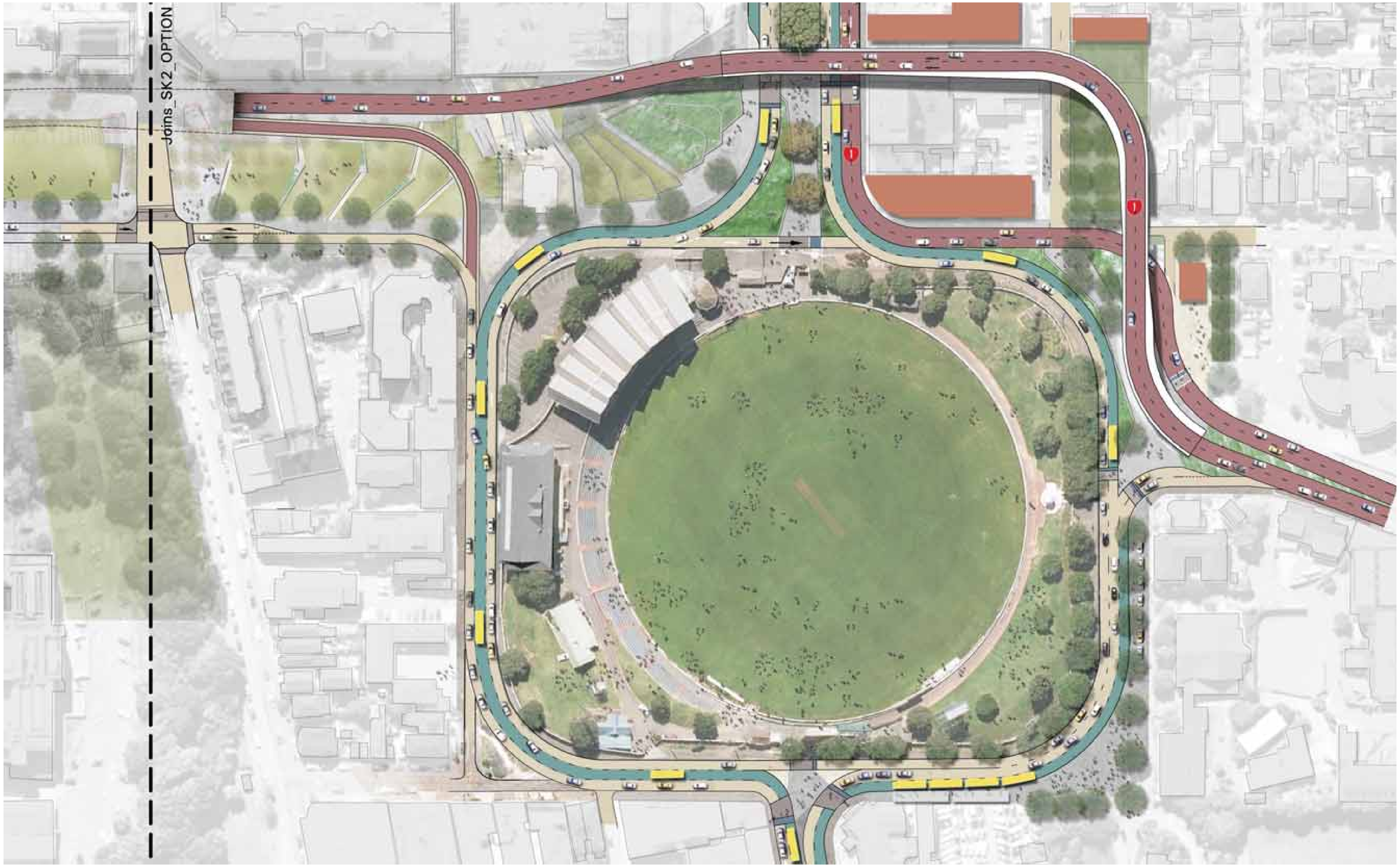


Figure 21.5: Option M Schematic

The key features of Option M are:

- Less impact on the Crèche than Option L since it does not have to be shifted.
- Provides improved access to the Basin Reserve with a pedestrian promenade.
- Minimises traffic volumes on Buckle Street therefore improving amenity for Memorial Park users.
- Reduces noise levels within Memorial Park enabling some park users to use the park for solitary reflection: an activity consistent with the park's purpose.
- No severance within Memorial Park. Pedestrians are able to freely cross the full length of Buckle Street between Tory Street and Taranaki Street.
- Improved journey times for local and SH1 traffic at Taranaki Street resulting from improvements to the intersection's efficiency.
- Improves bus journey times through the intersection of Taranaki Street and Buckle Street as a result of the intersection being more efficient. This supports Wellington City Council's plans to implement bus lanes on Taranaki Street.
- Land between Tory Street and Kent Terrace is severed by the bridge structure. This affects the use of the land for buildings.
- Elevated may impact views to / from Kent and Cambridge Terrace and Mount Victoria.
- Future proofing is less complicated than other options since a westbound grade separated link is already constructed from the Mount Victoria Tunnel past Taranaki Street. The bridge structure near the Basin Reserve would need to be constructed in such a way that an eastbound grade separated link could be built in the future.
- Requires traffic from Buckle Street to travel further to reach the CBD since there is no provision for turning movements at Taranaki Street.

Figure 21.6: Option M


Joins_SK2_OPTION

22 Cost Estimates

Option estimates have been prepared generally in accordance with NZTA's *Cost Estimation Manual*. The cost of constructing the Memorial Park itself is not included. The estimates exclude GST and escalation and have been subject to an external peer review. To be consistent with previous estimates, a cost index base date of September 2009 has been used. Construction cost rates have been determined from recent roading projects in the Wellington area and adjusted to reflect the base date where necessary.

In order to provide robust cost estimates, we have assessed appropriate cost risk to reflect the level of uncertainty in quantities and rates at this stage of the project. This applies to all cost items in the estimate, such as land, fees and construction items. To reflect this uncertainty, the project costs are expressed in terms of the expected value and the 95th percentile value. The latter is the estimated upper limit, which on average should only be exceeded once in every 20 projects.

The following assumptions were made when forming the estimate:

- Service relocations are based on ICB Services Drawings (2002), and incorporate services installed during the ICB project including the Te Aro culvert. Only preliminary discussions with Wellington Electricity have been completed. No other discussions with service providers have been undertaken.
- The trench construction is assumed to have minimal impacts on ground water in the area.
- All traffic and pedestrian movements will be maintained at all times during construction, but the number of lanes and speeds may be temporarily reduced on the roads adjacent to the construction areas.
- No allowances for additional costs associated with future proofing for an eastbound tunnel link in the vicinity of Memorial Park and the Basin Reserve have been included.

Further details on the cost estimate and the associated assumptions are contained in *Appendix E*.

There is significant uncertainty around some key items in this cost estimate. To reduce this uncertainty and improve the estimate the following actions are recommended:

- Further geotechnical investigation.
- Refine the design and construction method for the tunnel, allowing the creation of a more detailed build up of the tunnel costs.
- Liaison with service authorities, especially about the Tory Stormwater Culvert, Newtown Sewer, and the 33kV electrical cables. These services have the potential to be very significant cost and time constraints on the project.
- Some buildings need to be moved to create adequate working space for construction. Further investigation of the feasibility of moving these buildings is needed.

22.1 Tunnel Ending Before Taranaki Street Estimate

Estimates have been prepared based on the previous Option F estimate[1] undertaken for the Basin Reserve project in December 2009. The previous estimate had an expected cost range of $160 million (expected estimate) to $220 million[2] (95th percentile estimate), excluding escalation and GST and with a cost index of September 2009.

However, since the estimate was completed, the following aspects of the design have been revised:

- Addition of an on-ramp from Sussex Street to the War Memorial Tunnel;
- Widening the tunnel and trench to three lanes to accommodate the Sussex Street on-ramp;
- Upgrading at-grade Buckle Street in its reduced width to be at an appropriate standard to tie in with the competition winning Memorial Park design;
- Addition of a third ICB lane between Taranaki Street and Cuba Street (including additional property costs);
- Additional urban design mitigation for the proposed works between Cuba and Taranaki Street; and
- Intersection priority changes at the intersection of Cuba Street and SH1.

22.2 Tunnel Ending After Taranaki Street Estimate

There are a number of important services located at Taranaki Street and extending the tunnel under Taranaki Street will interfere with these services. The estimate requires further input from the service authorities. The following assumptions were made when forming the estimate:

- The un-reinforced concrete building at 30 Arthur can be sufficiently strengthened such that it can be temporarily moved to provide construction working space.
- Service relocations are based on ICB Services Drawings (2002), and incorporate services installed during ICB project.
- The main electricity distribution cables (33kV) are gas filled cables, which are no longer available. Therefore short sections of these cables are no longer able to be relocated; if this cable needs to be relocated, a much longer length must be moved.

22.3 ICB Improvements

A feasibility cost estimate has also been undertaken for the ICB improvements. Although the majority of the work is minor in nature there are number of significant costs for property purchase and amending the approach to the ICB trench structure. The amendment to the ICB trench structure includes replacing existing retaining walls. The ICB improvements cost estimate is summarised in *Table 22.1*, below.

Table 22.1: ICB Improvements Cost Estimate

	Base Cost	Expected Cost	95th Percentile
ICB Improvements	$17M	$22M	$39M

The above costs are exclusive of escalation and GST. The cost index for the estimates is June 2010. The above figures should be read in conjunction with the notes included in the ICB Improvements Report.

22.4 Ruahine Street

The cost estimate for the Ruahine Street project is documented in *The Optimisation of SH1 - Ruahine Street to Kilbernie Crescent - Project Feasibility Report*, prepared by Opus International Consultants Ltd for NZTA, June 2010. The Ruahine Street improvements cost estimate is summarised in *Table 22.2*, below.

Table 22.2: Ruahine Street Improvements Cost Estimate

	Base Cost	Expected Cost	95th Percentile
Ruahine Street Improvements	$7.5M	$9M	$13M

The above costs do not include escalation or GST and use a cost index of March 2010.

22.5 Option Cost Estimates

The Option cost estimates for each of the eight options are included in *Table 22.3*. A total 'project' cost estimate has been prepared by combining the expected estimates for work at the Basin Reserve, War Memorial Tunnel, ICB Improvements and the Ruahine Street Improvements. A combined 95th percentile cost has also been provided but it should be noted that by summing the 95th percentile costs for the different projects this figure may be more conservative than considering the scope of works as a single project.

Splits for Basin Reserve and Memorial Park costs are based on a comparison of the tunnel options against the at-grade solutions (Options J and K).

The cost for Options F and G have not been split as there is no Basin tunnel option that ties in with an at-grade option in front of the War Memorial.

01 The cost estimate is documented in the Transportation Improvements Around the Basin Reserve Options Report, prepared by Opus International Consultants Ltd. for NZTA.

02 These cost estimates exclude escalation and GST and use a cost index of September 2009.

Table 22.3: Option F to M Cost Estimates

<table>
<tr><th>Option</th><th></th><th>Total</th><th>ICB Improvements</th><th>Ruahine Street</th><th>Basin Reserve</th><th>War Memorial Tunnel</th></tr>
<tr><td rowspan="2">F</td><td>Expected</td><td>$230M</td><td>$22M</td><td>$9M</td><td colspan="2">$200M</td></tr>
<tr><td>95th Percentile</td><td>$330M</td><td>$39M</td><td>$13M</td><td colspan="2">$280M</td></tr>
<tr><td rowspan="2">G</td><td>Expected</td><td>$290M</td><td>$22M</td><td>$9M</td><td colspan="2">$260M</td></tr>
<tr><td>95th Percentile</td><td>$420M</td><td>$39M</td><td>$13M</td><td colspan="2">$370M</td></tr>
<tr><td rowspan="2">H</td><td>Expected</td><td>$195M</td><td>$22M</td><td>$9M</td><td>$90M</td><td>$75M</td></tr>
<tr><td>95th Percentile</td><td>$275M</td><td>$39M</td><td>$13M</td><td colspan="2">$225M</td></tr>
<tr><td rowspan="2">I</td><td>Expected</td><td>$210M</td><td>$22M</td><td>$9M</td><td>$105M</td><td>$75M</td></tr>
<tr><td>95th Percentile</td><td>$305M</td><td>$39M</td><td>$13M</td><td colspan="2">$255M</td></tr>
<tr><td rowspan="2">J</td><td>Expected</td><td>$120M</td><td>$22M</td><td>$9M</td><td>$90M</td><td rowspan="2">No Tunnel</td></tr>
<tr><td>95th Percentile</td><td>$175M</td><td>$39M</td><td>$13M</td><td>$125</td></tr>
<tr><td rowspan="2">K</td><td>Expected</td><td>$130M</td><td>$22M</td><td>$9M</td><td>$105M</td><td rowspan="2">No Tunnel</td></tr>
<tr><td>95th Percentile</td><td>$205M</td><td>$39M</td><td>$13M</td><td>$155M</td></tr>
<tr><td rowspan="2">L</td><td>Expected</td><td>$265M</td><td>$22M</td><td>$9M</td><td>$90M</td><td>$145M</td></tr>
<tr><td>95th Percentile</td><td>$375M</td><td>$39M</td><td>$13M</td><td colspan="2">$325M</td></tr>
<tr><td rowspan="2">M</td><td>Expected</td><td>$280M</td><td>$22M</td><td>$9M</td><td>$105M</td><td>$145M</td></tr>
<tr><td>95th Percentile</td><td>$400M</td><td>$39M</td><td>$13M</td><td colspan="2">$350M</td></tr>
</table>

The above costs are exclusive of escalation and GST. The cost index for the Basin Reserve estimates is September 2009. Some of the above figures have been rounded. The above estimates should be read in conjunction with the notes included in *Appendix E*.

