FINAL REPORT

Britomart West Rail Extension Feasibility Study

Prepared for

Rapid Transit Group

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Executive Summary

The Britomart West Rail Extension is a proposed tunnel from the Britomart Station to the Western Rail Line at Mt Eden along with two new stations (below ground) and a relocated Mt Eden Station. This is shown on Figure 1 below (indicative alignment only). The tunnel extension would enable Britomart Station to operate as a through station. This would increase the available capacity of the Britomart Station, enabling it to meet projected future network demand and opening up rail access to the west side of the CBD.

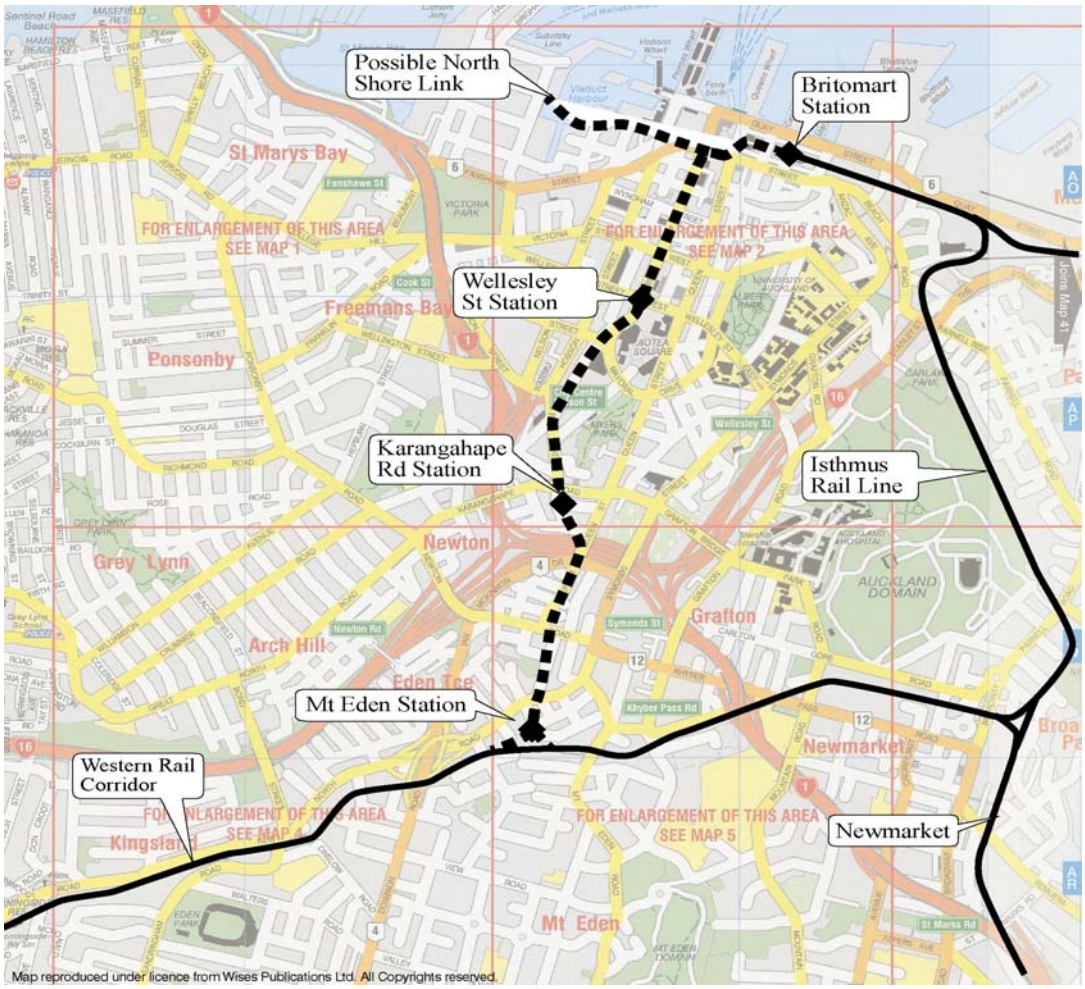

Figure 1

The objective of this Feasibility Study was to confirm the technical feasibility and the potential economic viability of the Britomart West Rail Extension Tunnel.

The Tunnel would:

- Enable more efficient operation of the rail network;
- Address capacity problems at Britomart if built by 2009;
- Provide much better access to the Central Business District;
- Interface directly with the North Shore Busway.

Executive Summary

The study concludes that:

- The extension is technically feasible and the risks manageable;
- Through operation of Britomart Station offers operational efficiencies for the Auckland rail network;
- The capital cost would be in the order of $500 million with an accuracy of ±30% and with construction taking place over a two year period;
- However, if the project is completed by year 2009 (assuming the Rail Business Plan timing applies), then there are considerable cost savings in the order of $106 million ±30%. These cost savings include:
    - A duplicated or widened eastern entrance to Britomart Station and enhancements to the line out to Newmarket;
    - Part of the duplication and electrification of the Western Line from Mt Eden to Newmarket and the upgrade of Newmarket Station.
- A further $14 million could be saved if there is a west connection only to the Western Line at Mt Eden;
- That to meet the expected Rail Business Plan train movements;
    - Around, year2009, capacity improvements will be needed. However, these improvements could be either, include building the Tunnel and Stations or enhancing the approach into Britomart and the line out to Newmarket;
    - Around, year 2021, further capacity improvement may be needed depending upon train movements and patronage forecasts. This could be achieved by constructing the option that was not chosen to address the capacity constraints around 2009.
- The project is marginal economically if built for operation in 2009 – but note that the economic analysis is very conservative. The analysis does not take into account the full congestion benefits (avoided construction, growing congestion delays), nor does it take into account the urban form benefits from the new stations – if these were equal to around $100 million then the project would be viable for construction for 2009;
- The project is likely to be economically viable around 2019 if, as mentioned above, another addition to capacity is required around 2021;
- The preferred alignment has twin tunnels connecting Britomart Station (Platforms 1 and 5) heading westward under Albert Street/Pitt Street/Upper Queen Street/ to the Western Rail line. Highly specialised tunnelling work is required over the initial 300m to pass through the piled foundations under the old Post Office building and the Downtown Centre building;
- Two new stations are proposed: at Wellesley Street and Karangahape Road and the Mt Eden station would be relocated. The Wellesley Street Station could directly access the proposed bus interchange on Albert Street;

- Most of the CBD would be within a 5-minute (400m) walk of a station. Potentially this would have a very considerable impact upon rail patronage. The prospect of achieving the Rail Business Plan patronage target would be greatly enhanced.

Next Steps

The economic analysis shows that the prospect of building the Britomart West Rail Extension tunnel with two new stations, and relocating the Mt Eden Station, is worth further investigation. At this stage we do not support a full Scheme Assessment Report (SAR) as the next stage of this project. However there are areas where we suggest that further work is warranted. These are:

- Investigate Funding Potential;
- Patronage Analysis;
- Further Economic Analysis including urban form, growing congestion delays and avoided road construction;
- Confirmation of Gradient;
- Rail Development.

Britomart Station is the key hub of the Auckland regional rail network, extending from Swanson and Waitakere Stations in Waitakere City to Pukekohe Station in Franklin District. Britomart Station is currently a five track, five platform terminal station accessed via a doubled tracked tunnel from the Eastern and Parnell Rail Lines.

The Britomart West Rail Extension has been identified to enable Britomart Station to operate as a through station, increasing the available capacity of the station for future demand and opening up access to the west side of the CBD through the provision of stations near the Aotea precinct and Karangahape Road. The previously proposed alignment for the Britomart West Rail Extension runs west from Britomart Station through to the Western Rail Line in the vicinity of the existing Mt Eden Station. This alignment is shown in Figure 2 below.

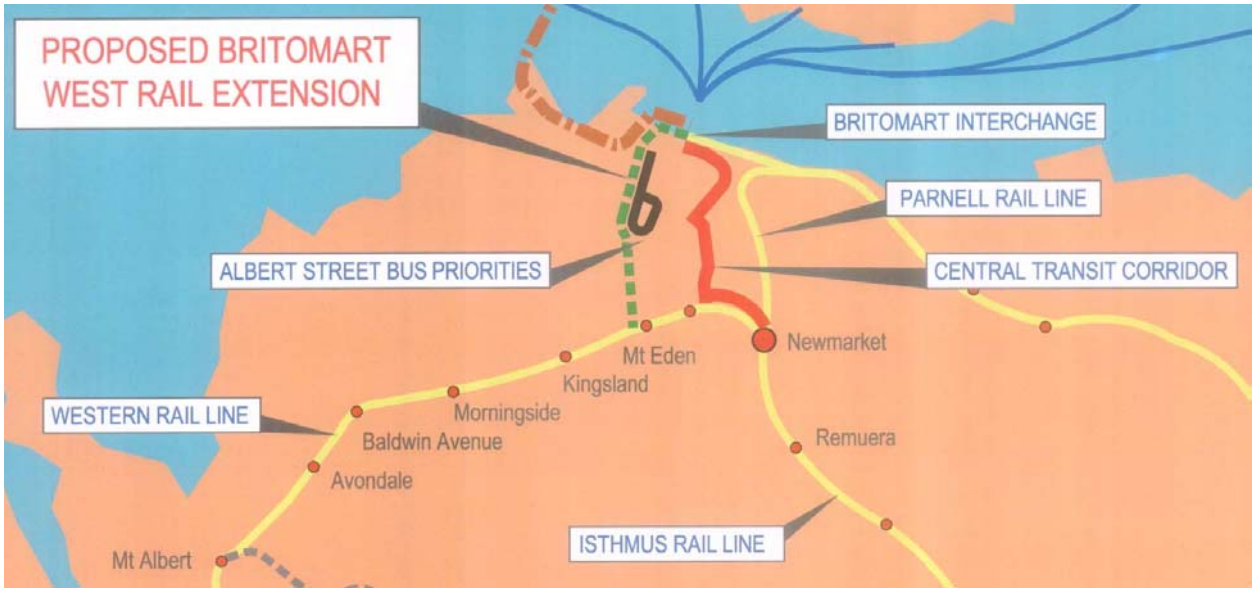

Figure 2

This study is based on the previous work carried out on the Britomart Station and the proposed Britomart West Rail Extension alignment, including:

- Britomart Station Rail Design, 2002. URS New Zealand;
- Britomart West Rail Link, December 2002. Tonkin & Taylor
- Britomart West Rail Link – Geotechnical Appraisal, July 2003. Tonkin & Taylor
- Britomart Station Pedestrian Capacity Modelling, January 2003. Beca Carter
- Britomart West Rail Link – Peer Review, February 2003. URS New Zealand

The objective of this study is to confirm the technical and economic feasibility of developing an underground rail extension tunnelled westwards from Britomart Station to connect with the Western Rail Line. The Britomart West Rail Extension would allow Britomart to operate as a through station and increase its capacity.

The key purpose of this feasibility study is to:

- Broadly assess the proposed operation of the West Rail Extension;
- Confirm the alignment options for the Britomart West Rail Extension with station locations and identifying the associated land requirements;
- Identify key risk issues and determine whether there are any 'show stopper' issues associated with the project; and
- Undertake a preliminary economic analysis to appreciate the financial viability of the project.

Key assumptions made in carrying out this study are:

- The Britomart West Rail Extension (and the Auckland Rail Network) would be electrified;
- The Britomart West Rail Extension would be based on extending Britomart Station tracks 1 and 5. Station tracks 2,3 and 4 would remain as a terminus operation.

This report has been divided into the following sections:

Section 3 - Alignments/Stations

Section 4 - Tunnelling

Section 5 - Rail Operations

Section 6 - Imapct on Private Property

Section 7 - Capital Costs

Section 8 - Economics

Section 9 - Risk

Section 10 - Conclusions

3.1 Design Assumptions

We have compiled the following design criteria from our previous experience with regional rail projects including Britomart Station and the ARTNL Infrastructure Scheme Plan Project:

- Horizontal curvature, absolute minimum – 100m (current curvature at Newmarket Junction);
- Horizontal curvature, desirable minimum – 150m;
- Vertical gradient, maximum - see later discussion;
- Preferred gradient through stations 0.25 % maximum;
- Station to be located on tangent track;
- Station platform length for six car train 135m minimum;
- Turnouts located on tangent track and constant gradient is preferred;
- No combination of horizontal or vertical curves is the preferred standard.

The vertical gradient of the tunnel based on the alignments previously studied, and with an added allowance to have a gradient of 0.25% through all stations (for system and passenger safety, and proper access for people with disabilities), is 3.5%. This gradient is thus higher than the present 2.6% steepest gradient on the Auckland network.

Following enquiries from the Study team, ARTNL advised that their preference would be for a 2.5 % maximum gradient but they could accept a 3.0% gradient. Similarly ARC advised that the rolling stock they plan to purchase could accommodate a 3% gradient, and if special provisions where made in the design as to maximum power and the number of wheels powered, they might be able to achieve slightly higher gradients.

Obviously, there will have to be further detailed consultation with ARTNL and the ARC to develop an appropriate design standard for the vertical gradient. LTSA may also have some input to this discussion.

In URS's opinion, gradients of the order of 3.0% are achievable and there are rail lines in New Zealand at this gradient. For example, the rail line through Otira Gorge runs passengers services on an extended gradient of 1 in 33 (3.0%). In the previous studies by Tonkin & Taylor, it is understood that Tranz Rail Ltd endorsed the 3.0% gradient for running passenger trains in the Britomart West Rail Extension tunnel (though after adding station allowances this was in reality 3.5%).