In summary the premium cost for providing a tunnel under Memorial Park that comes up before Taranaki Street is approximately $75M (Expected Cost). A tunnel that grade separates Taranaki Street and comes up prior to Cuba Street is approximately an additional $60-70M (Expected Cost) on top of the cost of providing a tunnel that ends before Taranaki Street. The 95th percentile costs have not been split between these two areas.

23 Economic Benefits and BCRs

Based on the Paramics model outputs, a preliminary analysis has been completed to determine the benefits[1] associated with each of the options. The indicative benefits only include travel time, vehicle operating cost and carbon dioxide benefits. Crash costs and trip time reliability benefits were not considered as part of the benefits analysis.

In terms of traffic operations and modelling there is minimal difference between the different grade separated options (Basin Reserve Options A, B and F) at the Basin Reserve. Rather, the options are differentiated by where the tunnel terminates, or if SH1 is at grade through the park. Therefore, the options were grouped by their alignment through Memorial Park for the modelling. Indicative benefits and BCRs for each of the options is summarised in *Table 23.1*. The BCRs may change as the modelling and cost estimates are refined and updated in subsequent stages of the project. Once the options have been remodelled using updated trip matrices, a more robust economic analysis should be completed.

The net present value (NPV) of the benefits of a scheme which includes a tunnel ending before Taranaki Street is $3 million less than a scheme with SH1 at grade. This difference is most likely caused by motorists from Sussex Street trying to weave to the right lane to turn right at Taranaki Street. In practice, if the weave is too challenging motorists will use an alternative route instead.

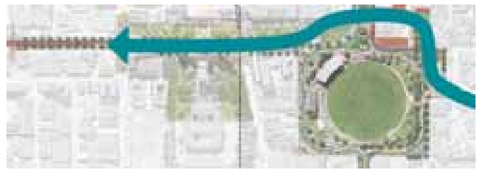
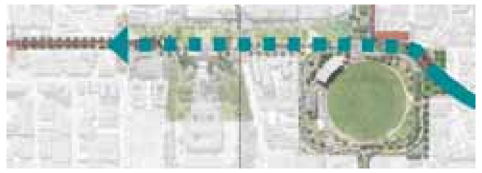
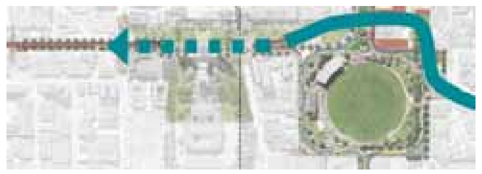
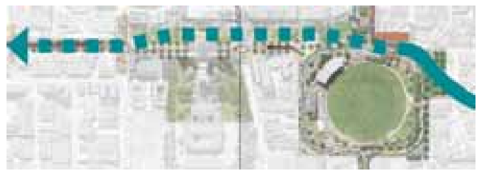
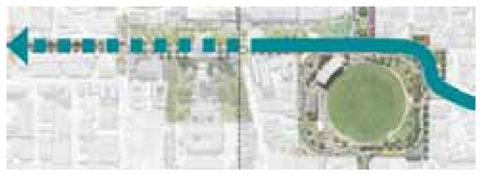
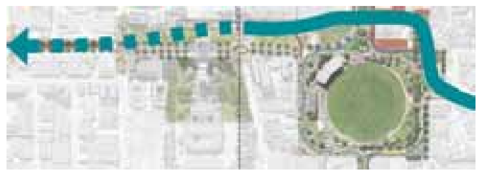
The scheme with a tunnel ending after Taranaki Street has the most benefits. This is due to efficiencies resulting from SH1 motorists be able to travel uninterrupted from the Mount Victoria Tunnel to Cuba Street. Also, with SH1 traffic removed from Buckle Street, the intersections of Tory Street and Taranaki Street are able to operate much more efficiently.

The at grade options (J and K) have the highest BCR since their construction costs are relatively low. The tunnel ending before Taranaki Street options (F, H and I) have BCRs of 0.9 to 1.0. The tunnel ending after Taranaki Street options (G, L and M) have BCRs of 0.7 to 0.8. The lower BCRs for these options are due to the high construction costs associated with the longer tunnel since these options have the most benefits.

The following assumptions have been used when completing this economic evaluation:

- 30 year benefit period;
- 2009 base date;
- Time zero is 2010;
- Construction period is 6 years with a start date of 1st January 2011 and assumes all schemes are built at the same time and there is no staging;
- The benefits end 30th June 2040;
- The annualisation factors are the same as those used for the Basin Reserve project;
- Discount rate of 8 percent, as set in the Economic Evaluation Manual; and
- Benefits have been capped to 2026 levels.

Table 23.1: Cost Estimates, NPV Benefits and BCRs

Option		NPV Benefits	Expected Cost[2] (95th Percentile)	BCR
At Grade Options				
J		$155 M	$120 M ($175 M)	1.7
K			$130 M ($205 M)	1.5
Tunnel Ending Before Taranaki Street Options				
F		$152 M	$230 M ($330 M)	0.9
H			$195 M ($275 M)	1.0
I			$210 M ($305 M)	0.9
Tunnel Ending After Taranaki Street Options				
G		$162 M	$290 M ($420 M)	0.7
L			$265 M ($375 M)	0.8
M			$280 M ($400 M)	0.8

01 The benefits are based on results from using do minimum trip matrices since these were used for all modelling. When the updated model is available option trip matrices should be used.

02 Costs included this table are for the whole package of works (ICB Improvements, Ruahine Street, Basin Reserve, War Memorial Tunnel) and are not discounted. The listed costs are discounted when calculating the BCR.

24 Future Proofing

NZTA have identified that when selecting a preferred solution, a consideration should be the ability to provide a fully grade separate route between duplicated Terrace and Mount Victoria Tunnels in the future. The area considered as part of this report is shown in *Figure 24.1*, below.

Figure 24.1: Extend of Assessment of Westbound and Eastbound Future Proofing

This assessment assumes any future westbound grade separated route would generally follow the alignment of the existing Wellington Inner City Bypass. In an eastbound direction the assessment considers the route from Taranaki Street to the Mount Victoria Tunnel. The eastbound route from the Terrace Tunnel may follow the existing ICB or it could take a more direct route.

Currently the geometric design through the Basin Reserve area is only providing a 50 km/h design speed. This may be less than desired for a future grade separated solution. There is the potential modify this design to increase the design speed, however this may have an effect on the urban design outcome for the area.

24.1 Westbound Future Proofing

With all options (SH1 at-grade, tunnel ending before Taranaki Street or tunnel ending after Taranaki Street) it is possible to construct a grade separated westbound link in the future without disturbing the memorials planned for Memorial Park. However, the difficulty of achieving a fully grade separated link in the future changes depending upon which option is constructed.

Constructing a tunnel under Taranaki Street requires the relocation / diversion of a significant number of underground services. This work is likely to cost millions of dollars and take a long period of time (months). Currently, the land where Memorial Park will be constructed is vacant which means it can be utilised for construction working space or a temporary road during construction. Once the park is constructed there is significantly less room and more extensive traffic diversions would be required. For example while constructing the tunnel, SH1 traffic may need to be diverted down Cambridge Terrace and along the waterfront.

The current design concept for an at-grade SH1 in Memorial Park provides 24m between buildings on the south side of Buckle Street and the main structure of Memorial Park. This space is assumed to be adequate for the construction of a three lane tunnel through the park in the future.

In terms of future proofing for a westbound grade separated link, options where the tunnel ends after Taranaki Street are preferred since the tunnel will be constructed under Taranaki Street while there is ample working space.

It is still possible, in the future, to provide a fully grade separated link if an option with a tunnel ending before Taranaki Street is constructed now; however constructing the tunnel under Taranaki Street will be more challenging since there will be less working space and options for creating traffic diversions.

Finally, if an at-grade option through Memorial Park is constructed now, it is still possible to construct a grade separated westbound link in the future, but it will be extremely disruptive to both motorists and park users.

24.2 Eastbound Future Proofing

In the future an eastbound link could be constructed utilising the land to the north of Memorial Park. While there is a service lane and parking which can be temporarily dug up to for the construction of a tunnel in the future, this may not provide sufficient space depending upon the final park layout. Up to 24 m is needed to construct the eastbound tunnel. Therefore, additional property to the north may be temporarily required for the construction of an eastbound tunnel.

In the vicinity of the Basin Reserve, it is possible to achieve grade separation in both directions. The optimal layout for a future eastbound grade separated link is dependent upon which option is constructed for the westbound traffic. It may be necessary to increase the curve radius on the bridge structures (Basin Reserve Options A and B) to enable these structures to be duplicated in the future to provide an eastbound connection.

If Option I, K or M (all incorporating Basin Reserve Option B) is constructed now, constructing an eastbound grade separated link is more challenging in the future. For the future eastbound connection either Basin Option B would need to be duplicated or a tunnel under Kent and Cambridge Terrace would have to be constructed. The tunnel option would need to cross under the bridge structure for the westbound traffic twice. The bridge would need to be appropriately designed to accommodate this future work.

On the approach to the Mount Victoria Tunnel, it is expected that the long term vision will include four dedicated SH1 lanes: two westbound and two eastbound. Between St Marks School and St Marks Church, it is also expected that additional merging lanes will need to be provided for local traffic. Design work completed thus far indicates that due to the width and relative levels of the proposed road space between St Marks School and St Marks Church, it seems unlikely that these lanes will fit within the current road reserve. Additional space will be required from one of the adjacent properties to provide an efficient and safe access to the duplicated Mt. Victoria Tunnel.

Figure 24.2 shows one possible option for constructing a grade separated eastbound connection in the future.

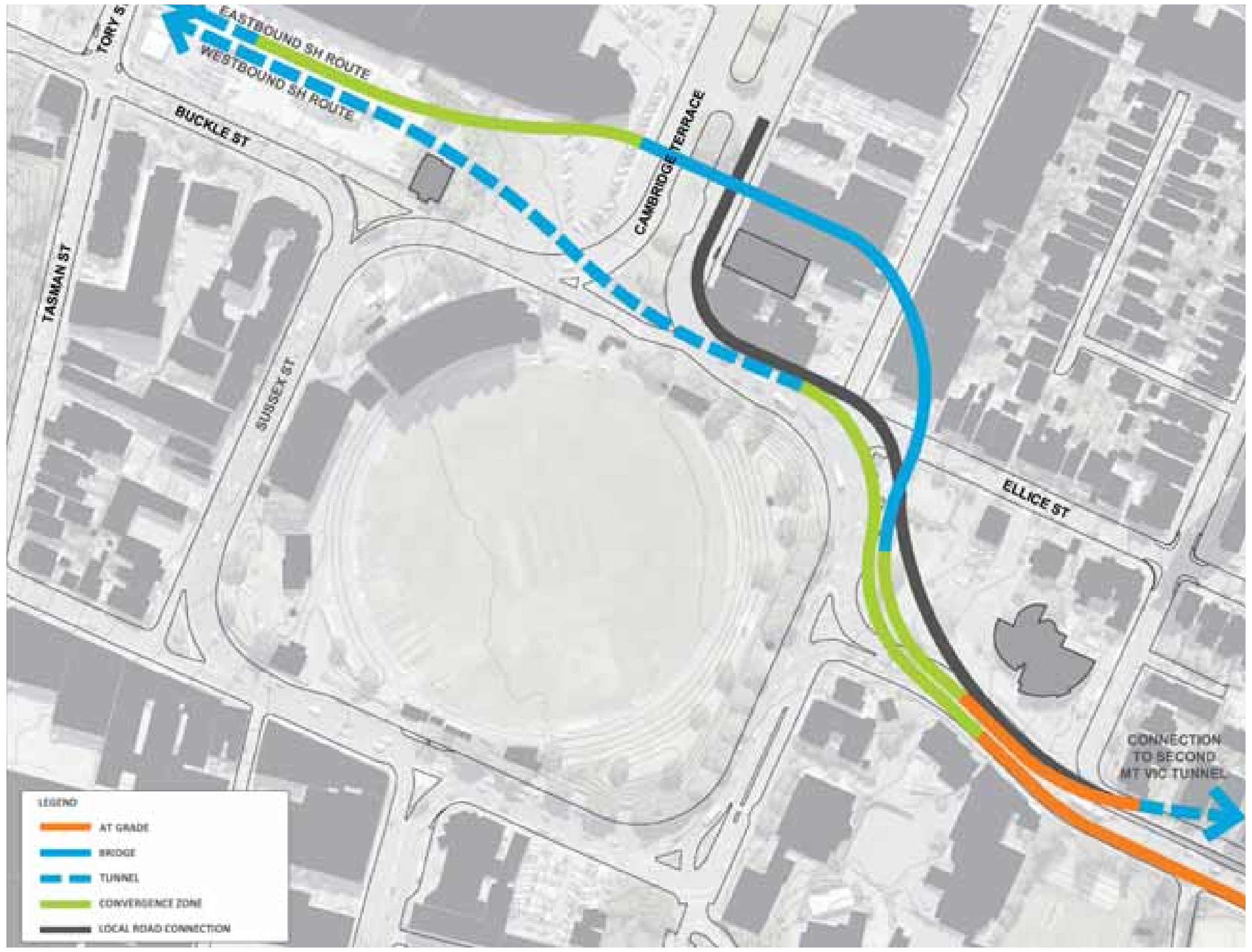


Figure 24.2: Illustration of possible future eastbound alignment to complement westbound tunnel solution

PART IV: Conclusions and Recommendations

25 Overview

Further to the work already completed on making Transportation Improvements around the Basin Reserve, we have investigated the feasibility of constructing a tunnel under the proposed Memorial Park for westbound SH1 traffic. We investigated the feasibility of constructing such a tunnel and explored two tunnel options: one with an exit portal before Taranaki St and one after Taranaki St. As a comparison, we also investigated leaving Buckle Street at-grade so that SH1 traffic passed through Memorial Park. Furthermore, we investigated the feasibility of connecting these three options through Memorial Park to the three grade separated options at the Basin Reserve approved by NZTA's board: Option A (bridge near Basin), Option B (bridge away from Basin) and Option F (tunnel around Basin).