ARC have confirmed in a letter dated 22/09/03, that they would prefer a maximum 3.0% gradient for the provision of future rolling stock. ARTNL have also confirmed the 3.0% gradient is acceptable, with the provision that signalling and immediate gradients out of the stations be addressed for safety requirements. These issues can be addressed in the preliminary design phase of the project.

In order to achieve a 3.0% gradient, the Western Line would have to be lowered at the southern end of the proposed tunnel and the tunnel extended to the west and the east along the Western Line. This is technically feasible, but requires further land acquisition to widen the existing rail corridor in the Mt. Eden area, and an increase in construction costs for the project.

3.2 Alignment Options

In assessing the possible variations to the currently proposed alignment, the key objectives are to:

- Minimise the length (and therefore the cost);
- Optimise the alignment for operational considerations (e.g. fewer curves and larger radius curves);
- Minimise the vertical gradients;
- Minimise the impact to private property; and
- Select station locations with the optimum and simplest passenger access potential.

Several alternative alignments have been investigated and the key alignment options are shown on Drawing C01. These are:

- **Option 1**: Albert Street ridge line/Pitt Street/Mercury Lane/under the Southern Motorway/Upper Queen Street/Newton Rd under New North Road to the Western Rail Line;
- **Option 2A**: As per Option 1, except for improving the operation of the alignment by removing curves near Karangahape Road and Upper Queen Street. The gradient is 3.0%;
- **Option 2B**: As per Option 1, except for improving the operation of the alignment by removing curves near Karangahape Road and Upper Queen Street. The gradient is 3.5%;
- **Option 3A**: Albert Street ridge line/Pitt Street/Mercury Lane/under the Southern Motorway/Ian McKinnon Drive;
- **Option 3B**: Albert Street ridge line/Pitt St/under the Southern Motorway/Ian McKinnon Drive;
- **Option 4**: Albert Street ridge line/Aotea Square/Myers Park/Queen Street/Upper Queen Street/Newton/New North Road to the Western Rail Line;
- **Option 5**: Nelson Street/Wellesley Street/Symonds Street/New North Road.

Option 1 is the alignment developed in previous studies. This option follows the road reserve as much as possible and this constraint introduces a significant number of horizontal curves along the alignment. Operationally this not ideal as the frequent changes in direction compromises passenger comfort and reduces the overall line speed in certain areas, resulting in longer trip times. The vertical gradient is 3.5%

Options 2A and 2B generally follow Option 1, except that horizontal curves are modified to enhance the operation of the line, allowing higher train operating speeds. The changes introduced to achieve the straighter alignment, do however, impact more private property in the vicinity of Karangahape Road/West Street. The gradients developed for this option are 3.0% for Option 2A and 3.5% for Option 2B.

Options 3A and 3B were identified and tabled at the Workshop. These alignments are located further to the west following Ian McKinnon Drive, to reduce the Option 1 and 2 impacts to the private property: in Upper Queen and at the junction with the Western Line. As raised in the Workshop these alignments would place the Mt Eden Station to the west of the existing Mt Eden Station. Further technical

assessment of these Ian McKinnon Drive options following the Workshop, has shown that these alignments would not be feasible due to the gradients required to achieve clearances of the carriageway and the bridge structures at New North Road where it passes under Ian McKinnon Drive.

Option 4 follows the Option 1 alignment to Wellesley Street, and then crosses under the Aotea Centre/Mayoral Drive/Myers Park/Queen Street area to re-join the Option 1 alignment in Upper Queen Street. This alignment is constrained by steep gradients (4.0%+) and difficulties with the tunnel, which would be close to ground level in the area of the Aotea carpark access. There would also be significant conflict with building foundations for the Aotea Centre and for 363-371 Queen Street.

Option 5 was developed and investigated to try and achieve a 3.0% gradient. The principal constraining point for this route is the intersection of Queen Street/Wellesley Street, where the alignment crosses the Queen Street gully. The operation of the line would be less efficient with a lower line speed as there are several 90-degree alignment changes. The alignment would have three stations located at Wellesley Street, Symonds Street/Karangahape Road and New North Road (Mt. Eden). Although the option is technically feasible, the latter two stations would be some 40m underground which would require special measures (construction and operations) for passenger facilities and movements and at this level is beyond most current industry experience for underground stations. In addition to this, the route length is ~700m+ longer, which would have a significant cost implication. As a result of these constraints, this option has not been investigated further at this stage.

The key attributes of each option are summarised in the table on the following page.

Alignment Options Table:

Option	Maximum Gradient (%)	Length (m)	Number Curves	Property Affected*	Station Locations	Technically Feasible	Comment
1	3.5	3197	11	29	Wellesley, Karangahape/Pitt, Mt Eden	Yes	Numerous curves to avoid property giving compromised operation. Gradient constrained by cover to Western Motorway.
2A	3.0	3500	7	34	Wellesley, Karangahape/Pitt, Mt Eden	Yes	Better operation, fewer curves than Option 1. Higher impact to private property. Gradient constrained by cover to Western Motorway.
2B	3.5	3250	7	33	Wellesley, Karangahape/Pitt, Mt Eden	Yes	As per Option 2A except gradient increased to reduce alignment length.
3A	4.5+	3426	7	6	Wellesley Karangahape Ian McKinnon	No	Gradient not feasible without major interchange works and rail corridor widening. Possible conflict with Southern Motorway.
3B	4.5+	3510	9	8	Wellesley Karangahape Ian McKinnon	No	Gradient not feasible without major interchange works and rail corridor widening. Possible conflict with Southern Motorway.
4	4.2	3105	6	47	Wellesley, Karangahape/Pitt, Mt Eden	No	Gradient not feasible. Constrained by level of Aotea Square and Mayoral Drive. Conflict with building foundations.
5	3.0	4200	13	41	Wellesley, Karangahape/Symonds Mt Eden/Symonds	Yes, but stations very deep	Long route with two 90 degree turns, which will restrict speeds. Station depths of 40m+ (near the Sheraton and Symonds/New North Road).

Note:
* - Denotes where the alignment passes into private property, not limited to impact on buildings. Excludes ACC land or Crown land.
Twin tunnel widths have been assumed to identify the land affected (18m total width, with 6.0m tunnels).
All alignments are based on a loop connection to Newmarket.

Alignment **Option 2** is the best operationally and has been taken forward for costing. This option, as shown, has been developed for both a 3.0 and a 3.5% grade solution. The different grades basically impact on the overall length (and therefore the cost) of the tunnel. As previously noted, the 3.0% gradient would seem to be the most desirable. The 3.5% gradient could be achieved, but would require special consideration in the design of the future rolling stock.

3.3 North Shore Link

The proposal to accommodate a future rail link from Britomart Station to the North Shore has always been a part of the planning for the West Rail Extension, as shown on Drawing C01 and C03. The link commences at the intersection of Customs Street and Albert Street and heads west along Customs Street towards the western reclamation. This link was identified in the Tonkin & Taylor Report (Britomart West Rail Link, December 2002).

There is no heavy rail network on the North Shore and a connection to the Northern Line (which passes through Helensville) would be a very high cost development. However, there could be a heavy rail (or future light rail) service to the North Shore. The gradient constraints of a heavy rail tunnel under the Waitemata Harbour may cause difficulties in passing under or through the incised valley in the harbour bottom. Previous studies showed that light rail vehicles could be accommodated either in a tunnel or even on the existing Harbour Bridge, particularly when the second bridge is constructed in the future. While this study has not studied the profiles or routes of any future harbour crossings for rail, the design of the Britomart West Rail Extension can be developed to provide future branch rail lines to the North Shore that might follow one of several alternative routes.

To provide services to a future North Shore Link would require utilising some of the capacity available on the Network, thus reducing capacity available to the Western Line. The operational service scenarios of the North Shore Link and the implications of it are outside the scope of this study and have not been assessed.

Potential for the Grade Separation of the Future Link to the North Shore

The grade separation of the future link to the North Shore (under QE Square) was first investigated in the Tonkin & Taylor Report (Britomart West Rail Link, December 2002). Trains to and from the North Shore and on to the Britomart West Rail Extension would have to pass through the following constrictions:

- Quay Park North Junction;
- Britomart Station Throat;
- Station platform 1 (eastbound) or 5 (westbound).

The best that could be expected from a flat double junction (where the North Shore Link would leave the West Rail Extension) is 2.5 a minute frequency, which is the capacity through Britomart and the Britomart West Rail Extension with two way access at Mt Eden, as detailed in Section 5.4.2. This shows that grade separation of the North Shore Link would not improve capacity unless Britomart Station Throat and Quay Park North Junction were also to be upgraded.

The grade separation (if required) is however technically feasible, although the Britomart West Rail Extension from the junction through to the Western Line would require additional tunnelling and deeper stations to achieve this grade separation, with significant impact on the overall costs of the Britomart West Rail Extension.

3.4 Station Access/Location

The current strategy proposes three station locations at Wellesley Street, Karangahape Road and Mt Eden, as shown on Drawing C07. Associated with each station are different infrastructure, access, land use, patronage and design opportunities.

3.4.1 Albert/Wellesley Street

The current platform alignment below Albert Street is closer to Wellesley Street East than to Victoria Street West. However, potentially the best means of main station access would be further towards Victoria Street West, where there is an area of land currently used for car-parking serving local commercial and retail activities. A station at this location would provide good access to the proposed Albert Street Bus Interchange, Atrium, Mid City Centre, the ANZ Centre, Sky City (including hotel and convention centre), hotels (Crowne Plaza; City Central Hotel), and more widely, to Aotea Square, Wellesley Street, Queen Street and Victoria Street. A typical section through Wellesley Station is shown on Figure 2 on the following page.

Given the level differences between the proposed rail platform and the car park area, it should be possible to provide access between them without interfering with the existing access road serving the Crowne Plaza and the ANZ Centre.

View south toward Wellesley Street.

The current status of the car-parking area is not specifically known, although it is prime (re)development land providing the opportunity to integrate a high quality station area with both office and retail activities.

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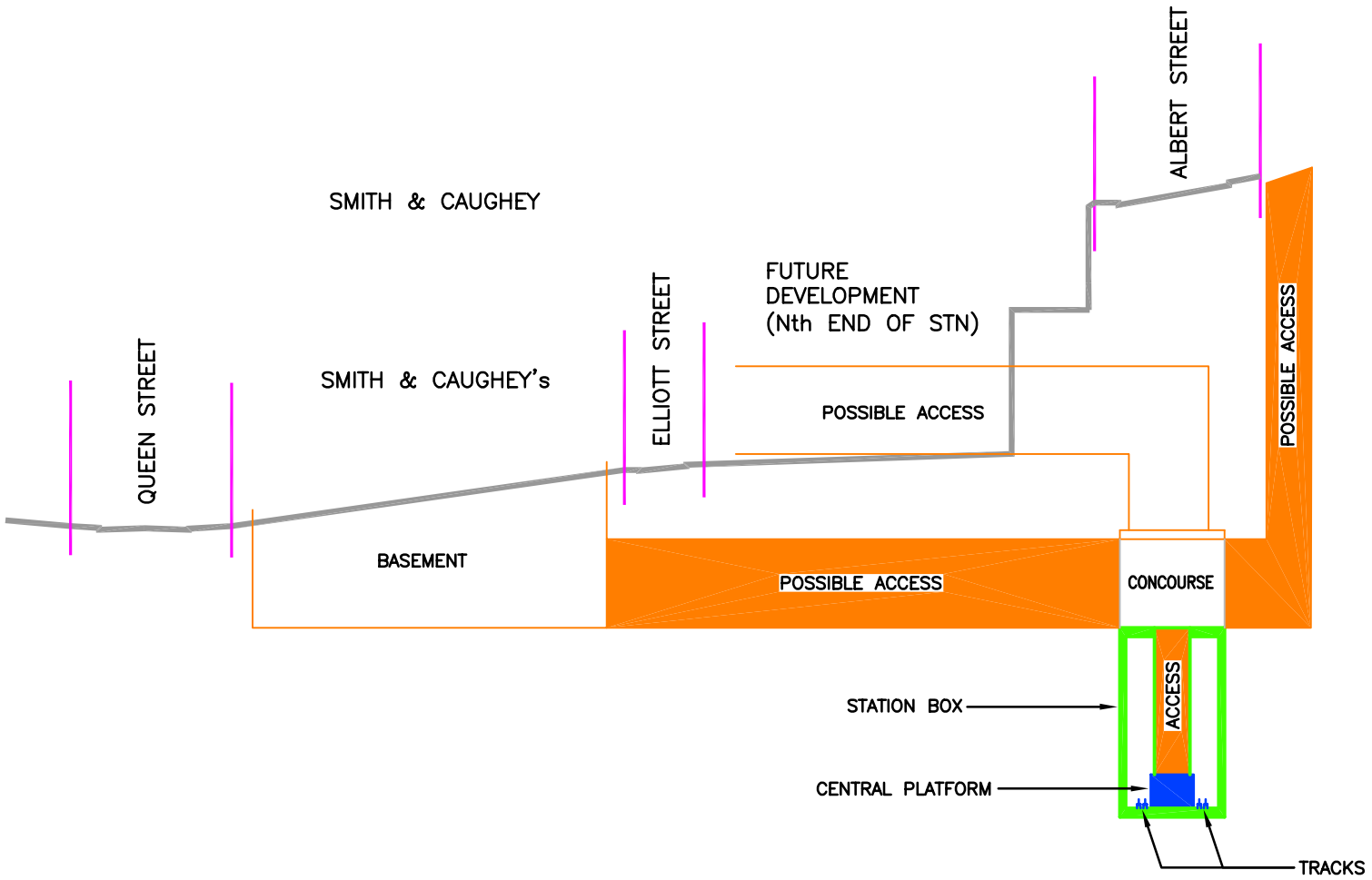

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Title
WELLELSEY STATION SECTION

Figure No. **3**

Given the uplift in retail and office rentals typically associated with transit stations, resistance from the site owners or property developers would not be anticipated. Nonetheless, site ownership and status should be established as soon as possible, with consideration given to designating an area to safeguard for future station development and access.

3.4.2 Karangahape Road / Pitt Street

The proposed station location is directly below Pitt Street to the north of Karangahape Road. The buildings in this locality are mostly single or double story heritage buildings, making integration with a new station unpractical. The alternative locations under Mercury Lane and its general environs (narrow; steep gradient, closed in), makes it an undesirable station access location. Beresford Street, however, affords good opportunity for station access to the preferred location. It would be possible to provide a fairly discrete access or, alternatively, to consider a more comprehensive development, entailing integration with existing retail uses (although this would require Beresford Street to be closed before Pitt Street) and strong link to Karangahape Road.

View down Beresford Street from Pitt Street

3.4.3 Mt Eden (New North Road)

The proposed station location is below Exmouth Street and adjacent to Basque Park. This station would provide access to commercial activities along New North Road and Newton Road, residential properties along Exmouth Street and around Rendall Place/Couldry Street (high density), and Basque Park.

View southwest across Basque Park towards Rendall Place.

Following community consultation, Basque Park has been landscaped designed with the installation of new wastewater pipes being carried out during August to November, 2003 (see above photograph) and park redevelopment programmed for between November 2003 and May 2004. The works will include an amphitheatre for local community events, seating areas and extensive feature tree plantings.

Although small-scale station development at ground level is anticipated, it would be appropriate to initiate the process of securing a designation for the station development as soon as possible. This process should seek to ensure local community consultation (and support) and be undertaken to avoid potential conflicts with the proposed landscaping works. Appropriate station design could integrate with the park and minimise impacts.

4.1 Route Geology and Associated Tunnelling Conditions.

Some pertinent aspects of the materials that are likely to be encountered are given in the paragraphs that follow. A brief overview of the route is:

Britomart to Albert Street: Highly variable poor quality fill, generally clayey and sporadically containing rubble and organic material.

Albert Street to Karangahape Road vicinity: Waitemata sandstones and mudstones and residual soils derived from these rocks. These materials are of a "good" quality in terms of tunnelling terminology.

Karangahape Road to Mt Eden Station: Tauranga Group ash/tuff and basalt lava is expected. The basalt rock may be very hard and the tuff will be variable in strength ranging from a firm to very stiff soil.

Indicative sub-surface conditions along the tunnel alignment are captured in a report commissioned by Auckland City and undertaken by Tonkin and Taylor (Report 20421.1 dated July 2003).

From a geotechnical viewpoint the following aspects should be noted:

- Waitemata sandstones and mudstones typically range in unconfined compressive strength between 1Mpa and 6Mpa;
- Faulting will be present and variable, but generally the lateral extent perpendicular to the fault line is not wide – i.e. brecciation zones across the faults are not present or only of limited extent. The route does not run in close proximity and near parallel to any known fault;
- Depths of weathering vary but are more substantial in the Wellesley Street area and again in the Exmouth Street area;
- The residual soils are generally near their plastic limit in situ. If wetted, the softened product is often sticky and difficult to handle;
- Groundwater can be highly variable in the Waitemata rocks, generally with low storativity being manifested. However, joint continuity and higher fracture frequency in places can give rise to sustained inflows because of hydraulic continuity. Water volumes are not a likely issue, but potential impacts on the ground water regime may arise, especially should overlying soils be allowed to depressurise;
- The tunnel may encounter Pleistocene silts and clays over a short length, i.e. a short length of soft ground tunnelling may arise;
- Pyroclastic materials (ash and tuff) will be encountered in the New North Road area and dependant on composition may readily drain ground water. Water release may accompany comminution and make muck disposal more difficult;

- Basalt lava in the Mt Eden area will comprise multiple flows sometimes interspersed with non-welded scoraceous materials. The lava is a strong to very strong rock;

None of these aspects present a potential caveat or a high cost premium on tunnelling.

The shallow cover in soft material near Britomart Station and possible soft ground near the Mt Eden section of the route may require specific measures, but this represents a minor length of the route.

4.2 Tunnel Construction Issues.

Tunnelling through Soft Material (Downtown Building Area)

As identified in the Tonkin and Taylor Report (Britomart West Rail Link, December 2002), the Britomart West Rail Extension between Britomart Station and Albert Street passes beneath several buildings and is constructed in soft materials. The only available construction access zone within the area is currently QE Square. A shaft in this area will allow access for the intricate mine-and-line operation required to tunnel through the piled foundations of the adjacent buildings.

Temporary shaft construction through soft materials as are present in this location generally has some lateral displacement linked to its construction. Given the amount of tunnelling activity that must be executed in this zone, the access shaft size will need to be large. This may expose the Downtown Centre and the former CPO buildings to some risk and in future studies, consideration should be given to constructing a permanent shaft. The airspace in the access shaft that will become available post construction could be integrated with any future extension of the concourse level under QE Square.

The two tunnels will need to be routed between and through existing building foundation piles. There is ample precedent for accomplishing such work safely, the most recent of which is the run-out tunnels at the Changi Airport Station of the Singapore MRT. In this instance special hydrophrase equipment was used to install diaphragm walling, which was used to carry beams that encased piles. Alternative methods include installation of new piles with transfer beams. Consideration can be given to improving the quality of the ground above the tunnel crown through modifications of jet grouting techniques, tying in the individual exposed piles to a specially formed tunnel section that transfers the pile load through the tunnel walls around to the floor and then demolishing the encapsulated length of pile. Such a system would require careful assessment of the existing building structures to establish realistic actual load characteristics at the individual location.

There is sufficient precedent to show that the work can be done without building distress resulting. Based on the Changi Airport development, not only it is clear that the execution of such work is not simple and that issues should be expected to arise and be resolved during construction, but that progress will be slow and costly whatever system is followed. Within the limits of the current scope of work, a cost allowance has been built up based on a detailed and intricate analysis of the buildings and the soil/structure and structure/structure interaction being required, both by designers and reviewers for Council and for property owners. To this has been added shaft costs, an allowance for slow, arduous construction for

supporting the buildings, removing piles as required, installing new piles and other works, all with a high labour content as well as specialised plant and with rigorous monitoring.

Tunnelling through the Waitemata Rocks.

The Britomart West Rail Link – Geotechnical Appraisal, July 2003, Tonkin & Taylor indicates that the major part of the tunnel will be excavated through Waitemata sandstone and mudstone. The material is a favourable tunnelling medium and no significant issues are expected. Some lengths of the tunnel will be in residual Waitemata soils with moisture contents around the plastic limit of the soil. If wetted up, the material will become sticky and handling and disposal issues may arise. However, these are within the normal ambit of a competent contractor.

Tunnelling through Pyroclastic Rocks and Soils.

The tuff and ash deposits are highly variable, but lie within a range readily accommodated through normal tunnelling procedures. Some of these deposits include relatively incompressible micro-aggregates that enclose discrete pockets of water. These natural aggregates are susceptible to structural breakdown on mechanical manipulation, releasing the interstitial water and changing from an aggregate to a plastic sticky mass that is difficult to handle.

The potential handling issues are allowed for in the overall excavation cost rate used.

Tunnel Portal (Mt Eden).

Option 2A (3.0% grade) will require some tunnelling and portals within the Western Line. Part of the excavation is likely to be in basalt rock. Based on local knowledge, initially the rock will be sufficiently fractured to permit mechanical excavation without requiring blasting. Once within the tunnel, excavation will be more difficult. Given that the length of tunnel through which basalt rock will be encountered, excavation may be through standard drill-and-blast methods or by selection of a TBM that can accommodate both the soft rock sandstone and the very hard basalt. The basalt will not be excavatable by means of a road header. The basalt rock is likely to be sufficiently competent for the excavation to proceed using industry standard rock reinforcement followed by installation of a concrete lining.

Over this zone, a premium of $3000/m is allowed for to cover the higher cost of tunnelling through the hard rock and for the box culvert type portal structures that will be required parallel to the existing tracks.

A corollary effect that arises from the operational requirements is the need for a drainage sump and lifecycle pumping to remove water influx in the portal zone and minor tunnel flows.

Option 2B (3.5% grade) has the junction with the Western Line in portals only, with construction generally within volcanic ash /tuff. The tunnel would commence outside the rail boundary where the link to Newmarket starts.

Groundwater and Settlement.

Underground construction in a fully developed urban environment raises concerns regarding distress of existing developments and infrastructure. In this instance, high-rise buildings line the streets underneath which the tunnel will be constructed. Ground coverage is extensive and consequentially ground recharge from precipitation is reduced.

Tunnel convergence and soil settlement resulting from water table lowering are two issues that integrate to affect changes to surface behaviour from tunnelling. It has been reported (Britomart West Rail Link, December 2002. Tonkin & Taylor), that surface effects from the construction of the Vector tunnel, where it traversed similar ground, were negligible. It is therefore unlikely that the construction of the tunnel will generate significant issues.

The twin tunnels are larger and at a shallower elevation than the Vector tunnel in the zone where the two schemes run through the same materials. The rail tunnels at times will have residual soils close to the crown and the residual soils contain pockets of Pleistocene clays. Depressurisation of these materials could result in settlement.

Presuming that there is hydraulic continuity along rock discontinuities (joints and bedding planes) and that this continuity prevails in the relic joint structure in the residual clay soils, some draw down / depressurisation may arise. A tandem tunnelling process in which the tunnel lining closely follows the excavation cycle can counteract this.

While groundwater issues are not seen to have a significant impact, provision is made for appropriate tunnelling methods to circumvent issues arising. This provides a margin for optimisation as the project advances through scheme assessment and detailed design phases.

4.3 Tunnel Profiles.

The two rail tracks can be accommodated within one large tunnel bore of about 10.6m ID or with one track in each of two smaller (6.0m ID) tunnels.

To delineate between the two options the following definition is applied:

- Single Tunnel: A single large tunnel accommodation two tracks;
- Twin Tunnels: Two small diameter tunnels each housing one rail track.

The route is essentially confined to street corridors to minimise private landowner issues. This restricts to about 20m the available width in which tunnelling can take place without property rights being infringed upon. A single tunnel with less overall width compared to twin tunnels, would impact less private property. This positive attribute is counterweighted by two factors. Firstly, the larger diameter results in less cover above the tunnel crown for a chosen grade line. In shallow conditions, either the grade line must be deepened or construction is complicated by a requirement for a short cut-and-cover operation or the incorporation of specialised ground support/ground improvement measures.

The second aspect is, importantly, cost. The typical cross section of a suitable single tunnel is 100m^2 while for a twin tunnel configuration it is 64m^2. For a single tunnel, material volumes excavated are thus more than 50% greater and in the case of the concrete lining the increase is about 75%. Overall scheme costs are thus increased by about 15% - 20%. Other aspects that tend to increase the cost differential between a single tunnel scheme and a twin tunnel scheme include ground support requirements, emergency egress provisions, fire protection measures and tunnel boring machine and related equipment requirements. These are not detailed, as the differential that results from excavation and lining requirements, as shown above, is deemed sufficient to warrant not pursuing the single tunnel profile.

The tunnel profile for a twin tunnel scheme is determined by sub-surface conditions in conjunction with construction considerations, operations requirements and external impacts such as the CBD development above ground. The grade is controlled by operational requirements.

For the length of tunnel involved and based on overall probable ground conditions, potential economies can be achieved from an optimised non-circular profile shape as depicted on Drawing C-05 in Appendix A. Such a profile can readily be excavated using a road header. At least 95% of the tunnel length can be excavated in this way and then lined using one made-to-suite shutter. The tunnel lengths in basalt rock and the soft ground conditions near Britomart can be accommodated by industry standard adjustments to the mining methods.

Use of a free operating road header provides economy in excavation rates as the equipment is relatively inexpensive, readily available and the associated plant required for the balance of the tunnelling cycle is not complex. There is, however, no groundwater control with this system.

To control with surety ground movements and to assure the on-going damage-free functionality of the adjacent high structures, ground water control is important. The Tonkin and Taylor geotechnical appraisal (Tonkin and Taylor, July 2003) indicates that the groundwater table is present roughly between 5m and 12m below the ground surface (10m to 20m above the tunnel crown). To minimise depressurisation and the settlements associated with it, a mine-and-line system should be followed. It is assumed that the tunnel will be constructed to be essentially waterproof on completion. The non-circular profile is thus eliminated from further appraisal in this study.

A circular cross section utilising a double gasket pre-cast segmental lining similar to the Singapore MRT system is adopted for costing purposes. This ensures minimal seepage, minimal ground movement and assures that adequate provision is made in costing so that cost optimisation can be achieved if further stages demonstrate that less stringent measures are required to address groundwater issues.

The profile is shown on Drawing C-05 in Appendix A. The profile depicts the twin tunnel pair, showing the tunnel centrelines separated by two tunnel diameters. The full width is thus of the order of 18m, which can be generally accommodated within the street corridor without impacting on private property.