26 Conclusions

In undertaking this study for a War Memorial Tunnel, we are able to draw the following conclusions:

1. Making the transportation improvements around the Basin Reserve and placing SH1 westbound traffic in a tunnel under Memorial Park introduced additional delays along Ruahine Street and the ICB between Cuba Street and the Terrace Tunnel. It turned out that these additional delays consumed many of the economic benefits of freeing up traffic around the Basin Reserve. Therefore, in order to realise the full benefits of the Basin Reserve Improvements, and to ensure that the War Memorial Tunnel does not impede traffic flows along the ICB, it will be necessary to undertake additional minor improvements on the ICB and along Ruahine Street.
2. It is feasible to construct the War Memorial Tunnel, allowing Memorial Park to be constructed on top of it. While a service road would be retained in front of the War Memorial to provide property access, this road would have very low volumes of traffic and would lend itself to be designed as a shared space with other users such as pedestrians and cyclists. In order to minimise traffic using this service road, an on-ramp to the tunnel would need to be provided for vehicles travelling from Sussex Street towards the ICB. This adds to the cost of providing a War Memorial Tunnel.
3. The cost of this total project, including the Basin Reserve, War Memorial Tunnel and improvements on the WICB and Ruahine Street, varies with the options considered. The total project[1] has an 'expected cost' of between $195 million and $290 million[2]. (Resulting in a net present value cost of $150 million to $220 million.) The net present value of the economic benefits resulting from improved traffic flows for this total project are between $150 million and $160 million[3]. This gives a Benefit Cost Ratio for this total project of between 0.7 and 1.0.
4. The expected cost of the total project without a War Memorial Tunnel is between $120 million and $130 million[4]. This means that the expected cost of the War Memorial Tunnel is between $75 million and $145 million, depending on the option chosen.
5. The War Memorial Tunnel is likely to add only up to $10 million in economic transportation benefits to the project. The key benefit of the War Memorial Tunnel is improved amenity for park users. It will reduce severance between Memorial Park and the War Memorial, and the City and the War Memorial. It will make the park significantly quieter, allowing users to talk, reflect and meditate. It will avoid the need for SH1 road closures during formal events held on ANZAC day and during other ceremonies.
6. Two War Memorial Tunnel options are feasible.
    a. **A tunnel exiting before Taranaki Street.** This is the cheapest of the two tunnel options and would add another $75 million to the 'expected cost' of the project. Because it exits before Taranaki Street, it will require an uncovered trench structure through Memorial Park near Taranaki Street. This reduces the size of Memorial Park and has the potential to create a barrier for pedestrians and other users travelling between the City and War Memorial. It has the potential to create visual impacts on the views of the park from the Carillon. In saying that, these impacts have been largely mitigated by extending the tunnel lid as close as 60m from Taranaki St.
    b. **A tunnel exiting after Taranaki Street.** This is the most expensive of the two tunnel options and would add another $145 million to the 'expected cost' of the project. Because it exits after Taranaki Street, Memorial Park can utilise all the land between Taranaki Street and Tory Street. Unlike the shorter and cheaper tunnel option, it does not create a barrier for pedestrians and other users travelling between the City and War Memorial. While extending the tunnel under Taranaki Street provides travel time savings for vehicles travelling along Taranaki Street or along SH1 these benefits are offset by the disbenefits of SH1 vehicles wanting to access the City who must re-route to Willis Street intersection. A further advantage of having the tunnel exit after Taranaki St is that it enables land set aside for the Memorial Park to be used for diverting traffic during the construction of the tunnel under Taranaki St. Construction of the tunnel under Taranaki St will be challenging due to underground services, large traffic volumes and a confined site. Once Memorial Park has been constructed, it will be difficult for future generations to extend the shorter War Memorial Tunnel under Taranaki Street without diverting all SH1 traffic along the waterfront for many months.
7. Both War Memorial Tunnel options can be connected to all three NZTA approved grade separated Basin Reserve Options (Option A, Option B or Option F).
8. If it is decided not to construct the War Memorial Tunnel, then there are only two NZTA approved grade separated Basin Reserve Options (Option A and Option B) both of which involve bridge structures around the Basin.
9. If it was decided that the preferred option for the Basin Reserve was to provide a tunnel around the Basin to avoid the visual impacts of elevated structures, then it would also be necessary to construct the War Memorial Tunnel.
10. If there is a plan to allow westbound SH1 traffic to be placed in a tunnel at sometime in the future, then it is preferable for that tunnel to be constructed before construction of the Memorial Park. It will not be possible to construct a tunnel under Memorial Park once it has been developed. While it is feasible to allow enough land between the War Memorial and Memorial Park to enable the construction of a westbound tunnel for SH1 in the future, this could only be achieved by diverting all SH1 traffic (nearly 20,000 vehicles per day) along the waterfront for a period of one or more years. This would create significant traffic problems for Wellington.
11. It may be prudent to allow for the possibility that future generations may want to build an eastbound tunnel through Memorial Park. Such a tunnel could be partially constructed under land to the north of Memorial Park: land set aside for a road and car parking. Land may also need to be temporarily acquired from Mt Cook school and other land owners adjacent to the Park. If provision for an eastbound tunnel is considered desirable, it will be necessary for the land under the road and car park to be retained in NZTA ownership and not incorporated into the reserve land created as part of Memorial Park.
12. The more expensive War Memorial Tunnel that extends past Taranaki St should be constructed if there a preference to avoid impacts on Memorial Park and to allow future generations to enhance SH1 by constructing a grade separated link between Mt Victoria Tunnel and Terrace Tunnel.
13. The less expensive War Memorial Tunnel that exits before Taranaki St should be constructed if there is a preference to build a tunnel for the least cost.
14. If it was decided to provide an option for the least cost, then retaining westbound SH1 at grade is the preferred option. A positive feature of this option is that it would allow the thousands of car users to experience the Park as they travelled through it each day. However, this option would reduce the land available for the Memorial Park, create severance for pedestrians using the Park, generate noise levels that would make conversations difficult and not create an environment that would be conducive to reflection or meditation.
15. If it is decided to four lane Ruahine Street, duplicate Mount Victoria Tunnel and construct the War Memorial Tunnel in the short term and make provision for SH1 to be grade separated between Taranaki Street and the Terrace Tunnel in the future, it may be necessary to increase the design speed used on the options around the Basin Reserve. This will require the curve radius used on the bridges for Options A and B to be increased. Furthermore, it may be necessary to increase the curve radius to allow future generations to duplicate bridges around the Basin Reserve to provide a future eastbound connection.

01 The total project includes the Improvements around the Basin Reserve, the War Memorial Tunnel, improvements to the ICB and improvements to Ruahine Street.

02 The 95%ile cost of the total project is between $275 million and $420 million.

03 This is the net present value of transportation benefits over 30 year period, calculated in accordance with the NZTA Economic Evaluation Manual.

04 The 95%ile cost of the total project without War Memorial Tunnel is between $170 million and $200 million.

27 Recommendations

It is recommended that:

1. The Basin Reserve project should be progressed at the same time as the War Memorial Tunnel, Ruahine Street and the WICB Improvements.
2. Agreement is reached with the Ministry of Culture and Heritage on making the necessary provisions in the design of the Memorial Park to construct an eastbound tunnel at a future date.
3. Agreement is reached with Wellington City Council with regards to the proposed improvements to the WICB and Ruahine Street.
4. Further design work, sufficient to proceed to public consultation, is undertaken on the 'total scheme', including the War Memorial Tunnel, Basin Reserve, Ruahine Street and WICB Improvements.

APPENDIX A:
Aquatic Habitat Assessment

1 Introduction

1.1 Background

The Basin Reserve is an iconic site of New Zealand sporting heritage. The gyratory that passes around the Basin is a key choke point in the local and State Highway road networks. The Basin Reserve's close proximity to the Mount Victoria Tunnel as well as key local and State Highway linkages results in significant travel time delays for drivers of both private motor vehicles and for public transport users. As a consequence of this traffic congestion, high vehicle speeds and traffic volumes, cyclists and pedestrians face a number of safety issues particularly in the peak traffic periods. The Basin Reserve Improvements Investigation aims to address the existing transportation issues at a crucial junction in the local, regional and national road network. In order to provide a more efficient, less congested road network, any finalised option will separate the east-west (SH1) from the north-south (Kent/Cambridge Terrace and Adelaide Road) traffic and hence reduce the potential for conflict. Alleviating the existing issues will allow for projected future growth and for improved passenger transport movements on Kent Terrace, Cambridge Terrace and Adelaide Road.

Opus International Consultants (Opus) has been engaged by the New Zealand Transport Agency (NZTA) to prepare a scheme assessment report (SAR) for the Basin Reserve Improvements Investigation project under contract 380PN. The SAR needs to consider effects on the environment including ecosystems and their associated species of flora and fauna.

Options under consideration for the Basin Reserve Improvements were initially confined to Area A (*Figure 1*) and comprised mainly at grade or elevated structures. Subsequently, the possibility of tunnelling through Area B (*Figure 1*) along Buckle Street in front of the War Memorial has been advanced as a potential solution. The two tunnel options considered to date include a combination of tunnelling and trenching, with the tunnelling extending into Area A in both cases.

Initial scoping of ecological issues identified the potential for native fish to be migrating through project area via subsurface drains passing under the Basin Reserve to Prince of Wales Park. The possibility of fish migration through subsurface drains beneath Area B to Central Park was subsequently identified. As well as providing migration pathways these drains may also provide temporary or permanent habitat for some fish species. Disturbance to, or severance of, these migration pathways could result in adverse ecological effects. The options involving tunnelling and trenching are likely to involve the greatest risk of significant adverse effects to migratory pathways of native fish. Although, unlikely to result in a fatal flaw, the potential exists for a moderate negative effect, if fish migration was permanently prevented.

1.2 Purpose and scope

The purpose of this detailed scoping assessment is to obtain further information on fish migration routes and values of upstream habitats so that constraints, risks and opportunities can be more fully articulated, particularly given the potential for tunnelling and trenching through Areas A and B.

The scope of these further investigations was to:

- Obtain further information by habitat based field assessment and consultation on the nature of the migration pathways and values of upstream habitat.
- Consider in broad terms the potential effects of the full range of options that could be adopted in Areas A and B.
- Identify potential mitigation options and consider the likelihood of success.
- Identify further work that would need to be undertaken in the event that migratory pathways are likely to be significantly impacted by a preferred option.

Figure 1: Basin Reserve locations of Areas A and B

2 Methodology

This assessment was based on:

- Discussions with staff at Greater Wellington Regional Council, Wellington City Council and Capacity.
- Review of existing background information including; aerial photographs, city stormwater drainage plans and the New Zealand Freshwater Fish Database held by NIWA.
- A field survey undertaken on 11th July 2010. The survey focussed on recording the characteristics of the upstream catchments and their associated streams.

3 Habitat descriptions and associated fish species

3.1 Stormwater drainage system

A plan showing the stormwater drainage system within and surrounding project area is provided in Figure 2. This drainage system includes purpose built stormwater drains installed to service the urban environment but also includes culverts designed to pipe natural watercourses beneath the City. Some of the drains pipe streams from their source in parklands to the west and south-west of the Basin Reserve, to the sea. The older drains were constructed from brick and are usually oval in shape, while modern drains are circular concrete pipes. Drainage engineers at Capacity Infrastructure Services (managers of water, stormwater and waste services on behalf of Wellington City Council and Hutt City Council) indicated that baseflows in the drains conveying the permanent watercourses tend to be around 100mm depth. Drop structures in the flow paths, that could be potential obstacles to migratory fish, are usually >200mm.

Open streams in Prince of Wales Park enter subsurface drains at the ends of Rolleston Street and Papawai Terrace. The drains converge at Wallace Street from where the combined waters flow to Rugby Street. The drain then passes under the Basin Reserve to Cambridge/Kent Terraces and then flows northwards along Cambridge/Kent Terraces, eventually discharging into Lambton Harbour. The drains are tidal up to the Vivian Street intersection with Cambridge/Kent Terrace.

The open streams that drain Central Park, including the main Moturua Stream, enter underground drains at the park boundary and then converge at Brooklyn Road. The resulting combined flow crosses Arthur Street to the west of Caro Street and then flows in a north-easterly direction to the sea. This stormwater drainage plan (*Figure 2*) indicates that the Moturua Stream bypasses the western extremity of Area B and therefore is outside the area affected by construction works. A catchment plan for the area produced and provided by Capacity (*Appendix 1*) indicates that the Moturua Stream and associated drains are within a catchment that is largely outside the area potentially affected by the project, with only drains on the edge of the catchment potentially impacted.

3.2 Fish in the subsurface drainage environment

Discussion with drainage engineers at Capacity, who regularly inspect the stormwater system, has determined that eels are regularly observed in many parts of the drainage system within the city, particularly in low lying areas. Eels have been observed in stormwater pipes as small as 150mm. While large numbers had not been observed in any single location by the engineers consulted, eels were frequently encountered in many parts of the system, suggesting that they maybe more than an infrequent visitors that find their way into the system on occasion. It is possible that these subsurface drains provide temporary or permanent habitat for eels.

As yet no information has been obtained regarding the species of eel present. However, longfin eel is the most commonly recorded freshwater fish in the Wellington Region (Strictland & Quaterman, 2001) and therefore there is a high probability that at least this species is present. Longfin eel *Anquilla dieffenbachii* is classified as a threatened species on the basis that it is believed to be undergoing a gradual decline in population (Hitchmough *et. al.*, 2007).

3.3 Prince of Wales Park

Within the upstream catchment of the Basin Reserve there are small sections of open stream in Prince of Wales Park, where banded kokopu *Galaxias fasciatus* and koura *Paranephrops planifrons* (freshwater crayfish) were recorded in 2009 (National Freshwater Fish Database, NIWA). These are located almost 1km to the south-west of the Basin. Banded kokopu usually migrate to the sea to complete their life cycle. Migration of fish through the stormwater drains under the Basin Reserve is therefore possible, although this species is also known to form landlocked populations. There are no records of eels for these streams.

There are two streams within Prince of Wales Park a very small stream of approximately 280m length which enters a 0.5m concrete drain at the southern end of Rolleston Street. It is 0.5 to 1m wide, has a steep gradients, with a bed of sands and gravels. The stream is largely unshaded for most of its length.

The main stream in the park has a length of approximately 600m and ranges between 0.75m and 1.0m in width for most of its length, with a maximum width of approximately 2m. It has a steep gradient with riffles and pool sequences. The stream bed is gravels and sands. Depth generally ranges between 0.15 and 0.25m, with a depth of up to 0.3m in pools. Based on a visual appraisal, water quality appears good, with high clarity. Much of the catchment of this stream is wooded with a canopy of mature pines Pinus sp. and poplars Poplar sp. The sub-canopy however supports a variety of native trees and shrubs; *manuka Leptospermum scoparium*, rangiora *Brachyglottis repanda*, *hangehange Genistoma rupestre*, mahoe *Melicytus ramiflorus*, kawkakawa *Macropiper excelsum* and silver fern *Cyathea dealbata*.

A section of this stream located adjacent to playing fields (*Photo 1*) is much more modified with mown grassland along the riparian margin that is next to the field next to the field. Downstream of the playing field there is a steep cascade of approximately 2m which will only be passable by climbing fish species. The stream enters a 0.75m concrete pipe just upstream of Papawai Terrace (*Photo 2*).

3.4 Central Park

Minor streams

There are four small sections of stream draining the eastern part of Central Park. These appear to have their headwaters within the park and range in length from approximately 100m to 150m. They are up to 1m wide and generally very shallow, although in pools they reach a depth of 0.3m. All these streams enter culverts on the boundary of the park adjacent to the tennis courts. Whilst, some sections of these streams may be permanent, some are certainly ephemeral sections i.e. they contained no flowing water at the time of survey, at a time of year when permanent streams would be expected to contain flowing water.

The streams are fairly naturally in their form and have steep gradient, including small natural waterfalls. They may support native species such banded kokopu and koura. However, given their very small size and potentially ephemeral nature of some the stream sections, populations are likely to be small. The catchments of these streams are largely wooded with an exotic canopy of pines and eucalypts. However, there is a native under storey supporting kawakawa, silver fern, manuka, rangiora and mahoe.

All these streams are crossed by one of the park's main walking tracks requiring them to be culverted. Some of these culverts are perched and may not be passable by fish.

Moturua Stream

The main watercourse in the park, the Moturua Stream, is a more substantial permanent stream. It is 450m in length, with headwaters to the south of the park. It ranges between mainly 1.0 and 1.5m in width but in places this increases to 2m. Average water depth is 0.1-0.2m. It has a steep gradient, with riffle and pool sequences. The stream has a gravel bed and water clarity is good. Most of the stream channel has a natural physical character however there are at least two weirs along its course. One of the structures is a 0.75m vertical concrete weir (Photo 4) the other, located close to where it passes into the underground drainages system near Brooklyn Road, is a vertical concrete slab with a minimum 0.4m drop (Photo 3). These structures have the potential to impede fish passage.

The catchment of the stream is largely wooded, with an exotic canopy of pines and eucalypts. However, there is a substantial native component to the sub-canopy with lemonwood *Pittosporum eugenioides*, pate *Schefflera digitata*, wineberry *Aristotelia serrata*, kanono *Coprosma grandifolia*, hangehange, *Carex virgata*, kawakawa, rangiora, kowhai *Sophora sp*. and flax *Phormium tenax*. In some locations this appears to be the result of planting, however, in other areas natural regeneration is occurring.

Banded kokopu and koura (freshwater crayfish) were recorded in Central Park in 2009 (National Freshwater Fish Database, NIWA). Presumably these were recorded in the main stream, although the records do not confirm this. There are no records of eels for these streams.

The main stream given its generally natural character, good water quality and wooded nature of the catchment, provides potentially good upper catchment habitat for native fish. Banded kokopu prefer small streams with bush covered catchments and breed in forest litter when water levels are high so the environment while being somewhat modified in terms of having an exotic canopy, is likely to be good for this species.

That stated, there are at least two man-made structures which may be impeding some fish movement and the underground passage to the park from the sea is likely to prove challenging given the steepness of the gradient and observed water flow velocities entering the drain within the park.

4 Ecological values of stream environments

4.1 Assessment criteria

There are various approaches that can be used to assess the ecological significance of site or species. Section 6(c) of the Resource Management Act (1991) requires the protection of significant indigenous vegetation and significant habitats of indigenous fauna to be recognised and provided for by local authorities as a matter of national importance. As a consequence, a key feature of any approach/criteria used is that it needs to assist in the identification of sites that constitute significant indigenous vegetation and significant habitats of indigenous fauna.

For the purposes of this assessment reference will be made to the following documents/criteria to assist in the process of determining ecological values and sites covered by Section 6(c) of the RMA:

- For sites excluding rivers and lakes

  Environment Waikato and Wildland Consultants Ltd. (November 2002): *Areas of Significant Indigenous Vegetation and Habitats of Significant Fauna in the Waikato Region: Guidelines to applying Regional Criteria and Determine Level of Significance*. Environment Waikato Technical Report TR 2002/15.
- For rivers and lakes

  Warr, S., Perrie, A. and McLea, M. (2009). *Selection of rivers and lakes with significant indigenous ecosystems*. Greater Wellington Regional Council.
- Species

  Hitchmough, R.; Bull, L.; Cromarty, P. (comps) 2007: *New Zealand Threat Classification System lists - 2005*. Department of Conservation, Wellington 194p.

4.2 Values assessment

One of the indicators used by Warr *et. al.* (2009) to identify rivers with significant indigenous ecosystems was the presence of one or more threatened fish species. Banded kokopu, which have been confirmed in the streams forming the upper reaches of this system are not classified as threatened species. No records of longfin eel occurring Prince of Wales Park, or nearby Central Park, were found during this study. This species is classified as threatened by Hitchmough *et. al.* (2007), however, longfin eel is not included in the list of threatened native fish for the purposes of identifying rivers and streams with significant indigenous ecosystems in the Wellington Region Warr *et. al.* (2009). Longfin eel is the most commonly recorded fish in the Wellington Region and its inclusion in the list would have resulted in the majority of rivers and streams being classified as ecologically significant. Warr *et. al.* (2009) considered it to be unrealistic for all watercourses in the Wellington Region to be managed as significant ecosystems.

The lack of records for longfin eel in Prince of Wales Park and Central Park streams does not mean the species is not present, and its occurrence cannot be ruled out. However, even if it were confirmed present at a future date, this would not significantly increase the status of these streams for the reasons stated above.

The sections of stream in Prince of Wales Park and Central Park are not identified in Warr *et. al.* (2009) as watercourses supporting significant indigenous ecosystems. Based on the available information none of these streams would meet the criteria for significant indigenous ecosystems at the Regional level for migratory fish based on the criteria in Warr *et. al.* (2009). However, the presence of native fish and the reasonable habitat quality found in the open sections of streams means that they should be considered to be locally significant.

The stormwater drains that provide connection between the upper catchment habitat and the sea, whilst being highly modified environments, potentially provide critical migratory pathways for banded kokopu and possibly other as yet unrecorded fish species. Furthermore, the frequent observation of eels in the stormwater drainage system indicates that the system is providing some temporary or possibly permanent habitat for one or both species of native eel.

A further factor that needs to be considered is that there has been a community care group associated with undertaking protection of and improvement works on the streams in Prince of Wales Park. There is therefore a community value placed on the streams as well as its intrinsic ecological value i.e. while may only rank as being of local significance when assessed from a biodiversity perspective, it has a very high value to at least some members of the local community.

5 Issues, constraints and risks

5.1 Issues and constraints

A tunnel option through Areas A and B is likely to impact upon and require re-configuration of subsurface drainage structures. This study has determined that the stormwater drains beneath Area B do not extend to upstream habitats and therefore options impacting the subsurface drains within this area should not result in the disruption of fish migration. The stormwater drainage plan (*Figure 2*) indicates that the Moturua Stream bypasses the western extremity of Area B and therefore is outside the area affected by construction works and therefore is avoided.

There is the potential for a tunnel option to impact on stormwater drain at the southern end of Cambridge Terrace in Area A, which connects to the streams in Prince of Wales Park with the sea. Consequently, there is the potential for impact on fish migration. At this stage, the only migratory fish species confirmed as present in Prince of Wales Park is banded kokopu. Other migratory climbing species could however also be present.

Given that eels are regularly observed in many parts of the stormwater drainage system in this part of the City there is the potential to impact upon temporary or permanent eel habitat in both Area A or B, wherever stormwater drains are impacted by the project. However, given that they appear to be widely observed throughout the system, localised works are unlikely to significantly impact on this habitat. Any eels inhabiting this drainage system are able to tolerate what is a highly artificial underground environment, very different from the streams in which they naturally occur i.e. little or no light, artificial substrates of concrete or brick and a wide range of physical and biological components which typical make-up natural stream ecosystems.

5.2 Risks

Impact on fish migration

Tunnelling through the southern end of Cambridge Terrace may result in a significant impact on the migration pathway of native fish between the sea and Prince of Wales Park. However, this would require further investigation to confirm that migration is occurring as this species is also known to form landlocked populations.

If it is assumed for the purposes of assessing risk that migration is occurring could significantly disrupt this migration or prevent it from occurring completely. Clearly severance of drains would require an engineering solution that would reconnect the drainage system however the solutions available may not permit fish passage. One possible solution would be siphon structure that would pass beneath the tunnel. If such structures could be designed so that flow velocities were low enough this may permit fish pass for at least some periods of the year. However, if low enough velocities cannot be achieved or there are other unseen technical design difficulties, permanent loss of fish passage could result. A component significant of the stream fauna would be permanently lost from the upstream environment. This would be a permanent locally significant impact and would result in an effects rating of moderate negative, if no offset mitigation could be achieved.

One possible off set mitigation solution could involve introducing banded kokopu from landlocked populations into the impacted sections of streams. This could also require modification to the streams to create optimal habitat conditions for the survival and reproduction of such a population. However, this option would be dependent on the availability of local landlocked populations to act as a source. There is no guarantee that such an approach would be successful. However, it may be worth attempting if fish passage cannot be achieved. Other forms of offset mitigation could be undertaken such as contributing to other improvements in upstream habitat e.g. native riparian planting or by undertaking improvements to other stream environments in the Region. However, the loss of a species from a section of stream is difficult to ever fully mitigate and such a loss would need to be weighed against the other benefits of the scheme.