4.4 Underground Station Construction Aspects.

Wellesley Street Station

The current planned distance from rail level to street level is about 19.5m, requiring a construction excavation depth of the order of 23.5m. Up to 15m of the excavation will be through residual Waitemata soils and the balance will be in Waitemata rock. Groundwater levels are indicated to be about 6m below ground level.

For minimal risk construction, this excavation will require the use of a diaphragm wall, linked to top-down construction through the upper 15m. This top-down concept incorporates flooring elements being constructed in tandem with excavation so that lateral bracing beams are provided and there is no requirement for external support to the excavation in the form of anchoring. This method was used in the construction of the Britomart Station. Top-down construction is more restrictive on the excavation process, but eliminates concerns that could arise from excavation adjacent to high-rise building foundations. Equipment for the construction of diaphragm walling is not currently available in New Zealand and an allowance for the required importation has been made in the costing of the work.

Karangahape Road / Pitt Street Station

The station is located in Pitt Street with depths from the road level to top of rail varying from 29m to 35m. Surface structures are generally low-rise heritage type buildings. In this area, there will be about 12m of residual Waitemata soils, grading into Waitemata rock. The depth to the groundwater is of the order of 7m.

Overall subsurface conditions are not adverse and the constraints imposed by surrounding buildings are less severe (but damage protection for heritage structures may be strict). These factors combine to provide more leeway for construction methodologies. The costing elements include for substantial lateral support systems over the upper 15m with cognisance being taken of the self-support offered by the rock at depth.

Mt Eden Station

The location of the station is proposed to be adjacent to Basque Park in Exmouth Street. The tunnel alignment varies rapidly along this section, with rail to ground differences varying between 12m and 25m. The excavation will pass through a variety of materials ranging from volcanic tuff/ash, Pleistocene clays and residual Waitemata soils. Waitemata rock is not likely to be encountered. The level of the groundwater changes in association with changes in the ground surface, which falls towards the south. It will range from about 5m to 9m below ground level along the station.

There are no significant structures in the station locality but the sub-surface conditions are less favourable and good lateral support will be required over the full depth of the excavation. Due allowance for such support is included in the cost structure.

5.1 Proposed Train Plan

Britomart Station is a terminus station and as such its capacity for train movements is governed by the number of trains able to arrive and depart from the station in peak times in accordance with required operational and passenger safety requirements. The proposed train plan for the Auckland Urban Rail Network is currently set out in the Rail Business Plan as follows:

Stage 1 (July 2003)	10 minute headway Papakura – Britomart
	30 minute headway Swanson/Waitakere – Britomart
	30 minute headway new Lynn – Britomart
Stage 2 (2005-6)	10-minute headway Papakura – Britomart
	30-minute headway Manukau – Britomart
	10-minute headway Otahuhu – Britomart via Glen Innes
	10-minute headway Swanson – Britomart introduced in stages
Stage 3 (2021)	5-minute headway Papakura – Britomart
	15-minute headway Manukau – Britomart
	5-minute headway Otahuhu – Britomart via Glen Innes
	5-minute headway Swanson – Britomart

The development of the future operation of the Network and how the train plan targets are met, are outside the scope of this study. The scenarios included in this study assist us to confirm the feasibility of the West Rail Extension. The assessment of capacity for each scenario is based on experiential evaluation by expert professionals without the benefit of detailed simulation. The capacity analysis furthermore assumes capacity improvements are made elsewhere on the network, such as double tracking and signalling capability for five-minute headways on the Western Rail Line.

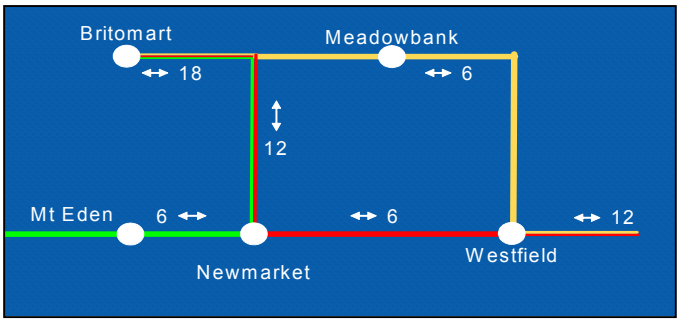
5.2 Britomart Station Train Capacity

The capacity of Britomart Station is limited by the number and the capacity of the available tracks into and out of the Station, and the potential conflicts at the crossovers from the tunnel into the five platforms and at the Quay Park junction (the old Auckland Railway Station area). The train capacity for Britomart under the present conditions of the rail network and the current rolling stock, is assumed to be 18-20 trains arriving and 18-20 trains departing during a peak hour.

By extending the tracks serving Platforms 1 and 5 into the Britomart West Tunnel, Britomart would become a through station and this would remove many of the station throat conflicts. Previous simulation work has been done for a similar scheme involving use of the previously proposed 'LRT Ramp' tracks (where the LRT vehicles used the tunnel but exited to the surface before the Station throat crossovers). This simulation suggests that the capacity for a through station could rise to about 24 trains per hour in each direction. This is also the approximate maximum practical performance of a flat double junction, which is in place at Quay Park, as demonstrated in the TCRP Report 'Rail Transit Capacity'. This level of capacity is similar to that achieved for terminal stations on the urban rail networks in Australia.

The demand for train capacity for the proposed 2005-2006 and 2021 train frequencies defined in the Rail Business Plan are shown on the following diagrams. In these diagrams, the train densities refer to the AM Peak hour services, as this is the time of most intense operation and greatest usage. The train numbers shown represent the total number of services in each direction on the relevant section of track. To these numbers must be added any freight or long-distance services using these lines during the period.

Proposed Operation 2006 – 2011 (Britomart Terminus Station)

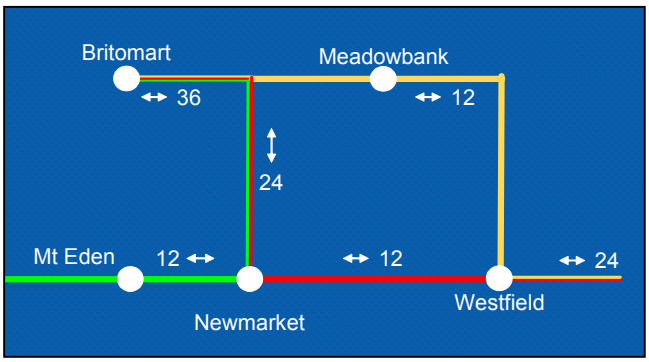


Max volume: 18 trains per line equals 3.3 minute headways
Train movements within Britomart: 36 (plus any Tranz Scenic trains)

Issues:
The reliable operation of Britomart Station will depend on precise arrivals and departures in accordance with the planned timetable. The 36 movements over the peak hour is a demanding target for everyday operations. A substantial number of these will be movements with potential conflicts involving use of the tunnel/platform entrance crossovers.

There is no potential in the proposed train plan to accommodate delays. Delays could occur from conflicting movements at the flat junctions in the wider network – in particular Quay Park North junction and also at Westfield. Any freight movements at Westfield in particular would add to these conflicts.

Operation 2021 (Britomart Terminus Operation)



Maximum volume: 36 trains per line equals 1.7 minute headways
Train movements within Britomart: 72 plus any Tranz Scenic trains.

Issues

In this scenario, which requires the capacity of the entrance tunnel and the crossovers to be doubled, headways would be cut to 1m 40sec. The proposed total of 72 movements would essentially be inoperable in the current station configuration. In addition, the increased number of conflicting movements at the three junctions would present a severe challenge to the reliable operation of the wider network.

For this operation the proposed movement of 36 trains per hour on each track of the Britomart West Rail Extension exceeds even the maximum capacity achieved by high-density subway type systems, and exceeds the capacity of an at-grade Quay Park North Junction by a factor of 80%. This operation is therefore not feasible.

Between the proposed 2009 and 2021 Rail Business Plan train frequencies at Britomart Station will reach capacity. To upgrade the station to achieve the higher frequencies will require either:

1. **Additional twin tracks through a new duplicated eastern tunnel leading into Britomart Station (adjacent to the existing tunnel) with possible grade separation of the Quay Park Junction (dependent on operation strategies); or**
2. **Britomart Station to be converted to a through station with the Britomart West Rail Tunnel.**

Proposed Operation Post 2021

The operation of the network post 2021 has not been identified in the Rail Business Plan. The number and complexity of options to develop the existing Britomart Station or possibly a second station to accommodate higher frequencies than 2021, is outside the scope of this study and no analysis has been undertaken of possible post 2021 operations.

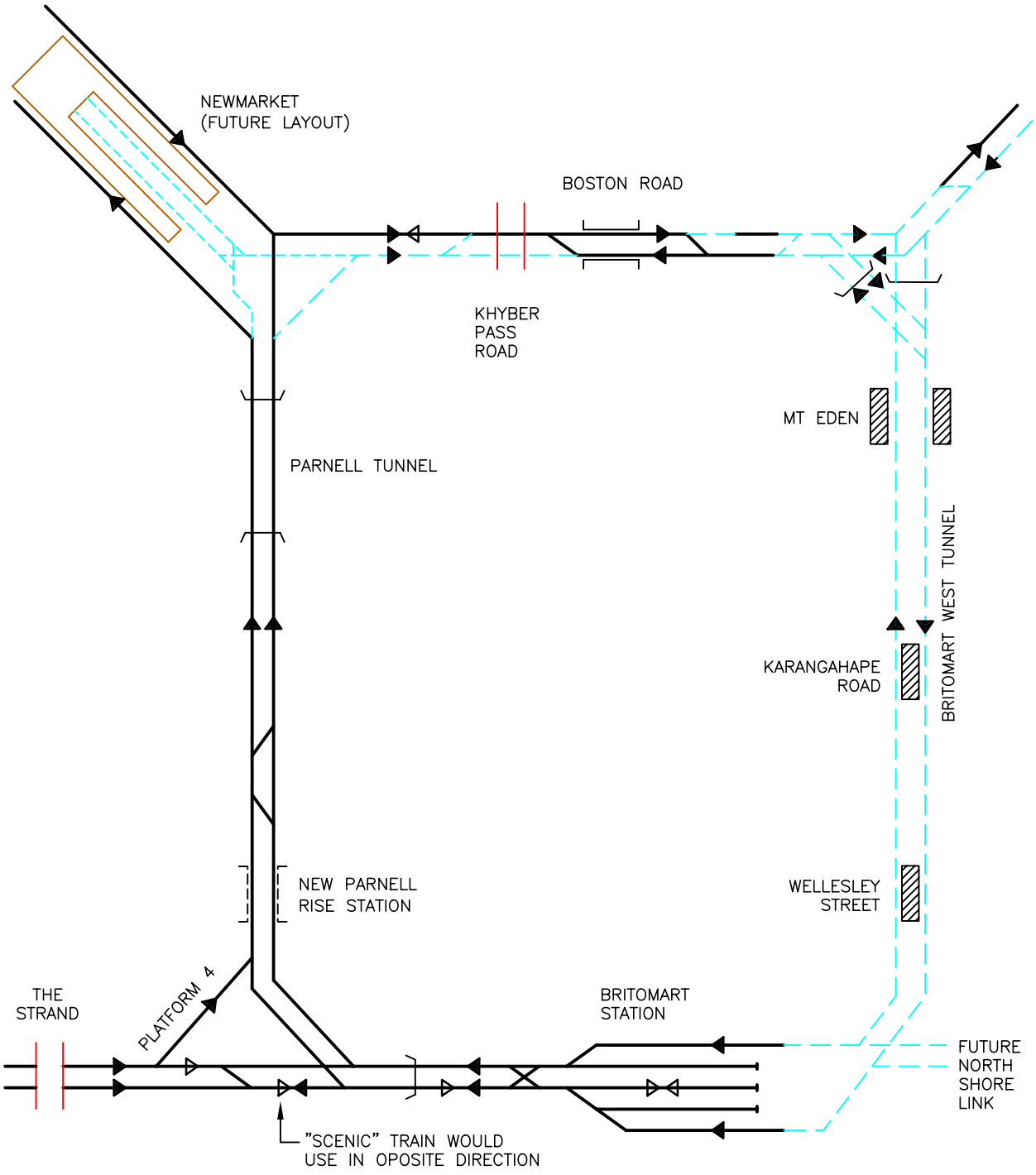
5.3 Tunnel Configurations

There are two basic alternative configurations for the Britomart West Rail Extension tunnel, plus the possible addition of a North Shore link. Train service patterns and frequencies for the configurations of the Britomart West Rail Extension tunnel are discussed in the following section. There are several other options such as a single-track tunnel, retaining the single track from Mt Eden Station to Newmarket. However, the most flexible option of two tracks (twin tunnels) and double track from Mt Eden Station to Newmarket is carried forward in this study.

The basic tunnel configurations are:

1. Double track (twin tunnels) with access from the west only at Mt Eden Station; and
2. Double track (twin tunnels) with access from both Newmarket and the west at Mt Eden Station.

The general track schematic for the Britomart West Rail Extension tunnel (Figure 4) and the Mt Eden junction options (Figure 5) are shown on the following pages.