In addition to tunnelling or trenching, it is possible that works associated with at grade or elevated structures may result in impacts on subsurface drainage structures e.g. piling. It is more likely that technical solutions to permit fish passage can be incorporated into the diversions around such structures than scenarios requiring drains to be diverted beneath a structure such as tunnels or trenches.

Impact on habitat values of subsurface drains

Any work which disrupts stormwater drains in either Area A or Area B could result in negative effects on eel habitat within these structures beneath the City. However, such effects are likely to be less than minor given the localised nature of any such effects. From discussions with drainage engineers eels appear to be widely distributed and highly mobile within the drainage system. Furthermore, it must be acknowledged that this is for the most part an artificial habitat the primary purpose of which is stormwater management.

5.3 Opportunities

If only minor impacts on subsurface drains occur and fish passage can be maintained it may be possible to improve fish passage through these drainage structures by removing or modification to any current obstacles to fish movement, while these works are in progress. This could increase the numbers of individuals accessing upstream habitat.

5.4 Further investigations

The need for further investigations is dependent on how much disruption the selected option is likely to have on the drainage system in the vicinity of the Basin Reserve and particular at the southern end of Cambridge/Kent Terraces.

If the option selected has no impact at all then no further investigations will be necessary. However, if there is likely to be impact on the drains then as a minimum some further investigations of the fish populations in the streams in Prince of Wales Park will need to be undertaken. This would probably include setting fish traps and electro-fishing.

If works were likely to have a severe impact on the drains with the potential to significantly disrupt fish passage, then in addition to the above, investigations to establish if we are dealing migratory or land-locked fish populations are recommended. However, the methods used involve analysis of the microchemistry of otoliths, which are calcified structures in the fishes head. This necessitates killing the fish. It would need to be established that the populations of species investigated could support the loss of at least 5 individuals from each species investigated. At this stage banded kokopu is the only known species to which this method could be applied.

There may also be some benefits of investigations of fish populations and movements in the subsurface drainage system. However, preliminary discussions with the drainage engineers at Capacity suggest that this may be difficult both logistically and technically. Further, discussions would need to be had to weigh benefits against the difficulties and costs involved before undertaking such work.

If disruption to fish migration was a possibility then consultation with the local community with an interest in the streams in the Prince of Wales Park was also need to be initiated.

6 Conclusions

- Most of the project and surrounding areas comprises built environment, where streams have been piped underground and form part of the Wellington's stormwater drainage system. There are two parkland catchment areas upstream of the project area where natural streams are still present and which support native fish: in Prince of Wales Park and in Central Park. Banded kokopu have been recorded in streams in both parks in 2009. This fish is normally migratory, requiring access to the sea to complete its' lifecycle, although the species can form landlocked populations.
- The Central Park catchment is connected to the sea via a drain which crosses Arthur Street, 100m to the west Cuba Street. The options reviewed to date indicate that tunnelling or trenching does not extend significantly to the west of Cuba Street and therefore fish passage between Central Park and the sea should not be impacted by the project.
- The Prince of Wales catchment is connected to the sea via drains beneath the Basin Reserve and which pass along Kent/Cambridge Terrace to Lambton Harbour. It is these drains that are at greatest risk of significant impact from the project.
- Any options requiring severance of the drains at the southern end of Cambridge/Kent Terraces could result in significant adverse effects on native fish migration pathways. These effects could be either temporary or permanent.
- Tunnelling or trenching presents the greatest risk of a permanent loss of fish passage. This would most likely involve construction of a siphon beneath the tunnel in order to allow water to pass. A key factor in determining whether or not fish can pass will be the flow velocities through the siphon. If velocities are low enough and there are no other obstacles to fish movement, it is possible that fish may pass. However, at this stage there is no guarantee that fish passage can be achieved. Assuming that the population of banded kokopu is migratory and a realistic and cost effective technical solution to allow fish passage cannot be found, the result would be an impact of moderate negative significance.
- One possible off set mitigation could involve the establishment of a land-locked banded kokopu population if a local donor population can be found. This would substantially offset the loss of a migratory population. However there is no certainty that this could be achieved. Other forms of offset mitigation could be undertaken such as habitat improvements within other stream in the Region. Such mitigation can only partially compensate for the loss of a species from part of its range. The residual negative effect with such offset mitigation in place would need to be weighed against the economic and social benefits of the project.
- If the preferred option is likely to result in impact on the drains in question further work will be required to more fully assess the effects on fish migration. Fish surveys will need to be undertaken in the upstream catchments to determine if other species are present. If there is a risk of significant impact on fish migration it is also recommended that investigations are undertaken to try to confirm if the fish are in fact a migratory population i.e. analysis of the microchemistry of otolith in the heads of the fish.

References

Environment Waikato and Wildland Consultants Ltd. (November 2002): *Areas of Significant Indigenous Vegetation and Habitats of Indigenous Fauna in the Waikato Region: Guidelines to applying Regional Criteria and Determine Level of Significance*. Environment Waikato Technical Report TR 2002/15.

Hicks, B. J.; Barry, B. J.; Markwitz, A.; Baker, C. F.; Mitchell, C. P. 2005. *Chronosequences of Strontium in the Otoliths of Two New Zealand Migratory Freshwater Fishes, Inanga (Galaxias maculatus) and Koaro (G. brevipinnis)*. International Journal of PIXE, Vol. 15, Nos 3 and 4 (2005) 95-101, World Scientific Publishing Company.

Hitchmough, R.; Bull, L.; Cromarty, P. (comps) 2007: *New Zealand Threat Classification System lists - 2005*. Department of Conservation, Wellington 194p.

Strickland, R.; Quarterman, A. 2001. *A review of freshwater fish in the Wellington Region*. Cawthron Report No. 669 prepared for Wellington Regional Council.

Warr, S.; Perrie, A.; McLea, M. 2009. *Selection of rivers and lakes with significant indigenous ecosystems*. Greater Wellington Regional Council.

Photographs

Photo 1: Section of stream in Prince of Wales Park adjacent to playing field

Photo 2: Main stream, Prince of Wales Park, entering subsurface drain

Photo 3: Moturua Stream - weir immediately upstream of subsuface drain

Photo 4: Moturua Stream

APPENDIX B:
Archaeology

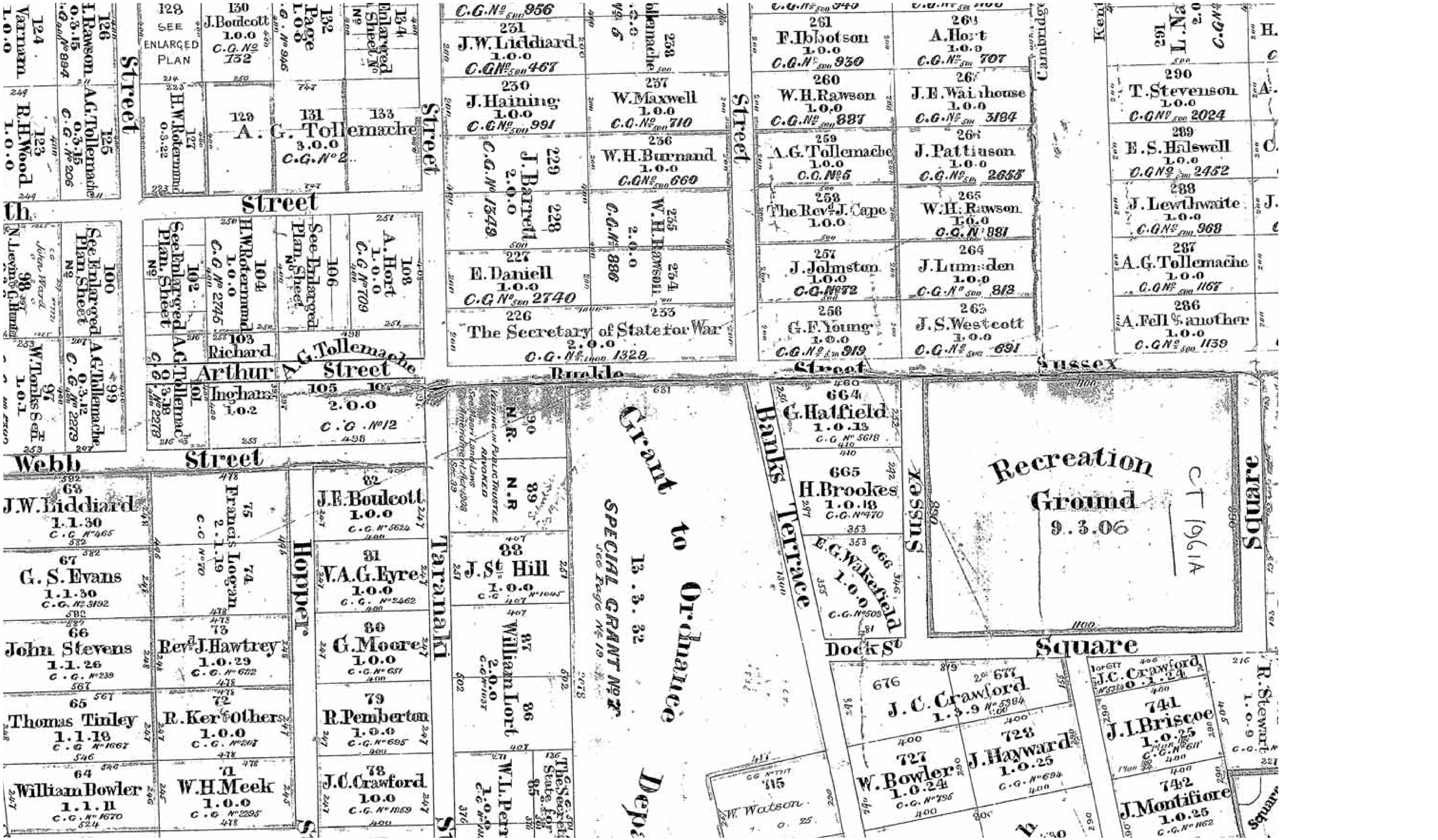


Figure B.1: Part Survey Plan SO 10295 drawn 1879 identifying Town Acres and owners

Town Acres 101, 103, 105 and 107

Town acres 101 and 107, as shown on Figure B.1 were originally purchased by Algernon Tollemache, forming part of the 34 town acres that he acquired from the New Zealand Company. Tollemache also purchased section 105, however he registered this in the name of his wife, the Marchioness of Ailesbury. Town acre 103 was originally purchased by Richard Ingram in 1858, however Ingram sold the section in January 1863 to a Mr Abbott, who sold it later in the year to Tollemache.

Granting of titles appears to have taken some time, however by 1864 Tollemache held titles for all four of the town acres. In January of that year he sold all four of the sections to William Tonks Jr., a local brick-maker. It appears that not long after purchase Tonks took out several mortgages on the properties with Tollemache, as well as with several other parties. In 1869 Tonks was declared bankrupt, and a year later all four sections passed to Walter Turnbull, presumably in order to satisfy mortgage debts (Stirling 2004:18).

The rate books for these sections indicate that the land had been divided into lots by 1868, with information indicating that Tonks had put up 8 houses on the four acres by 1865 / 1866. Although the subdivision of the four town acres may have been started by Tonks, it appears to have been completed by Turnbull, who by 1873 began selling off the 45 lots that now existed on the block. Stirling suggests that it was as a result of the subdivision that an existing lane was formalised, and enlarged to create a street that ran between Cuba Street and Taranaki Street (ibid.). This was named for Arthur, son of William Tonks.

Ward's 1900 plan of residential dwellings in central Wellington indicates that Arthur Street, like many of the small streets of the Te Aro flats, contained dense residential housing. This dense residential pattern remains evident in City Council plans from the 1930s. Many of the older houses on Arthur Street remained for much of the 20th century, although there was a marked shift from residential to commercial use of a number of the Arthur Street properties.

The most recent and dramatic change at the Cuba Street / Arthur Street intersection was the construction of the Inner City By-Pass. This has resulted in the relocation of a number of buildings in this area, and changes to the streetscape.

Town Acres 226 and 233

These two Town Acres border Buckle Street on the north side of the road and run from Taranaki Street at the western end, to Tory Street in the east. The Town Acres occupy Crown Land and have been used by successive governments for military and educational purposes.

Town Acre 226

After the departure of the British forces, Mount Cook became the base for New Zealand's permanent militia whose members were trained in Wellington for deployment throughout the Colony. By the late 1880s, the area occupied by the base had spread across Buckle Street to include land on the northern side of the road. A wooden drill hall was erected to serve the garrison artillery, and a neighbouring barracks provided billets for militia volunteers and members of the police force when they came to the capital for periods of drill instruction. The Defence Stores were situated in this location, from 1894 to 1905, as were quarters for staff.

At some time between 1907 and 1910, the original drill hall was replaced by a second drill hall - The Wellington Garrison Hall. The new hall was located on the corner of Taranaki and Buckle Streets and built from locally manufactured bricks. It was a formidable structure, built above a spacious basement allegedly containing three, 25 yard firing ranges (Aranui 2007:6). In 1913, the Wellington Garrison Hall was the scene of a stand-off between the army and striking seamen, and the military buildings feature in several photographs of this event.

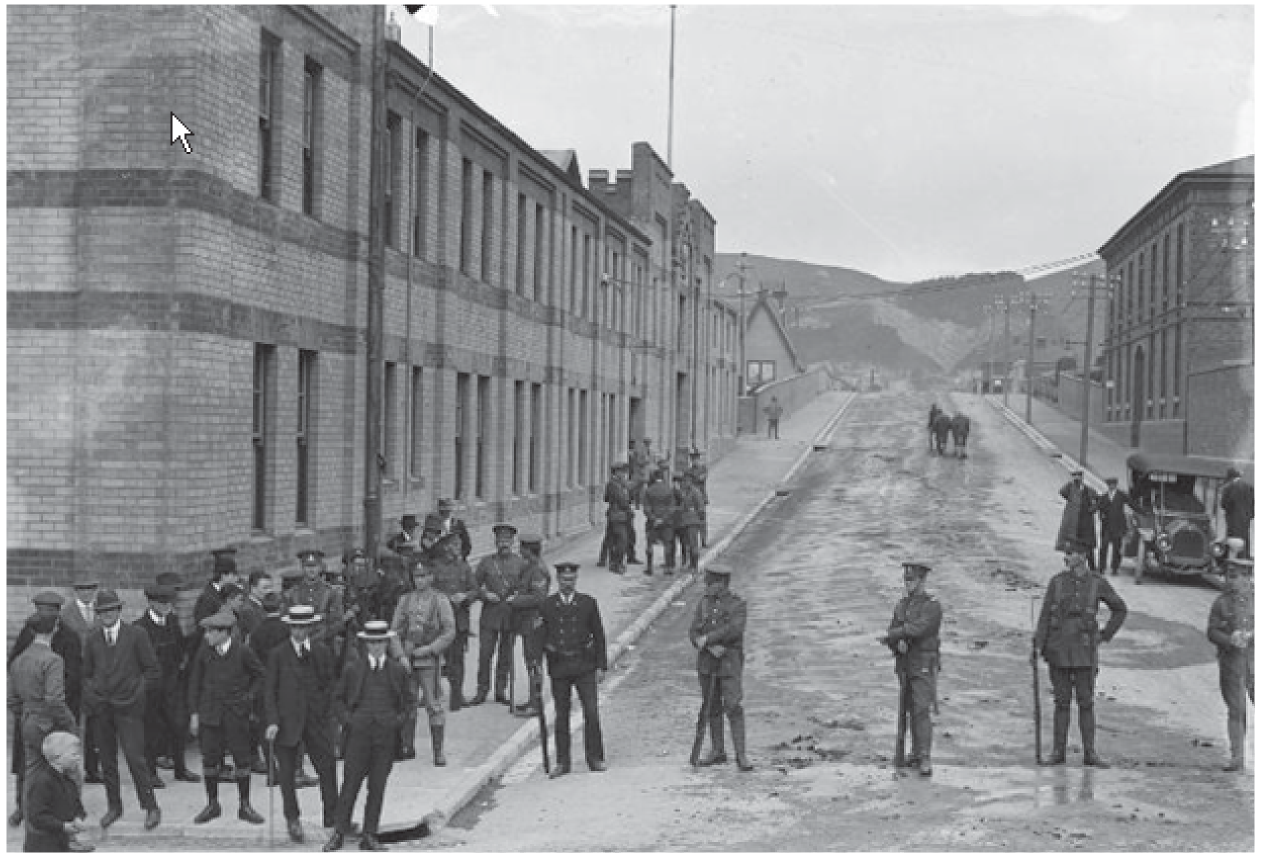


Figure B.2: Soldiers blocking access to Buckle Street during 1913 Waterfront strike. Taranaki Street is in the foreground, and the Garrison Hall on the left. Note also the rise in Buckle Street, in front of the Infants School (gable roof at centre left). Photograph taken by Sydney Charles Smith held in National Library of NZ ref 1/2-049064-G

Town Acre 233

The middle stretch of Buckle Street has had educational associations since the 1870s. The infant department of Mount Cook School was opened here in 1878, and there is some evidence to suggest that Mount Cook Schools forerunner, the Buckle Street (public) School for Boys and Girls, (also called Te Aro School) may have operated here for a time. Wise's Directory listings from 1892 - 1895 suggest that this earlier school occupied the western corner of the Buckle Street/Tory Street intersection, and that the Head Teacher of the Girls' Division, Mrs Catherine Tarn, lived next door to the school. The Mount Cook Infant School, a picturesque wooden building that fronted Buckle Street, was demolished in the mid-1920s, when the large, brick, Mount Cook School was built. This building is visible in the aerial photograph provided with this report as *Figure B.4*. The new school was situated on a site that over lapped Town Acres 226 and 233, and incorporated Mount Cook Girl's School from the south side of Buckle Street, Mount Cook Boys' School from Taranaki Street, and a school for infants. At the time it was built, dwellings on Franklin Terrace and Tory Place at the rear of the site, were demolished in favour of playgrounds. In 1930, Ako Hill, the steep gradient in the road in front of the school and visible in *Figure B.2* was reduced in the interest of improving the route between eastern and western suburbs of Wellington.

This section has been modified since the 1930s. Following demolition of the brick school in the late 1970s a petrol station existed on the Tory Street / Buckle Street end of the section. It is likely that installation of tanks for operation of the station has destroyed evidence of some of the earlier buildings at this location.

The southern side of Buckle Street in this block contains a significant number of heritage sites, including (from east to west) the Mt Cook Police Barracks, the Carillon, National War Memorial and former Dominion Museum building, the former General Headquarters NZDF, and HMNZS Olphert. There is also a brick wall, running from the intersection of Buckle Street north along Tasman Street that is registered as a Category II site with the Historic Places Trust, made of bricks by prisoners in the former Mt Cook prison. These buildings are discussed in the built heritage report to be provided by Ian Bowman as part of this project.

Although a number of significant heritage features and buildings exist on the southern side of Buckle Street opposite Town Acre 233, it is important to note that extensive earthworks on this part of Mt Cook have occurred over the years - from the construction of military barracks, a prison, and eventually the Dominion Museum and Carillon (see *Figure B.3*). It is also noted that there are a number of tunnels and underground bunkers reported to be located under and around the museum building, associated with military use of the site, particularly during World War II.

There are reports of historic underground tunnels from the northern side of Buckle Street crossing to Mt Cook, however research to date has not identified or confirmed any evidence of these.

Figure B.3: 1936 photograph of Carillon and Museum National Library of New Zealand http://timeframes.natlib.govt.nz PAColl-6585-62

Figure B.4: 1934 aerial view of Basin Reserve and surrounding streets. Note Dominion Museum on Mt Cook under construction, the two storied school opposite the Carillon and the rectangular military buildings to the west of the Carillon, including the GHQ. http://timeframes.natlib.govt.nz Reference No. PAColl-6301-59

APPENDIX C:
Tunnel Design Requirements

Background

The ventilation design and fire safety design for almost all vehicle tunnels will be carried out on a performance basis.

The required ventilation rate in normal operation will be affected by:

- The predicted emissions of the vehicle population expected to use the tunnel throughout the life of the tunnel;
- Allowable concentrations of pollutants within the tunnel and occupant exposure time; and
- Allowable discharges from portals or exhaust stacks.

The fire safety features provided for the tunnel including the distance between egress points will involve consideration of a multitude of factors including:

- Assessment of the design fire size (this will be affected by the use of the tunnel by dangerous goods vehicles, heavy goods vehicles, buses etc.);
- Assessment of the design fire growth rate;
- Tunnel geometry and gradients; and
- Tunnel ventilation philosophy, technology and capacity.

Since at the concept development stage none of these analyses have been carried out, it is appropriate to use simpler methods such as international standards and design guides to consider options.

Maximum length of tunnel not requiring mechanical ventilation

The primary need for ventilation of a vehicle tunnel during normal operation is governed by the need to control the internal air quality in the tunnel. For mixed vehicle traffic the governing pollutant is normally carbon monoxide (CO). Where a large proportion of the traffic is diesel based, the NOx emissions (NO and NO2) can become important. For vehicle tunnels CO normally dominates as the primary pollutant and a typical control range would be 50 - 100 ppm.

Natural ventilation is driven by the pressure differential created by differences in elevation between the portals, air temperature difference between the tunnel interior and exterior environment and wind effects.

Where there is uni-directional traffic flow in the tunnel, vehicle movement can create a piston effect. This may either assist or counter natural ventilation flows depending on the specific details of traffic flow and wind direction. For example, with a tunnel of east - west orientation with a prevailing westerly wind, traffic flow eastwards would aid the predominant natural ventilation. Conversely, traffic flow westward would counter the natural ventilation induced by the prevailing wind, and the natural ventilation would be less effective. Variable ventilation effectiveness would be the prime characteristic of a naturally ventilated tunnel.

The main limitation to the length of a natural ventilated tunnel is fire safety. Hot smoke from a fire will rise to ceiling level and create a ceiling jet which travels both ways down the tunnel (given that traffic and environmentally induced air flow is negligible). While the smoke remains stratified, the environmental conditions underneath the smoke layer are adequate for occupants to evacuate particularly in the early stages of a fire. However the smoke layer loses heat to the tunnel structure and the fire-induced and other natural air flows result into a flow into the tunnel from each portal. This flow also mixes with the hot smoke layer. The combined effect is to reduce the buoyancy of the smoke layer and to cause it to descend towards the tunnel floor, eventually compromising visibility and exposing evacuees to irritants and toxic products within the smoke. Coupled with the very real effect of environmentally induced and traffic induced air flows, the fire safety of naturally ventilated tunnels is highly variable. Therefore naturally ventilated tunnels are normally restricted to relatively short lengths. The definition of 'relatively short' is itself highly variable and has changed over time.

Many countries in Europe in particular have their own tunnel ventilation guides and standards. These are in a state of constant flux, but typically naturally ventilated tunnels of up to 700 m are allowed in Germany and up to 400 m in the U.K. provided there is technical justification.

ASHRAE [1] suggests that natural and traffic-induced ventilation are adequate for relatively short tunnels and those with low traffic volume or density, while long tunnels require mechanical ventilation. They indicate the tunnel length at which this change in design philosophy takes place is somewhere between 350 and 650 m. However it is unclear as to whether this recommended maximum length for a naturally ventilated tunnel is based solely on internal air quality, or includes fire safety criteria.

Two USA based fire safety standards, NFPA 502 [2] and NFPA 130 [3] apply to road and rail tunnels respectively. Neither addresses the issue of air quality within the tunnel during normal operations. Each has similar objectives in regards to smoke control and fire safety during emergencies. Both standards use tunnel length as an indicator of whether natural or mechanical ventilation is required.

NFPA 130 requires mechanical ventilation in tunnels of over 300 m. For tunnels between 60 m and 300 m it allows engineering analysis to be used to determine whether mechanical ventilation is required to provide adequate safety. Below 60 m, no such analysis is required, i.e. a tunnel of up to 60 m in length is deemed to be adequately fire safe using natural ventilation.

NFPA 502 does not apply to tunnels below 90 m. It requires conditionally mandatory mechanical ventilation for smoke control for tunnels of over 240 m.

In summary, based on the requirements of NFPA 130 and NFPA 502:

- Tunnels of 60 - 90 m have no analysis requirements, hence by implication, no mechanical ventilation is required and natural ventilation should suffice.
- Tunnels of order 240 - 300 m will require mechanical ventilation.
- Tunnels of 90 - 240 m may avoid the need for mechanical smoke control subject to being able to prove adequate fire safety (and internal air quality during normal operation).

One option for example could be to provide closer spacing between the means of escape, which would allow occupants to evacuate from the tunnel in a shorter period of time. Whether such a strategy could succeed may depend on control of the fire load within the tunnel and may require the eliminating of dangerous goods vehicles and possibly heavy goods vehicles (and even buses), as these provide a potentially higher peak fire load and faster fire growth rates than a tunnel restricted to light weight vehicles only.

Maximum length of tunnel not requiring require an independent fire rated means of escape which is separate from the main traffic lanes.

NFPA 502 [2] suggests the maximum distance between emergency exits in tunnels which otherwise comply with the standard should be 300 m. If the portals are treated as emergency exits, then only tunnels with a length of greater than 300 m would require a separate mid-tunnel means of escape.

NFPA 130 [3] suggests that spacing of cross passage-ways between tunnels should be no greater than 244 m, i.e. that means of escape should be no further apart than 244 m.

DR AS 4825 [4] suggests a maximum separation of egress points of 120 m in road tunnels and 240 m in rail tunnels.

A performance based design would balance the separation between egress points against the design fire size and growth rate (i.e. dangerous goods vehicles allowed / not allowed, heavy goods vehicles allowed / not allowed, etc), type and performance of the ventilation system (natural, longitudinal, full transverse, etc.) and provision of fire safety precautions (early detection, automatic deluge, manual deluge etc.). Longer distances between means of escape would inevitably require limitations to tunnel usage or increase in ventilation and suppression.

Summary:

- The conservative interpretation of the referenced documents is that egress points should be separated by no more than 120 m. Under this criterion, a tunnel more than 120 m long would require an intermediate egress point.
- Using a performance based design approach the separation between egress points could be increased but would probably require the addition of a mechanical ventilation system to provide smoke control, and/or fire suppression systems and/or restriction of types of vehicle that could use the tunnel.