LEGEND

- EXISTING TRACKS
- NEW TRACKS
- NEW POCKET TRACKS TO INCLUDE NEWMARKET IN LOOP

NOTE:

NOT ALL TURNOUTS SHOWN (FOR CLARITY)

DOUBLE TRACK LOOP OPTION

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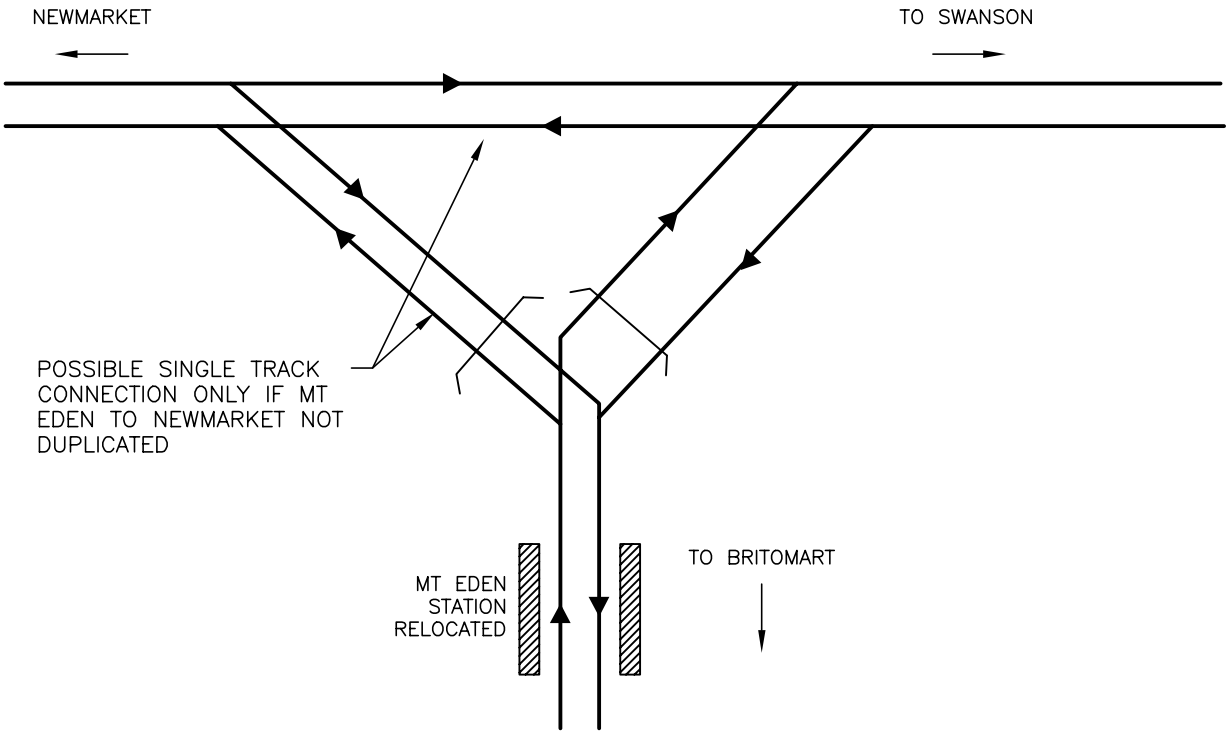
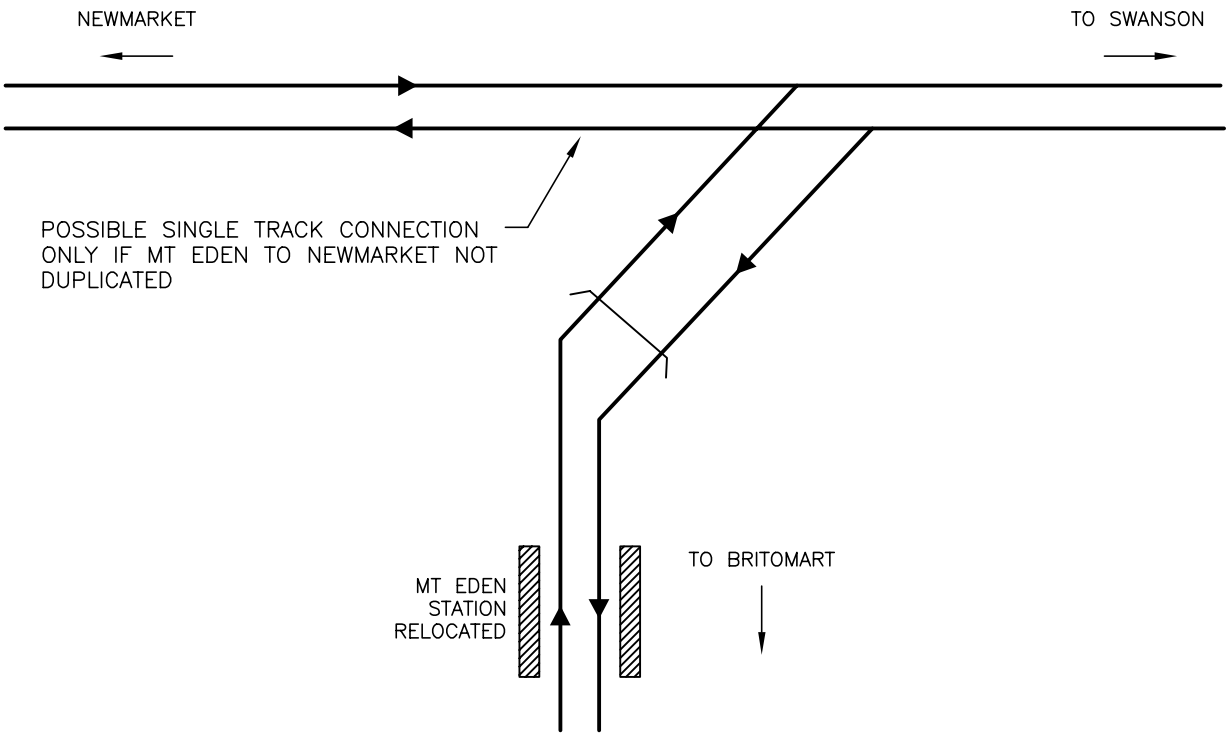
Figure No. 4



DOUBLE TRACK TUNNEL
(WITH WYE)



DOUBLE TRACK TUNNEL
(WITHOUT WYE)

URS New Zealand
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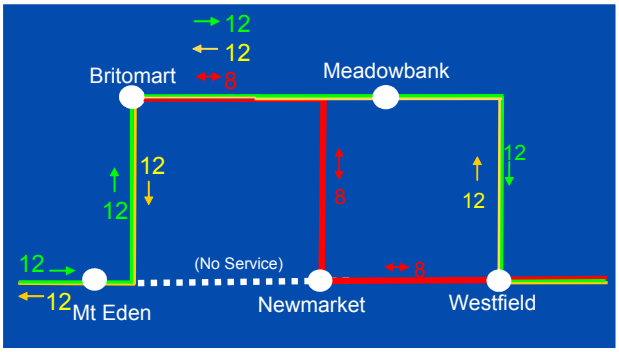
Figure No. **5**

5.3.1 Double track Britomart West Tunnel with access from the west only at Mt Eden Station

Train Services and Frequencies



Note that under this option, there is no passenger service from Mt. Eden to Newmarket though the current single track remains for freight use (and Boston Road). This option does not allow a Britomart – Newmarket loop.

Western and Eastern Line train services could be combined as through services running through the Britomart Station. Isthmus Line services would operate to terminate at Britomart as at present. There are many possible variations to the operations.

This would allow the proposed 2021 train frequencies (12 trains per hour, 5 minute headways) on the Western and Eastern Lines. Services on Isthmus line would depend on the performance of the Britomart Station Throat and Quay Park Junction. Service frequencies on the Isthmus line could be at least 8 trains per hour (6 minute intervals) or possibly the full 12 trains per hour (5 minute intervals) of the proposed 2021 service. Compared with the present operation there would be less conflict between trains in opposing directions in the station throat area, but whether this would permit full 2021 service levels on the Isthmus Line would need to be established by simulation modelling. The service operation is shown on Table 5.1 on the following page.

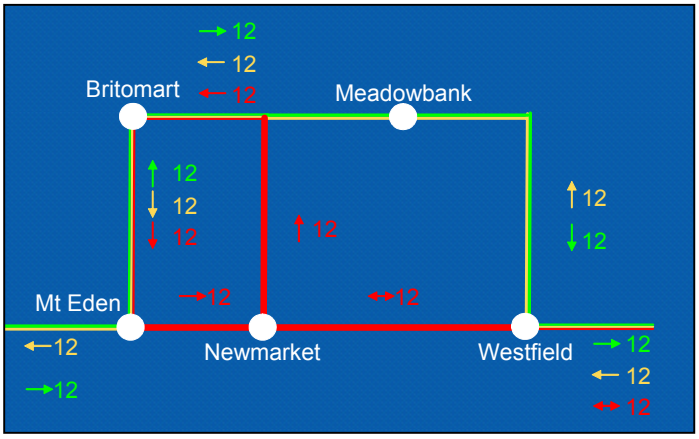
Table 5.1 - Train Service Operations for Double Track Tunnel with One Way Access at Mt. Eden

Route	Train Service Possibilities	Comments
Western Line	Direct to and from Britomart via West Rail Extension	No service to Boston Road. 5 minute service (12 tpdph*) possible on Western Line (with double track and re-signalling).
Isthmus Line	To Britomart as at present	Possibility of trains continuing as through Isthmus - Western Line services. Isthmus line services could rise to 8 or possibly 12 tpdph.
Eastern Line	To Britomart as at present	Possibility of trains continuing as through Eastern - Western Line services. 5 minute service (12 tpdph) possible on Eastern Line.
Tranz Scenic	To Britomart as at present	
Capacity limited by:	Quay Park North Junction	Limited to currently assessed capacity of about 20 tpdph, but operating Western Line trains via the tunnel would free up capacity for additional Isthmus and Eastern Line trains, and 24 tpdph may be possible.

* - tpdph: denotes trains per direction per hour

5.3.2 Double track tunnel with access from both directions at Mt Eden

Train Services and Frequencies



With this option, the full 2021 service could be operated. The service would be robust as there will be no conflicts between trains in opposite directions at either Quay Park or Mt Eden junctions (except for Tranz Scenic trains if operated during peak hours). Conflicts between trains in the opposite direction would occur at Newmarket. The service operation is shown on Table 5.2 on the following page.

Table 5.2 - Train Service Operations for Double Track Tunnel with Two Way Access at Mt. Eden

Route	Train Service Possibilities	Comments
Western Line	Direct to and from Britomart via Tunnel.	Continuing as through Western – Eastern line services. Under this scenario, there would be no service from the West to Boston Road. 5 minute service (12 tpdph) possible (with double tracking and re-signalling of the Western Line).
Isthmus Line	Looped via Parnell, Britomart and the West Tunnel	2021 level, 5-minute interval (12 trains per hour) possible. Boston Road served in southbound direction only.
Eastern Line	To Britomart as at present	Continuing as through Eastern - Western Line services. 2021 level, 5-minute interval (12 trains per hour) possible.
Tranz Scenic	To Britomart via Eastern Line as at present	
Capacity limited by:	Platform 5 at Britomart and West Tunnel southbound stations platforms	Large numbers of alighting and boarding passengers from crowded trains may make achieving the 2.5-minute headway difficult.

There are a number of network operation variations possible. For example, as an alternative to combining Western and Eastern Line services, all three services (Western, Eastern and Isthmus) could be looped around the CBD/Newmarket stations. This would require a north to west chord at Newmarket and a double track wye junction at Mt Eden, as shown on Drawing C04. Both tracks in the West Tunnel, through Britomart Station and the East Tunnel (except for Tranz Scenic trains) would operate in the same directions and all opposing direction conflicting moves at the junctions would be eliminated. All trains would then serve all stations (including Boston Road). This loop scenario would have implications for passengers travelling from the west to Newmarket, with the current station located outside the loop and also on the Network capacity (key areas Quay Park junction and Newmarket junction), dependent on the operation of the loop. The development of the Network operation including the loop is outside the scope of this study.

Tunnel tracks and station platforms would perform at 18 trains per hour, equivalent to 3.3 minute intervals and this would provide the most robust operation for the network.

5.3.3 Potential Single Track Option for the West Rail Extension

An alternative option to double tracking the Britomart West Rail Extension would be to have a single track link through the tunnel to the Western Line (from Britomart Station Platform 1 or 5). The Mt Eden Junction could operate either to the west only or in both directions. If operation were to be from both directions, then the capacity for Britomart Station would be 12,600 passenger arrivals per hour, with the capacity of the Eastern, Western and Isthmus Lines being 8 trains per hour (7.5min intervals). This would provide an intermediate operating level between the 2005-06 and the 2021 train service levels. This option could be seen as a first phase of construction of the Britomart West Rail Extension with the second track and second tunnel bore being installed when the additional capacity is required to achieve the 2021 levels.

This option has not been progressed at this time, as there would a major impact on constructing two tunnels at different times with a consequent escalation of total costs. Ultimately to achieve the 2021 service levels two tunnels for the Britomart West Rail Extension will be required.

5.3.4 Effect of Proposed Future Rail Network Developments

If the previously proposed rail connection from Avondale to Southdown is constructed, then freight trains will almost certainly no longer use the Avondale to Newmarket section of the Western Line unless industrial development along this section requires rail siding access. Therefore if the no wye option at the Mt Eden location were adopted, then the rail corridor between Mt Eden and Newmarket could be deemed to be “surplus”, though there are other issues that would have to be considered before any such decision could be made.

As the programme for the future implementation of the Avondale-Southdown link is unknown, and the timing is likely to be after electrification occurs, the option to remove the existing line between Mt Eden has not been investigated further.

Another variation is not to double track or electrify the Mt Eden to Newmarket section (though re-signalling would still have to be implemented), which would accommodate diesel powered freight trains. There would be a capital cost saving of some $26M if this strategy were adopted.

The impact to private property is shown on Drawing C06 for Options 2A and 2B. Generally the properties are not physically impacted as the tunnel passes under the property at depth. Any possible adverse effects during construction of the Britomart West Rail Extension would be mitigated by construction techniques for example, by stabilising the underlying and adjacent soils prior to excavation.
The number of properties affected the Britomart West Rail Extension are:

- Option 2A – 34; and
- Option 2B – 33.

Where the Britomart West Rail Extension passes under private property, a substrata lease would be required. This could be designated and acquired through the Public Works act if necessary. To secure the substrata leases may have a significant time and cost implication, which at this stage has not been investigated further. The compensation costs for the substrata leases are excluded from the cost estimate.

Land would have to be acquired by Auckland City for the Mt Eden Station and junction portals. The proposed works affect seven properties, subject to detailed surveys and more detailed design. Potential redevelopment of parts of these properties, and the sale of the air rights above the portals could offset the capital cost for this area, although this is not quantified in the study. The cost to acquire land in the junction vicinity is included in Section 7.
Where there is limited cover or the tunnel is very close to adjoining properties construction techniques as discussed in the Tunnelling Section 5 would be required to mitigate any adverse effects.

We have compiled a selection of international bench marking costs for rail tunnel projects similar to that of the West Rail Extension. These costs have been used to develop a per metre tunnel rate and station costs for this project current for 2003, and are summarised briefly in the table below:

7.1 Tunnel Rate

Table 7.1 Benchmarking tunnel per metre rates

Project	Length	Tunnels	Material	Stations	Cost $NZ/m
Chatswood, Sydney	13km	Twin 6.5m	Sandstone	4 underground	$71,500
Universal City to La Brea, Hollywood	3.75km	Twin 5.5m	Soft Rock	-	$55,000
Hiawartha, Minneapolis	2.25km	Twin 6.5m	Cemented sandstone	1 underground	$54,000
New Hampshire Ave Tunnels,Washington	0.94km	Twin 5x5.8 m	Clay and sands	-	$63,500
La Metro – Red Line, Costing Study 1995	-	-	-	Average cost (CPI to 2003)	$67,000
Eastern Region Line, Singapore	-	Twin 6.0m	Soft Rock	-	$50,000
				Average $/m	**$60,000**

Britomart West Rail	**3.1km**	**Twin 6.0m**	**Sandstone**	**3 stations**	**$60,000**

7.2 Station Costs

The station costs have been derived by WT Partnership from elements based on their local (Britomart Station) and offshore experience. The station costs range from $48,000,000 to $75,000,000 and have been bench-marked against similar stations types (depths and ground conditions). The station costs represent an average quality station. (It should be noted that a more sophisticated underground station including retail, platform isolation doors etc, could be as much $100M+).

7.3 Capital Cost

The costs above have been used to generate the capital cost of the Britomart West Rail Extension to an accuracy of ±30%, though it is noted that it is rare for a tunnel to cost less than initial estimates. The capital costs for Option 2A and 2B are as follows:

- **Option 2A : $515,000,000**
- **Option 2B : $469,000,000**

There could be potential costs avoided in the order of $120,000,000 ±30% dependent on the following:

- A duplicated or widened eastern entrance to Britomart Station and enhancements to the line out to Newmarket;
- If there is a west connection only from the Britomart West tunnel to the Western Line at Mt Eden
- Part of the duplication and electrification of the Western Line from Mt Eden to Newmarket and the upgrade of Newmarket Station.

A summary of the costs and clarifications and exclusions are included on the following pages. These costs include all design, legal, consents, construction, land acquisition and Council internal costs.

1	**ALBERT - KARANGAHAPE ROAD - MT EDEN STATION**			**Reference**		**Total Cost**
	ALIGNMENT 2A - 3%					
A	**CONSTRUCTION**		% in Stage			
A1	**Stations**					
	Wellesley Street Station	205m long x 19m wide x 18m deep	100%	A1.1		$ 48,000,000
	Karangahape Road Station	205m long x 19m wide x 34m deep	100%	A1.2		$ 75,000,000
	Mt Eden Station	205m long x 19m wide x 25m deep	100%	A1.3		$ 54,000,000
	Mt Eden Station	Demolition of Existing Station	100%	A1.4		$ 250,000
	Traffic Diversion	Street Closure & Diversions	100%	A1.5		$ 8,764,000
	Utilities Diversions	Relocation of Existing Services	100%	A1.6		$ 6,150,000
	Britomart Station	Works to Britomart Station	100%	A1.7		$ 2,000,000
A2	**Tunnel**					
	Twin Bore Tunnels	3035m long excluding stations but including trackwork, signals, electrification and fees ($60K/m)	100%	A2.1		$ 182,100,000
		Tunnel Portal - 200m	100%	A2.2		$ 5,000,000
		Extra value for tunnelling in hard rock basalt	100%	A2.3		$ 1,500,000
A3	**Trackworks & Signalling (excluding tunnel)**					
	Trackwork	1630m	100%	A3.1		$ 1,712,000
		Tie into Western Line Trackwork	100%	A3.2		$ 3,000,000
	Signalling	1630m	100%	A3,.3		$ 734,000
A4	**Electrification (outside of Tunnel)**					
	25KV AC	Catenary Supports	100%	A4.1		$ 408,000
		Power Supply and Connections	100%	A4.2		$ 1,000,000
A5	**Route Specifics**					
	Underpinning	Underpinning to Alignment	100%	A5.1		$ 6,000,000
	Service Relocations	Orakei Sewer	100%	A5.3		$ 1,000,000
		Remaining Services	100%	A5.4		$ 10,000,000
A6	**Land Purchase Costs**					
	Land Purchase	Land Purchase Costs for Mt Eden Junction and the Station	100%	A6.1		$ 23,000,000
A7	**Design & Contract Supervision**					
	Design & Supervision Fees	10% Design, 4% Supervision (excluding tunnel costs)	100%	A7.1		$ 31,433,000
A8	**Legals/ Consents**					
	Consenting	Resource & Building Consents and Associated Legal Fees 1%	100%	A8.1		$ 5,111,000
A9	**Council Internal Costs**					
	Council Internal Costs	0.50%	100%	A9.1		$ 2,331,000
A10	**Contingency**					
	Contingency	Contingency @ 10%	100%	A10.1		$ 46,850,000
	13th October 2003	**TOTAL ALIGNMENT 2A - 3% OPTION**				**$ 515,343,000**

1	ALBERT - KARANGAHAPE ROAD - MT EDEN STATION			Reference		Total Cost
	ALIGNMENT 2B - 3.5%					
A	CONSTRUCTION		% in Stage			
A1	Stations					
	Wellesley Street Station	205m long x 19m wide x 18m deep	100%	A1.1	$	48,000,000
	Karangahape Road Station	205m long x 19m wide x 30m deep	100%	A1.2	$	69,000,000
	Mt Eden Station	205m long x 19m wide x 20m deep	100%	A1.3	$	50,000,000
	Mt Eden Station	Demolition of Existing Station	100%	A1.4	$	250,000
	Traffic Diversion	Street Closure & Diversions	100%	A1.5	$	8,764,000
	Utilities Diversions	Relocation of Existing Services	100%	A1.6	$	6,150,000
	Britomart Station	Works to Britomart Station	100%	A1.7	$	2,000,000
A2	Tunnel					
	Twin Bore Tunnels	2635m long excluding stations but including trackwork, signals, electrification and fees ($60K/m)	100%	A2.1	$	158,100,000
		Tunnel Portal - 200m	100%	A2.2	$	5,000,000
		Extra value for tunnelling in hard rock basalt	100%	A2.3	$	-
A3	Trackworks & Signalling (excluding tunnel)					
	Trackwork	1630m	100%	A3.1	$	1,712,000
		Tie into Western Line Trackwork	100%	A3.2	$	2,000,000
	Signalling	1630m	100%	A3,.3	$	734,000
A4	Electrification (outside of Tunnel)					
	25KV AC	Catenary Supports	100%	A4.1	$	408,000
		Power Supply and Connections	100%	A4.2	$	1,000,000
A5	Route Specifics					
	Underpinning	Underpinning to Alignment	100%	A5.1	$	6,000,000
	Service Relocations	Orakei Sewer	100%	A5.3	$	1,000,000
		Remaining Services	100%	A5.4	$	10,000,000
A6	Land Purchase Costs					
	Land Purchase	Land Purchase Costs for Mt Eden Junction and the Station	100%	A6.1	$	20,000,000
A7	Design & Contract Supervision					
	Design & Supervision Fees	10% Design, 4% Supervision (excluding tunnel costs)	100%	A7.1	$	29,683,000
A8	Legals/ Consents					
	Consenting	Resource & Building Consents and Associated Legal Fees 1%	100%	A8.1	$	4,699,000
A9	Council Internal Costs					
	Council Internal Costs	0.50%	100%	A9.1	$	2,123,000
A10	Contingency					
	Contingency	Contingency @ 10%	100%	A10.1	$	42,663,000
	13th October 2003	TOTAL ALIGNMENT 2B - 3.5% OPTION				$ 469,286,000

7.4 Clarifications

Refer to the previous summary pages for section references.

Section A1 – Stations

- Three stations namely Wellesley Street, Karangahape Road and Mt Eden are provided;
- The station box has been assumed at 205m long x 19m wide with varying depths (depth as indicated on the longsection plan C02, Appendix A);
- The existing Mt Eden Station, is required to be demolished for both Option 2A and 2B;
- The costs include for major street closures and traffic diversion of the existing services at stations;
- Costs allow for extending the Britomart trackwork on Platforms 1 and 5 through and under the Central Post Office and for reinstating the Britomart Station on completion;

Section A2 - Tunnel

- Tunnel costs have been based on the benchmark costs from Sections 7.1 and 7.2 above;
- Tunnel costs include: Trackwork, signalling, electrification and professional fees;
- A 200m long portal connection to the Western Rail Line is included;
- The cost estimate includes a provisional allowance for tunnelling in hard rock basalt (2A only).

Section A3 and A4 – Trackwork, Signalling and Electrification

- We have allowed for trackwork signalling and electrification to those areas outside the tunnel (i.e. the stations, portal and connections to Western Line).

Section A6 – Land Purchase Costs

- Land Acquisition is required to construct the Mt Eden Station and Junction and at isolated locations along the route. The costs have been compiled from Terranet information based on the latest valuation information. These land purchase costs are: Option 2A - $23,000,000 and Option 2B - $20,000,000.

Section A7 – Sundry Costs

- Design and Consent fees have been included at 14% and 1% respectively;
- Council internal costs have been included at 0.5%;
- A 10% contingency has been included.

7.5 Exclusions

The following costs have been excluded from this cost plan:

- GST;
- Escalation;
- North Shore Link;
- Substrata lease compensation;
- Compensation costs above valuation associated with land purchase;
- Resale/Development value of land purchased to construct Mt Eden Station and junction, but that could become part of a comprehensive re-development.

8.1 Economic Summary

The results:

- Confirm that the project is marginal economically, if built for operation in 2009 – but note that the economic analysis is very conservative. The analysis does not take into account the full congestion benefits (avoided construction, growing congestion delays), nor does it take into account the urban form benefits from the new stations – if these were equal to around $100 million then the project would be viable for construction for 2009;
- Show that the project is potentially economically viable around 2019, if another addition to capacity is required around 2021;
- Show that to optimise the use of Britomart and to meet the expected number of train movements;
    - Around, year2009, capacity improvements will be needed. However, these improvements could be either, include building the Tunnel and Stations or enhancing the approach into Britomart and the line out to Newmarket;
    - Around, year 2021, further capacity improvement may be needed depending upon train movements and patronage forecasts. This could be achieved by constructing the option that was not chosen to address the capacity constraints around 2009.
- In addressing the capacity constraints expected around 2009, avoided costs are far more important than patronage in influencing the results. The results thus depend on cost saved and hence if the tunnel is not built for 2009 and the growth in patronage and train movements is less than expected and no further capacity constraints arise, then the tunnel will never be justified;
- Maximum patronage is expected to be 12% of all commuters and 6% of education travellers.

The proposed tunnel and stations would:

- Provide an urban form to the city and the region that is sustainable, meets current and future access needs and to promotes redevelopment in the Auckland CBD. However, no attempt has been made to estimate these benefits as part of this study as they are difficult and complex to measure but they likely to be very considerable;
- Take people off the congested road network where congestion delays are steadily growing and if rail does not take traffic off the roads then more roads will have to be built or capacity enhanced. While congestion delays are incorporated in the analysis, growing congestion delays are not because they are non-linear and difficult to model. A trial 2% growth in congestion was modelled but the results did not change significantly. Nor is there any allowance for the avoided costs of building more roads.

Three options were evaluated in comparison to the base case:

- Base Case Scenario:

New eastern tunnel at the entrance to Britomart, upgrade track from Mt Eden to Newmarket and upgrade Newmarket Station by 2009. After 2021 under the current Rail Business Plan further expansion of Britomart Station maybe needed - depending on patronage and train movements.

- Options Assessed:
  1) Tunnel ready for use in 2009 with access to the west and the east at Mt Eden;
  2) Tunnel ready for use in 2009 with access to the west only at Mt Eden;
  3) Test the effects of various tunnel completion dates.