If mechanical ventilation is required, can this be placed in a service tunnel to the side of the tunnel - rather than on top of the tunnel - to minimise the height of the tunnel?

The most common and lowest cost mechanical ventilation system used in tunnels is based on longitudinal ventilation, usually provided by axial jet fans mounted under the roof of the tunnel. If the tunnel traffic flow is uni-directional (as in this case) the fans can be lower cost uni-directional fans rather than the more expensive reversible fans. The fans can be used for both internal air quality control during normal operation and for fire safety.

Jet fans are normally located approximately 80 - 100 m from the portals to minimise electrical cable run distances. Location directly at the portals is not recommended as the installation becomes less effective and more plant is needed to achieve the same result. For a tunnel of about 300 m in length, typically there would be two sets of jet fans, each located 100 m from the portal and each other.

The current nominal tunnel height of 8.5 m allows a 2.5 m zone for ventilation and services above the traffic zone of 6.0 m height. The allowance of 2.5 m for services is generous and this could easily be reduced by 1.0 m to 1.5 m. Therefore an overall tunnel height of 7.5 m could reasonably be expected using jet fans for longitudinal ventilation.

Mechanically induced longitudinal flow can also be achieved using above ground fan plant to inject air into the tunnel through Saccardo nozzles integrated into the tunnel roof design. This allows the tunnel height to be reduced further at the expense of providing one or more plant rooms at grade. A smaller number of higher capacity, higher efficiency fans would normally be used in the at grade plant rooms resulting in more economical operation, but higher capital cost for the ventilation system compared with the jet fan case.

For a developing fire in a horizontal tunnel without external environmental or traffic induced effects, the smoke layer will spread equally in both directions. Since occupants in vehicles upstream of the fire will often be trapped in the tunnel (by the incident / accident which caused the fire) it is important to keep the upstream section of the tunnel free of smoke. Conversely, vehicles downstream of the fire can drive out of the tunnel (as long as the tunnel is not congested).

For uni-directional traffic flows, the jet fans would discharge in the direction of traffic flow. This would prevent smoke from back-layering down the tunnel towards the entrance and would create the required smoke free zone upstream of the fire to allow occupants of vehicles sufficient time to escape towards the entrance portal or other intermediate means of escape.

The mean velocity induced in the tunnel to prevent back-layering depends primarily on the peak fire size with tunnel gradient having a secondary effect. A typical back-layering velocity of 2.2 m/s is recommended for planning purposes. For tunnel dimensions of 14.0x7.5 m, a volume flow of 230 m3/s would be required. A downhill sloping tunnel will have an additional gravitational buoyancy component which needs to be overcome, increasing the required flow by up to 25% typically. Of course local wind effects can either assist or hinder the smoke clearance system operation.

Note that this longitudinal smoke control philosophy is not recommended for bi-directional traffic flows as downstream of the fire location, the excessive turbulence generated by the jet fans will normally disrupt the smoke layer sufficiently to fill the tunnel with smoke. Similarly, use of jet fans in congested uni-directional tunnels can be problematic, as vehicles downstream of the fire may not be able to drive out of the tunnel ahead of the advancing smoke layer. Once the jet fans are turned on (to create a smoke free area upstream of the fire), the contaminated downstream zone will become a major risk if occupants have not evacuated the tunnel.

An alternative to the use of jet fans is the use of semi-transverse or full transverse ventilation.

Semi-transverse ventilation would consist of either:

- A supply air plenum along the length of the tunnel, typically supplying at low level through at or near road level transverse to the tunnel direction. The supply air plenum could be mounted on one side of the tunnel, on both sides, or under the roadway; or
- An exhaust air plenum at high level through the tunnel exhausting air from under the ceiling slab. In principle a single exhaust plenum at the side of the tunnel could be used. However given that the tunnel has a nominal width of 14.0 m, the exhaust ventilation during normal operation would become ineffective in the lanes most remote from the intake points to the exhaust plenum, i.e. in exhaust only operation, the ability to scavenge vehicle exhaust products from the far side of the tunnel would be limited.

The alternative is to provide exhaust plenums on both sides of the tunnel (which increases overall tunnel width), or to provide exhaust across the full width of the tunnel by creating a ceiling plenum. The latter would effectively save no vertical height compared with a jet fan installation.

For both semi-transverse configurations the supply or exhaust fan plant would be located at or near the tunnel portals, i.e. outside the tunnel proper.

A full - transverse ventilation system would comprise both low level supply air and high level exhaust air systems as discussed for the semi-transverse configuration options above. This could be effective in a 14 m wide tunnel with a single low level supply and single high level exhaust duct appropriately arranged such that the transverse supply air discharge encourages contaminated air to move towards the single sided exhaust plenum.

The smoke control philosophy is more complicated with these systems [5]. The exhaust rate in the fire zone and further downstream is maximised while minimising the amount of outside air that is supplied in these zones.

A longitudinal airflow in the direction of traffic flow is then created by operating the upstream ventilation zones in maximum supply.

To achieve a typical design back-layering velocity of 2.2 m/s a supply and exhaust volume of the order of 230 m3/s would be required. At a peak average in-duct velocity of 15 m/s, this would require a supply and exhaust duct of approximately 15 m^2 each.

Summary:

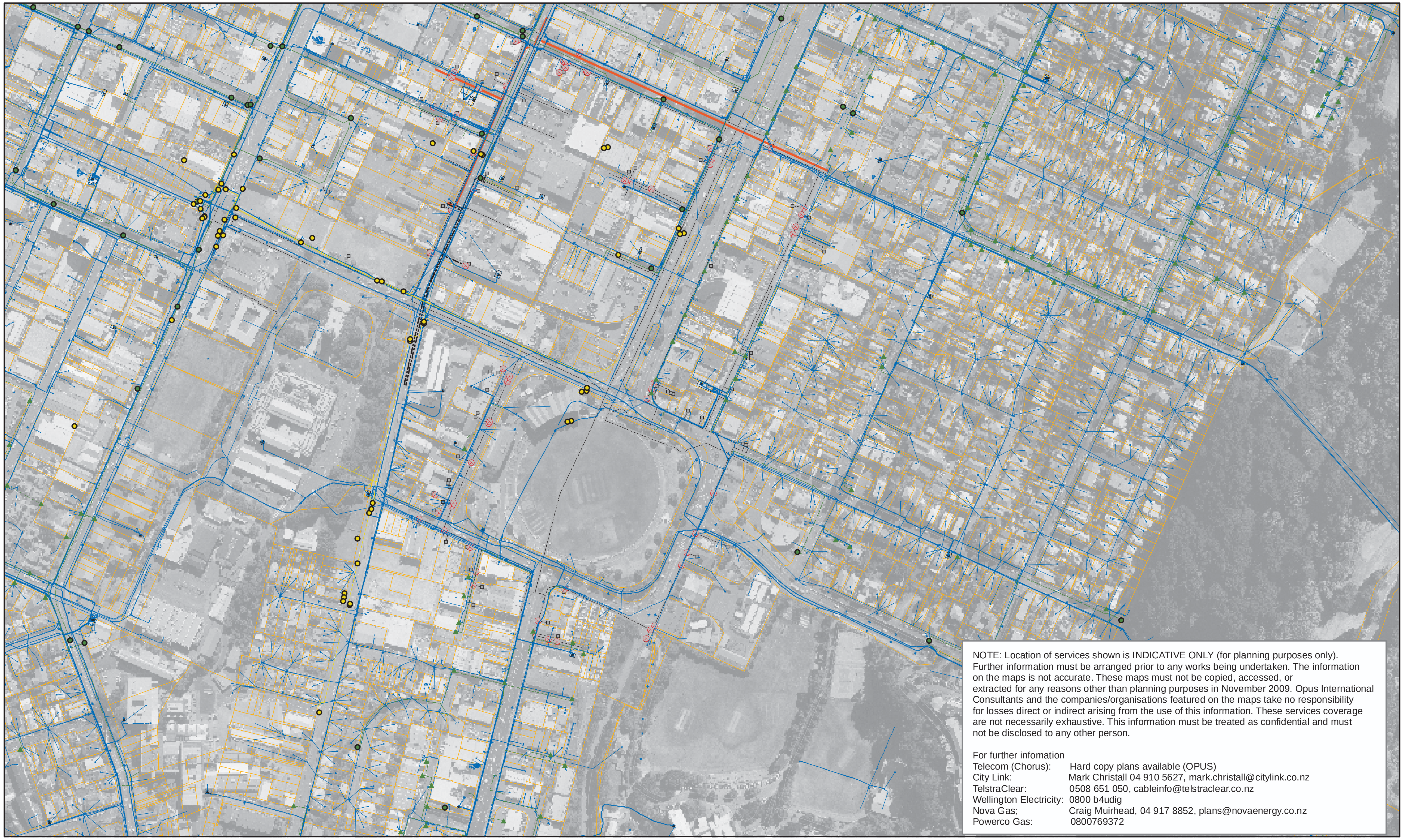
- Adequate ventilation for normal operation can be achieved with ventilation ducts located at the side of the tunnel. Supply and exhaust ducts of approximately 15 m^2 each would be required. This space allowance would be fine-tuned during the design process.
- Ventilation plant rooms would be required outside the tunnel at grade.

References

1. 2007 ASHRAE Handbook, HVAC Applications, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.
2. NFPA 502:2010, Road Tunnels, Bridges and other Limited Access Highways, National Fire Protection Association.
3. NFPA 130:2010, Standard for Fixed Guideway Transit and Passenger Rail Systems, National Fire Protection Association.
4. DR AS 4825, Tunnel Fire Safety (Draft), Standards Australia
5. Beard, A. and Carvel, R., The handbook of tunnel fire safety, Thomas Telford Publishing, 2005

APPENDIX D:
Service Plans

Basin Reserve Utilities



NOTE: Location of services shown is INDICATIVE ONLY (for planning purposes only). Further information must be arranged prior to any works being undertaken. The information on the maps is not accurate. These maps must not be copied, accessed, or extracted for any reasons other than planning purposes in November 2009. Opus International Consultants and the companies/organisations featured on the maps take no responsibility for losses direct or indirect arising from the use of this information. These services coverage are not necessarily exhaustive. This information must be treated as confidential and must not be disclosed to any other person.

For further infomation
Telecom (Chorus): Hard copy plans available (OPUS)
City Link: Mark Christall 04 910 5627, mark.christall@citylink.co.nz
TelstraClear: 0508 651 050, cableinfo@telstraclear.co.nz
Wellington Electricity: 0800 b4udig
Nova Gas; Craig Muirhead, 04 917 8852, plans@novaenergy.co.nz
Powerco Gas: 0800769372

Client:

Prepared By:

City Link
Point
Cable

Telstra
Pedestal
Vault
Trench

Wellington Electricity
Cable
Transformers/Sub-Stations

Telecom
Cable
Fiber Optic High Capacity

Nova Gas
Pipe

Power Co
Valve
Gas Measure
Installation
Syphon
Tee valve
Coupling

In Use
LIP 700-1200kPa
LMP25-210kPa
Not in use but cant be removed (Gas duct)
Not in use but cant be removed

Kerbs
Parcels

Project:
Basin Reserve Project

Job No:
5-C1617.00

Date:
Nov 2009

Scale
1:3500

N

Basin Reserve Water Services

Client:

Prepared By:

WCC Services
- Drain Sewer Nodes
- Drain Stormwater Nodes
- Network Nodes
- Service Nodes
- Sewer Pipes
- Stormwater Pipes
- Network Pipes
- Service Pipes
- Kerbs
- Parcels

Project: **Basin Reserve Project**

Job No: **5-C1617.00**

Date: **Nov 2009**

Scale **1:3500**

N

APPENDIX E:
Cost Estimating

NOTES ON OPTION F - M ESTIMATES

AS AT 16TH OF AUGUST 2010

The following notes are intended to outline the assumptions made during the cost estimating process and also to show how the estimates were built up.

Option F Cost Estimate

- Based on original cost estimate carried out on the 24th December 2009 and cost estimate modified to include Sussex Street on-ramp on 26th of June 2010.
- Changes to estimate include works associated with new on-ramp (Geotechnical, services, traffic management etc) and cost of new on-ramp. Option F estimate already has provision for a three lane section of tunnel.
- For cost estimate it was assumed that the 33kV cable running parallel to the southern side of Buckle Street would not require relocation. This is based on the current design which has the Sussex Street on-ramp at a similar level to the existing levels over the cable. Should the design change and the levels require the cable be relocated a significant cost would be associated with these works.

Option G Cost Estimate

- Option G cost estimate is a based on the Option F estimate carried out on 26th of June and the additional estimating undertaken for the tunnel to continue from east of Taranaki Street to Cuba Street.
- Methodology and assumptions for Option G can be found In 'Option G War Memorial Tunnel Methodology'.

Options H through M;

- Options H, J and L are based on Option A from the original Basin Reserve option estimates with various options through Memorial Park added onto them. For assumptions associated with Option A see the Options Estimate Report produced December 2009.
- Options I, K and M are based on Option B from the original Basin Reserve option estimates with various options through Memorial Park added onto them. For assumptions associated with Option B see the Options Estimate Report produced December 2009.
- No allowance for the construction of the Memorial Park has been included in these estimates.