8.2 Introduction

This is a complex project due to uncertainty as to how the network will change and evolve and the timing of those changes particularly if the tunnel is constructed – patronage and train operating pattern are unclear at this stage. For instance, if the tunnel and stations are completed before the need or decision to electrify and double track Mt Eden to Newmarket, and to enhance the station and the approach to Newmarket Station then considerable savings can be made. If the tunnel is completed after these investments then they are sunk costs and no savings can be made.

The most significant benefit is the opportunity for Auckland City to re-establish the CBD as a place for work, entertainment, recreation, health services and education. It is almost impossible to value this aspect.

Patronage is difficult to forecast. Currently, only 12% of the Region's work force works in the CBD. Only 35% of the people coming over the harbour bridge go to the CBD, the rest go elsewhere. More people cycled to work in the CBD than used the train in 2001[1].

Readers should note that this is an economic not a financial analysis – some of the benefits are intangible: such as the benefits of less pollution and increased reliability of travel time. Other benefits do not result in any cash accruing to the rail system operator.

8.3 Assumptions

The key assumptions made in the economic analysis are:

a) The system is electrified, new signals are installed and operating
Without electrification the tunnel would probably not be built, as diesel would require significant safety and ventilation and the cost would be prohibitive;

[1] Statistics NZ, Census 2001, Journey to Work data

b) The Western Line is double tracked from Mt Eden westward by 2009
The operating capacity ca not be met without double tracking and with a single line the are no capacity issues at Britomart to address;

c) Adequate numbers of electric units are available when necessary
We are assuming that the service provided will carry the passengers predicted in the Rail Business Plant;

d) Operating costs do not vary significantly from the base case
This is a reasonable assumption: it does cost more to maintain a rail line in a tunnel but it is not a significant amount in the overall scheme of things. This is a matter for the next stage in the analysis;

e) With the tunnel start at 2009 there would be no need to double track Mt Eden to Newmarket nor fully rebuild Newmarket Station.
The loop line only needs a single track from Mt Eden to Newmarket.

8.4 Options

The Base Case consists of: new eastern tunnel at the entrance to Britomart, upgrade track from Mt Eden to Newmarket and upgrade Newmarket Station by 2009. After 2021 under the current Rail Business Plan further expansion of Britomart Station may be needed - depending on patronage achieved and train movements.

Three options were evaluated in comparison to the base case. They were:

1). Tunnel ready for use by 2009 with access to the west and the east at Mt Eden;

2). Tunnel ready for use by 2009 with access to the west only at Mt Eden;

3). Test the effects of various tunnel completion dates.

8.5 Development Opportunities

It may well be possible for the Council to use its holdings and the stations to generate additional money through new development opportunities. For example, in an arrangement with the owner and occupiers, the Downtown Centre could be demolished, so removing the problem with the foundation piles. A new Downtown Centre could then be built, directly linking to the station and in keeping with the City's plans for the area.

8.6 Evaluation

The Economic evaluation is based on the following considerations:

1) Costs by year, incurred or avoided

a) Capital costs:

i) Infrastructure cost: what has to be done over and above the do minimum and when it has to be put in place. This includes: planning, design, consents, hearings, excavation, rails etc;

ii) Costs for what **no longer** has to be put in place that is included in the do minimum. This could include such things as avoided double tracking of the Mt Eden Newmarket line and selling off the land when the Avondale line becomes available for freight.

b) Operating costs:

i) The increased costs of maintaining the new line and the stations;

ii) The operational costs or savings in comparison with the do minimum – timetable; station management; revenue collection; safety; train operations; signal operations.

2) Benefits by year either gained or lost

a) Revenue (additional) collected by the operator for departure from or delivery to the new stations;

b) Pollution - local and national air and noise;

c) Benefits for road users such as safety, congestion and reliability;

d) Urban form benefits, this was not quantifiable;

e) System efficiencies – benefits over and above the incremental benefits, this was not quantifiable.

8.7 Capital Costs

The capital costs for alignments Option 2A and 2B with access to the west and east at Mt Eden, as detailed in Section 7, are listed in the Table 8.1 below with expenditure over two years:

Table 8.1 Capital Costs.

Capital	Alignment Option 2A		Alignment Option 2B	
	2007	2008	2007	2008
Design A7	31,433,000		29,683,000	
Consents A8	5,111,000		4,699,000	
Council Costs A9	1,166,000	1,166,000	1,062,000	1,062,000
Contingency A10	23,425,000	23,425,000	21,331,000	21,331,000
Land Purchase A6	23,000,000		20,000,000	
Build Tunnel A2	94,300,000	94,300,000	81,550,000	81,550,000
Route Specifics A5	17,000,000		17,000,000	
Tracks A3	2,723,000	2,723,000	2,223,000	2,223,000
Electrical A4	704,000	704,000	704,000	704,000
Stations A1	97,082,000	97,082,000	92,082,000	92,082,000
Sub-Total	295,944,000	219,400,000		
Total		**515,343,000**		**469,286,000**
Avoided Capital investment				
Entrance to Britomart (Prov Sum)		80,000,000		80,000,000
Total		80,000,000		80,000,000

The capital costs for access to the east and west at Mt Eden are as above less $80 million (Provisional Sum) for the work avoided. The work avoided is the provision of additional twin tracks through a new duplicated eastern tunnel leading into Britomart Station (adjacent to the existing tunnel) with possible grade separation of the Quay Park Junction (dependent on operation strategies).

The capital costs for the access to the west only at Mt Eden are as above, except for the additional avoided investment for not having to upgrade Newmarket Station, and the electrification and double tracking between Newmarket and Mt Eden. This would save $40 million (Provisional Sum). This includes $26 million for saved upgrading works and $14 million for not constructing the connection to the east at Mt Eden. Accordingly, the avoided investment in total would be $120 million ($80 million + $40 million) for access to the west only.

8.8 Patronage

Maximum rail patronage is expected to be 12% of all commuters and 6% of education travellers. Only passengers travelling to the CBD from the South, West and East were considered as potential travellers to the stations. Ten percent of public transport users from the North Shore were estimated to use the rail network from the stations. This is less than 1% of commuters to the stations.

Employment growth forecast were used to estimate the growth in commuter numbers. The current student numbers at institutes in the CBD plus forecast population growth were used to estimate student numbers. Recreational patronage is estimated at 70% of commuter patronage.

Patronage was estimated using three approaches:

1. Low – a behavioural approach: commuter and recreational patronage start off very low, continue low and reach the maximum 20 years after the start. Education travellers are expected to take full advantage from the beginning. This is considered to be the most likely scenario

2. Medium – a linear approach: commuter and recreational patronage start off very low, and increase in equal steps to reach the maximum 20 years after the start. Education travellers are expected to take full advantage from the beginning

3. Optimistic – all travellers' start off at their expected maximum patronage levels. We see this as unlikely but the introduction of travel demand management may see a result closer to this scenario.

Figure 5 on the following page shows the three alternatives: the top line is the optimistic scenario; the straight line increasing by 5% pa is the medium scenario and the bottom line is the low or behavioural scenario.

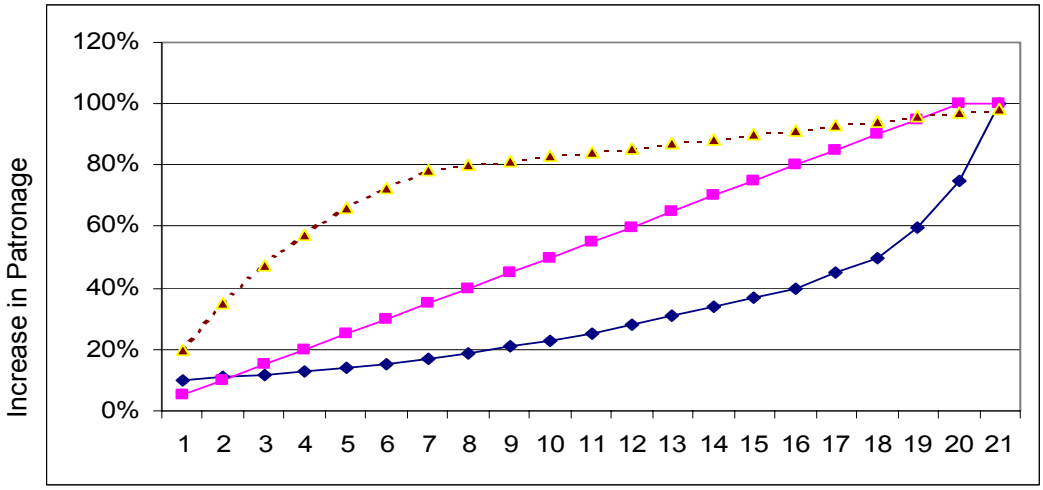


Figure 5.

The low scenario is considered the most realistic. It would take considerable change in behaviour to move to anything like the patronage in the optimistic scenario.

The following paragraphs and table illustrate the journey to work situation from the 2001 Census. In essence, commuter patronage has two components. These are shown in Table 8.3 below.

1. Those people who wish to come to the CBD. Only 400 commuted by train while 500 cycled.

2. Those people who wish to depart from the CBD.

Table 8.3 Commuting data to and from the CBD.

	Commute to the CBD in 2001
12%	Of all Regional workers, work in the CBD
41,000	People work in the CBD
1,000	People live and work in the CBD
40,000	Thus come from outside the CBD
9,000	Come over the Harbour bridge (2,000 by public transport)
31,000	Implying 31,000 could commute by train to the CBD
	Commute from the CBD in 2001
15,000	Additional people come over the bridge and go outside the CBD
1,000	People commute from the CBD: east, south and west
16,000	Could commute by train from the CBD
12,500	Busway passengers expected by 2011
6,000	Current PT over the Bridge patronage

Source: Statistics NZ Journey to Work data 2001 Census, ARC Model coding
Infrastructure Auckland website for the Busway information

8.9 Parameter Values

We estimate the other benefits as:

- Pollution and accident savings are $.0.84 cents per 10.5 km trip based on the Transfund Project Evaluation Manual with 1.25 people per car;
- Congestion $5.04 per 10.5 km from the work completed in researching Patronage Funding by Booz Allen Hamilton with 1.25 people per car;
- $100 million from the increase in property values around the two new stations.

8.10 Results

As discussed in Section 5 – Rail Operations, two tunnel configurations have been economically evaluated, these are: double track with access from both directions at Mt Eden and double track with access to the west only at Mt Eden.

If the base case includes the tunnel and stations considered in this analysis being built in 2021, and this point needs to be examined further, then the results are:

Option	B/C	IRR
West access only	0.8 to 0.9	8% & 9%
East and West access	0.7 to 0.8	7% & 8%

There is no allowance in this analysis for growing congestion, avoided roads, the impact on urban form and the fact that the stations would form part of the network necessary for the growth strategy. It may well be considered that these benefits would make the project worthwhile. To make the B/C equal 1.0 these benefits would need to be worth $100 million.

If the base case does not include the tunnel and stations being built in or around 2021 in this analysis, then the results are:

Option	B/C	IRR
West access only	0.4 to 0.5	4% & 6%
East and West access	0.4 to 0.5	3% & 4%

The results for a starting time after 2009, *if there is no tunnel in the base case*, are less than that above. This is because capital investment on alternative entrances into Britomart is made in 2009 and so the benefits of avoiding them are lost.

The results for different starting points, *if there is a tunnel in the base case*, are:

West Access only	B/C	IRR
2011 to 2016	0.8 to 0.9	8% & 9%
2017 to 2020	1.0 to 1.2	10% & 15%

The results show a significant rate of return (B/C greater than 1) from 2017 up until 2020. This is because the benefits from avoiding capital investment on alternative entrances into Britomart is maximised in this period. After 2021, under the assumptions as outlined above, the returns from the project fall back to B/C = 0.5 and IRR = 4%.

However, it must be noted that, as already explained, this project has taken a conservative approach for the patronage and benefits. Further economic evaluation will be required to identify these elements and how they affect the projected returns.

8.11 Economic Peer Review

This section was peer reviewed by BECA for Auckland City and Booz Allen Hamilton for URS/GHD. BECA noted that the results were conservative and we would agree. The BECA review is included in Appendix D. Booz Allen Hamilton also noted that the results were conservative and suggested some alternative parameters. These were: 5¢ per km for pollution; 5¢ per km for accident costs; 60¢ per Km for decongestion; 10.5 km for average trip length; and car occupancy at 1.25.

When run with these parameters the results show little difference. In essence 0.1 is added to the B/C results and 1% is added to the IRR results.

To develop an appreciation of the risks to this project, we reviewed information both specific to the technical engineering work[2], and more generally relating to the rail transport system[3]. The technical information formed the basis for a draft **Risk Register** (Appendix B), while the general information helped identify potential "show stoppers" that were discussed in the group workshop held on the 6th August 2003.

During the workshop participants identified eight "showstopper" issues as summarised in the Table 9.1 below.

Table 9.1 Show Stopper Issues

Item	Issue	Responsibility	Action for URS Team	Comments
Funding	Not understanding the long-term nature of the payback. Not enough to start project. Not enough to maintain and/or renew	ARC leads involvement from IA, ACC, Crown, private	Noted. Not addressed in the feasibility study, apart from proposing the least cost solution, except for possible Station development	Developer contributions are important 20 – 25 year timeline, 2008/09 decision point
Electrification	Failure to electrify network	ARC	Noted	Assumption that electrification needs to occur prior to tunnelling
Political climate	Change of politicians (city, regional, national)	ARC	Noted (ARC will lobby and address through their management strategy)	General uncertainty
Land access	General issues, especially access to the Downtown	ACC	Reflect technological and economic implications in the	Can mitigate by: purchasing, alternate routes,

[2] Britomart west Rail Link (December 2002 Tonkin & Taylor), ACC Britomart West Rail Tunnel Peer Review (URS and Beca comments), Report to Transport Committee from Manager City Planning (Britomart West Rail Tunnel to the Western Rail Corridor and North Shore Auckland City, 13 Feb 03).