Options H and I

- Option H is based on Option A with the addition of a short tunnel surfacing before the Taranaki Street intersection.
- Option I is based on Option B with the addition of a short tunnel surfacing before the Taranaki Street intersection.
- For both options the western end of the tunnel is assumed to be constructed more similar to an open top trench than a cut and cover tunnel.
- Options H and I are assumed to have no significant effect on the ground water in the area.

Options J and K

- Option J is based on Option A with the addition of an at-grade solution in front of the war memorial. The at-grade estimate is based on the feasibility estimate for the Buckle Street Re-alignment produced 20 July 2009 by Opus. Escalated to the September 2009 index.
- Option K is based on Option B with the addition of an at-grade solution in front of the war memorial. The at-grade estimate is based on the feasibility estimate for the Buckle Street Re-alignment produced 20 July 2009 by Opus, escalated to the September 2009 index.
- This estimate allows for some decorative concrete works in front of the war memorial.

Options L and M

- Option L is based on Option A with the addition of a long tunnel surfacing before Cuba Street. The cost of this tunnel is based on the estimate produced for Option G.
- Option M is based on Option B with the addition of a long tunnel surfacing before Cuba Street. The cost of this tunnel is based on the estimate produced for Option G.
- Options L and M are assumed to have no significant effect on the ground water in the area.
- Options L and M will follow a similar methodology to construction a tunnel across Taranaki Street as Option G.

OPTION G WAR MEMORIAL TUNNEL METHODOLOGY

AS AT 16TH OF AUGUST 2010

The following methodology was produced to show how a tunnel could be constructed from Buckle Street adjacent to Sussex Street through to Cuba Street. This is only one possible methodology for construction through this area. This methodology does not deal with the construction issues associated with construction of the tunnel from the Mt Victoria Tunnel through to Sussex Street. This methodology could also apply to the same portion of tunnel for Options L and M.

Givens:

- Methodology and Estimate cover Sussex Street on-ramp, and tunnel and trench sections on SH1 for the length from Station 200.00 to Station 730.00 (DWG 5/10/2/5504/172 Option G Tunnel Through Taranaki St (Memorial Park) Including Sussex St On-Ramp).
- All traffic and pedestrian movements must be maintained at all times but the number of lanes and speeds may be temporarily reduced.

Assumptions:

- Cost for 'Memorial Park' excluded.
- Tunnel is fully constructed up to Station 730 where the Memorial Park section of works begins.
- Finished levels of road surfaces which have been cut for the tunnel will be reinstated to the same as existing.
- No services can be made redundant without replacing them elsewhere.
- Services are able to be diverted to a standard acceptable to the relevant service authorities, no cost share allowance has been made.
- Assumed that the un-reinforced concrete building at 30 Arthur can be suitably strengthened such that it can be temporarily moved, an allowance to strengthen has been included.
- Assumed noise attenuation measures include noise barriers, planting etc.
- Site security allowed for in P&G.
- Relocated buildings will not be occupied while in temporary storage, hence no allowance for temporary services (other than stormwater) has been made.
- No improvements to existing Pavements (e.g. low noise surfacing) will be made.
- Service relocations based on WICB Services Drawings (2002), and incorporate services installed during WICB project.
- A 48 month period has been allowed for construction for this section of the works. This time does not allow for the construction of other sections of the Basin Reserve Improvement project.
- The Arthur Street temporary road diversion will be constructed with a sealed pavement and removed once the Buckle Street trench works are completed.
- Some services will need to be shifted before construction of 'cut and cover trench', some during construction and some after construction.
- The Arthur Street service lane will be reinstated after construction of the trench is complete, some disruption to access to the service lane and parking on the service lane will occur during construction.
- The trench is assumed to have minimal effects on ground water in the area.

The following methodology should be read in conjunction with drawing SK-G1 which shows the positions of the features identified in the methodology.

Construction Methodology:

1. Tunnel is constructed from Stn 730 up to Tory Street intersection. Sussex St on-ramp trench to be constructed at the same time with little effect on traffic.
2. Tory Street diverted to the East of the existing intersection while Tunnel across Tory Street is constructed. Tunnel across Tory Street to be of Top Down construction method.
3. Reinstate Tory Street intersection as per previous.
4. Construct Tunnel up to Newtown Sewer (approximately at Stn 480), excavated material can be removed via entrances to site on Taranaki or Tory Streets. Construction using 'cut and cover' method. Temporary soil stabilisation via soil nails or sheet piling if space becomes limited.
5. Divert Newtown Sewer under newly constructed tunnel section.

6. Construct new tunnel section up to Taranaki-Buckle Intersection, excavated material can be removed via Tory Street, 'cut and cover' or sheet piles if space limited.
7. Diversion of Tory Stormwater Culvert (approximately at Stn 380), potentially diverted from Southern side of Taranaki Street east across Taranaki Street and along Buckle Street until turning north at a point where there is sufficient cover for it to cross the tunnel and rejoin at the manhole on the northern side of the tunnel. The Tory Culvert is planned to tie into the new Te Aro culvert in the future, coordination for this eventuality needs to be further investigated.
8. Taranaki Street Services - divert 33kV east and over new tunnel section, remove end 10-20m of Te Aro Culvert. Other services may need to be diverted over new tunnel section or above ground. This work can only be undertaken between Christmas and New Year when there is sufficient redundancy in the system to allow this cable to be turned off. Tory Street stormwater will also need to be relocated at this stage.
9. Construct Tunnel section across southbound Taranaki Street (using Top-Down construction method), divert traffic over new section of tunnel to the east. Set back Buckle Street intersection to the east of the existing position to make way for realigned Taranaki Street. Excavated material can be removed via the tunnel. Geometrics of diversions may be to a reduced standard.
10. Reinstate Roadway atop of new tunnel section (could be done before this tunnel section is completely finished).
11. Construct Tunnel section across northbound Taranaki Street (using Top-Down construction method), leave Southbound Taranaki on same diversion, divert Northbound Taranaki over new portion of Tunnel. Realign first 30-50m of Arthur Street to the South on footpath and pedestrian facility at intersection. Excavated material can be removed underground via the tunnel.
12. Temporarily relocate (or demolish) buildings on the south-east corner of Cuba and Arthur Street and other building further to the east on Arthur Street. Realign Arthur Street to the North of existing SH1 so all traffic is outside of Trench construction footprint. Possibly close off Cuba Street either side of SH1 to improve flow.
13. Remove Te Aro Culvert and reinstate on new route (further to the West on Arthur Street). Majority of Arthur Street services are in the service lane, any services needed to be diverted could also be put into the service lane. Arthur Street services cause largest issues at Taranaki and Cuba intersections.
14. Construct Trench Structure down Arthur Street Section (potential to send traffic around Webb Street if only for temporary time). Access to the Arthur Street service lane will be disrupted during this stage (loss of car parking on the service lane, reduced lane width).
15. Once trench is completed construct new on-ramp from Taranaki Street and then shift relocated buildings back to their original location.

These notes are to be read in conjunction with the 'Option G' Cost Estimate prepared on the 16h of August 2010.

Project Estimate

FE

Basin Reserve Improvements Investigation

Item	Description		Option F	Option G	Option H	Option I	Option J	Option K	Option L	Option M
			Base Estimate	Base Estimate	Base Estimate	Base Estimate	Base Estimate	Base Estimate	Base Estimate	Base Estimate
A	Nett Project Property Cost		10,800,000	16,000,000	12,200,000	21,800,000	12,200,000	21,800,000	14,000,000	23,600,000
	Investigation and Reporting									
	- Consultancy Fees		8,800,000	8,800,000	6,140,000	6,300,000	3,020,000	3,140,000	8,800,000	8,800,000
	- NZTA Managed Costs		2,940,000	2,940,000	2,050,000	2,100,000	1,010,000	1,050,000	2,940,000	2,940,000
B	Total Investigation and Reporting		11,740,000	11,740,000	8,190,000	8,400,000	4,030,000	4,190,000	11,740,000	11,740,000
	Design and Project Documentation									
	- Consultancy Fees		7,330,000	7,330,000	5,110,000	5,250,000	2,520,000	2,620,000	7,330,000	7,330,000
	- NZTA Managed Costs		2,940,000	2,940,000	2,050,000	2,100,000	1,010,000	522,500	2,940,000	2,940,000
C	Total Design and Project Documentation		10,270,000	10,270,000	7,160,000	7,350,000	3,530,000	3,142,500	10,270,000	10,270,000
	Construction									
	MSQA									
	- Consultancy Fees		5,990,000	8,090,000	5,110,000	5,250,000	2,520,000	2,620,000	7,330,000	7,330,000
	- NZTA Managed Costs		2,400,000	3,240,000	2,050,000	2,100,000	1,010,000	1,050,000	2,940,000	2,940,000
	- Consent Monitoring Fees		1,200,000	1,620,000	1,030,000	1,050,000	510,000	530,000	1,470,000	1,470,000
	Sub Total Base MSQA		9,590,000	12,950,000	8,190,000	8,400,000	4,040,000	4,200,000	11,740,000	11,740,000
	Physical Works									
1	Environmental Compliance		300,000	300,000	300,000	300,000	150,000	150,000	250,000	300,000
2	Earthworks		1,130,000	1,350,000	1,450,000	1,720,000	965,000	1,180,000	1,520,000	1,610,000
3	Ground Improvements		2,300,000	4,000,000	1,875,000	1,900,000	350,000	350,000	2,400,000	2,450,000
4	Drainage		1,160,000	1,370,000	1,240,000	1,360,000	870,000	1,000,000	1,260,000	1,370,000
5	Pavement and Surfacing		1,590,000	1,980,000	1,770,000	2,190,000	1,840,000	2,240,000	1,920,000	1,830,000
6	Bridges		0	0	18,000,000	17,600,000	18,000,000	17,600,000	18,000,000	17,600,000
7	Retaining Walls		0	0	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000	3,000,000
8	Traffic Services		2,760,000	3,730,000	2,760,000	2,870,000	2,010,000	2,270,000	3,410,000	3,410,000
9	Service Relocations		8,000,000	17,500,000	3,500,000	3,500,000	1,500,000	1,500,000	13,000,000	13,000,000
10	Landscaping		8,450,000	9,680,000	9,820,000	11,430,000	9,310,000	10,930,000	12,040,000	13,860,000
11	Traffic Management and Temporary Works		2,000,000	3,970,000	2,100,000	2,500,000	970,000	980,000	3,750,000	4,000,000
12	Preliminary and General		23,940,000	32,340,000	20,440,000	21,000,000	10,050,000	10,450,000	29,320,000	29,320,000
13	Extraordinary Construction Costs		68,040,000	85,470,000	35,912,000	35,612,000	1,200,000	600,000	56,721,000	55,030,000
	Sub Total Base Physical Works		119,670,000	161,690,000	102,167,000	104,982,000	50,215,000	52,250,000	146,591,000	146,580,000
D	Total Construction		129,260,000	174,640,000	110,357,000	113,382,000	54,255,000	56,450,000	158,331,000	158,320,000
E	Project Base Estimate	(A+B+C+D)	163,000,000	213,000,000	138,000,000	151,000,000	75,000,000	86,000,000	195,000,000	204,000,000
F	Contingency (Assessed/Analysed)		33,836,000	45,190,000	28,518,900	31,149,400	15,276,000	17,628,500	40,875,200	42,809,000
G	Project Expected Estimate	(E+F)	196,000,000	258,000,000	167,000,000	183,000,000	90,000,000	104,000,000	236,000,000	247,000,000
		% of Base	120%	121%	121%	121%	120%	121%	121%	121%
H	Funding Risk (Assessed/Analysed)		82,947,393	111,969,538	56,629,715	71,579,994	33,704,647	49,506,149	88,081,883	102,256,143
I	95th percentile Project Estimate	(G+H)	279,000,000	370,000,000	224,000,000	254,000,000	123,000,000	153,000,000	324,000,000	349,000,000
		% of Base	171%	174%	162%	168%	164%	178%	166%	171%

Date of Estimate	16/08/2010	Cost Index, Sep 2009
Estimate prepared by	[signature] 16/8/10	Simon de Rose
Estimate internal peer review by	[signature] 16/8/10	Keith Atkinson
Estimate external peer review by		
Estimate accepted by NZTA		

Note: (1) These estimates are exclusive of escalation and GST.
(2) Option F does not include Sussex Street on ramp
(3) Option G is draft only and requires further inputs regarding
- Property Cost
- Landscaping and Urban Design mitigation
- Services
(4) To be read in conjunction with 'Option G Memorial Park Cut and Cover Trench Methodology'

Want to find out more?

Our contact details

For general enquiries, or contact information about NZ Transport Agency please check our website ***www.nzta.govt.nz*** or email us at ***info@nzta.govt.nz***

NATIONAL OFFICE
Victoria Arcade
44 Victoria Street
Private Bag 6995
Wellington 6141
Telephone: +64 4 89 5400
Fax: +64 4 894 6100

NZ TRANSPORT AGENCY
WAKA KOTAHI

New Zealand Government