[3] Auckland Regional Land Transport Strategy 2001/2002 (ARC), Travel Demand Management Strategy (Nov 2000), Auckland Passenger Rail Upgrade Project Rail Business Plan (Boston Consulting, May 2003 draft).

	Shopping Centre		feasibility study	designation
Patronage	Patterns of patronage change over time, and we might misjudge	ACC and Land Transport Strategy	Associated economic analysis is a major part of the feasibility study – giving recommendations	Project may still come out "winner" due to providing "missing link"
Cost blow-out in scheme assessment	Changes over long project lead-time, including time and cost escalation	URS/GHD	Get estimates correct in the feasibility study	Expect accuracy of +/- 30% in the feasibility study
Traffic Demand Management	Gets it wrong	ARC	Noted	
Conflicting infrastructure	Someone else "gets in before us"	ARC	Noted	

"Showstoppers" were defined as issues *almost certain to threaten the survival of the overall programme, its administration, and the organisation involved either financially or politically*. For each issue the group provided a description, a responsible party, an expectation for the URS Team in the Feasibility Study, and additional comments if relevant. The group decided that while technical risk factors could be significant, they were likely already managed as part of the provision of professional engineering services.

10.1 Conclusions

From the work undertaken in this study, we can conclude the following:

Alignments
Options 1, 2A/2B and 5 are technically feasible, as shown on Drawing C01. These alignments generally remain within the road reserve where possible. Options 2A and 2B are the best operationally and were taken forward for economic analysis.

One of the main constraints to the Britomart West Rail Extension is the gradient on the line, which is between 3.0 and 3.5%. Comment has been sought from the ARC and ARTNL on this matter. They have responded saying that 3.0% would be acceptable. In our (URS/GHD) opinion 3.0% is achievable and 3.5% although technically achievable may require modified rolling stock and may have higher ongoing maintenance and operations costs

Stations
Three station locations have been identified, Wellesley Street, Karangahape Road and Mt Eden (Exmouth Road). Each has good access potential to surrounding areas and depending on the timing of the project, the potential to integrate the station with future residential and/or commercial developments. Wellesley Street Station would have the opportunity to have an access directly to the proposed bus interchange on Albert Street.

Tunnelling
A twin tunnel profile has been selected as providing the optimal configuration to accommodate both technical and economic considerations. Most of the tunnel length will be excluded in competent ground. Highly specialised tunnelling work is required over the initial 300m from Britomart to progress the tunnels through the old Post Office building and the Downtown Centre building where piled foundations will be encountered.

The three stations would be constructed in a cut-and-cover operation. Given the high-rise buildings that line the street at the site of the Wellesley Street Station, a diaphragm wall top-down construction method has been considered appropriate and used as a basis for costing purposes.

Rail Operation
Between the proposed 2009 and 2021 Rail Business Plan train frequencies, Britomart Station would reach operational capacity. To upgrade the station to achieve the higher frequencies will require either:

- Additional twin tracks through a new duplicated eastern tunnel leading into Britomart Station (adjacent to the existing tunnel) with possible grade separation of the Quay Park Junction (dependent on operation strategies); or
- Britomart Station to be converted to a through station with the Britomart West Rail Tunnel.

If the Britomart West Rail Extension is constructed, a double track tunnel with access from both directions at Mt Eden, provides for the full 2021 service on Western, Eastern and Isthmus Lines and also

the maximum flexibility. The most robust operation would be to loop all three services through the CBD Stations.

Impact on Private Property

Generally the properties are not physically impacted as the tunnel passes under the property at depth. Any possible adverse effects during construction would be mitigated by construction techniques. The tunnel corridor under these properties would require a substrata lease, which may have timing and cost implications.

Some land would have to be acquired by Auckland City for the Mt Eden Station and junction portals, as the property and buildings would be physically impacted for construction.

Capital Costs

The capital cost of the Britomart West Rail Extension has been identified to be in the range of $469,000,000 to $515,000,000 with an accuracy of ±30%, dependent on whether a 3.0% or 3.5% gradient is adopted. There could be potential costs savings in the order of $120,000,000 dependent on whether there is an eastern connection at Mt Eden and when the project is built.

Economic

The economic analysis shows that the project could be economically viable (that is, in terms of economic benefit to the City and the region) between 2019 and 2020. However this analysis does not rule out the project going ahead for 2008-2009 (when capacity of the existing station will be reached), as the B/C is almost 1 and this is a conservative analysis. As a next step we suggest that there is a need for:

- Greater certainty around the rail capacity issues in the base case;
- Greater certainty around patronage;
- More clarity in the benefits from less road congestion;
- A better basis for the impact on land values in the vicinity of the stations; and
- Estimating a value for the benefits from avoided costs of building or enhancing the road network.

Risk

A number of "show stopper" issues have been identified for the Britomart West Rail Extension. The ACC and ARC are responsible for managing the majority of these shows stoppers. At this feasibility stage it is believed that the issues are manageable. A risk register has been set up during the study and will be useful as a comprehensive tool to assist in any potential scheme assessment.

10.2 Overall Conclusions

The capacity of Britomart Station can be enhanced to the meet the projected 2021 Rail Business Plan patronage on the Auckland Rail Network by the construction of the Britomart West Rail Extension.

The project could be economically viable between 2019 and 2020, and although this analysis does not conclude that the project should go ahead for 2009 (when the Britomart Station reaches capacity), the analysis also does not rule out this earlier implementation.

The capital cost of the Britomart West Rail Extension is in the range of $469,000,000 to $515,000,000 with an accuracy of ±30%. There could be potential costs savings in the order of $120,000,000 dependent on when the project is built.

The three proposed stations will provide service directly to Queen Street, the universities and the Aotea precinct, Karangahape Road and the Mt Eden residential and commercial area.

10.3 Next Steps

The economic analysis shows that the prospect of building a tunnel with two new stations, and relocating the Mt Eden Station, is worthy of further investigation. We do not support a full Scheme Assessment Report (SAR) as the next stage of this project; however there are specific areas where we suggest that further work is warranted. These areas are outlined below.

10.3.1 Funding

While the project may be economically viable, it is not financially viable (that is, does not provide an acceptable return on investment). Few public transport projects in New Zealand are financially viable. It is therefore important to a certain whether funders would be willing to commit to the project, the amount they would be willing to commit and the level of justification they require before confirming that commitment. In essence, if funders are not available, then there is little point in continuing the analyses.

***Action**: Draw together a preliminary funding package after discussions with The Treasury, Ministry of Transport; Transfund; Infrastructure Auckland; Manukau City; Waitakere City and the Auckland Regional Council and clearly establish:*

- *Whether they would be willing to commit to the project;*
- *The amount they would be willing to commit;*
- *The level of justification they require before confirming that commitment.*

10.3.2 Patronage

This drives both the revenue that the rail operator receives from the project and also the need for rail system expansion. Current patronage projections were developed in the Rail Business Plan. We need to more clearly define the funding gap and the average fare requirements.

***Action**:*

- *Establish the likely patronage (boardings) in term of commuters, education and recreation users to Britomart Station, the two proposed new stations and the relocated Mt Eden Station;*
- *Establish where those patrons came from (destination Auckland CBD) and were going to (origin Auckland CBD). The accuracy should be suitable to enable the rail development work planning to identify likely investment paths given three growth scenarios (low, medium and optimistic);*
- *Establish the average fare.*

10.3.3 Economic

The economic analysis is very conservative and tests show that most of the risks appear to be on the upside. There is a need to undertake an analysis based on savings from reduced expenditure on the road network plus congestion benefits.

***Action**:*

- *Undertake a more in depth analysis of the economic benefits of building the tunnel in terms of congestion, improved access and avoided expenditure on the road network;*
- *Capture the benefits of improved urban form and CBD revitalisation;*
- *Investigate the potential for developer joint funding based on the benefits to landowners adjoining the stations.*

10.3.4 Confirmation of Gradient

One of the key aspects to the technical feasibility of this project is the acceptability of the tunnel's vertical gradients and the impact this has on Network operation and the procurement of rolling stock. Stakeholders must agree on the assumption that a gradient of between 3.0% (or greater) is acceptable.

***Action**:*

- *Determine an acceptable and agreed gradient standard with the relevant network stakeholders (Auckland City, ARTNL, ARC, rail operator, Tranz Rail etc) to confirm capital cost for further economic evaluation.*

10.3.5 Rail Development

As the projected 2021 patronage levels are approached, the whole need for and solutions available to further increase the capacity of the Britomart Station node, must be determined. These future decisions will have an impact on investment strategies for the Britomart West Rail Extension Project.

***Action**:*

- As part of ongoing studies of the Britomart West Rail Extension Project the long-term patronage and network expansion beyond 2021 must be further developed.

Appendix A

Drawings

Alignment Options – C01

Longsections – C02

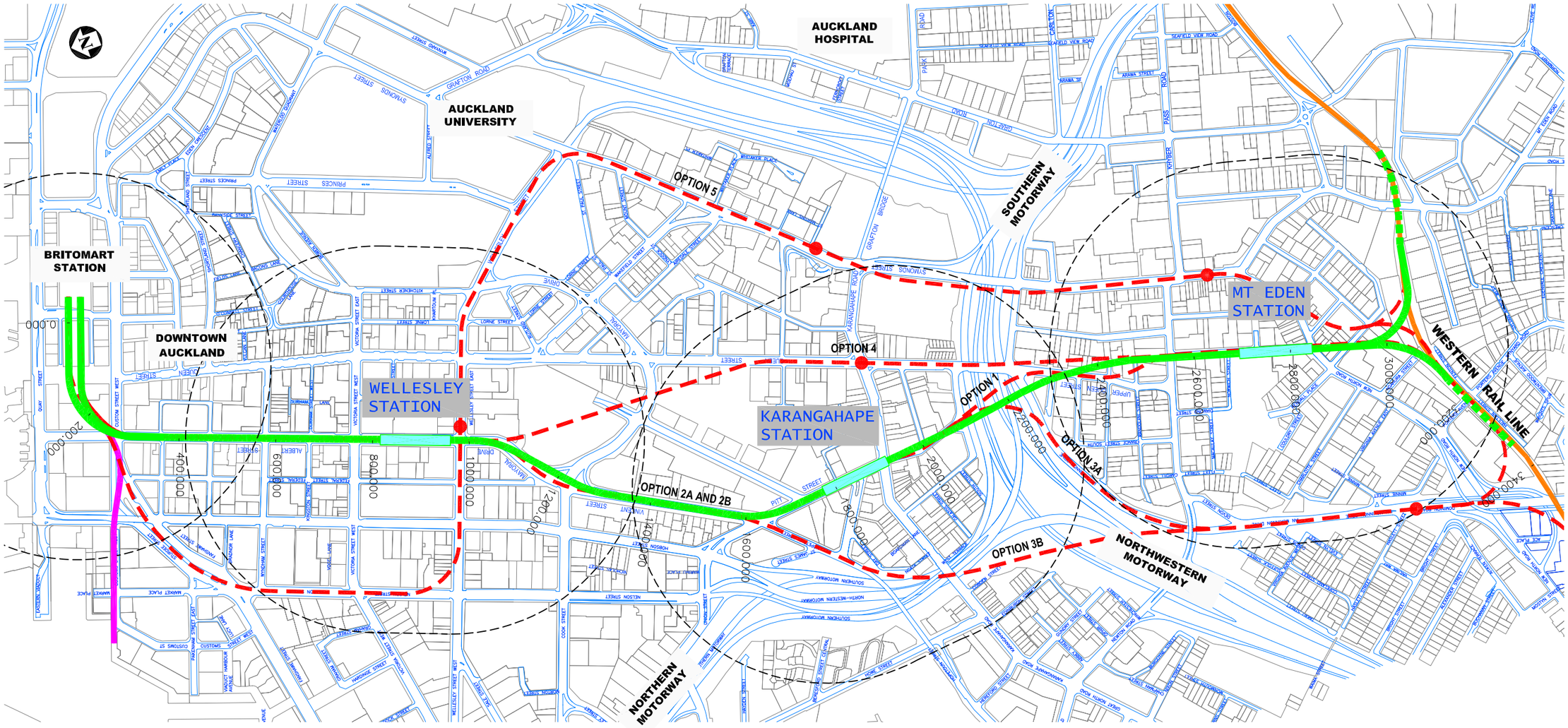
North Shore Junction – C03

Mt Eden Junction – C04

Tunnel Cross Sections – C05

Property Affected – C06

Station Locations – C07



LEGEND:

- ALIGNMENT OPTION 2A (3.0%)
- ALIGNMENT OPTION 2B (3.5%)
- ALTERNATIVE OPTIONS STUDIED AND STATIONS
- PROPOSED STATION LOCATION
- PED SHED (400m)
- FUTURE NORTH SHORE LINK
- WESTERN RAIL LINE

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
B	FINAL DRAFT			
A	DRAFT ISSUE	PH	BR	14/10/03

AUCKLAND CITY

GHD

URS New Zealand

Engineering and Environmental Management

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New Zealand
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CAD FILE NAME: U:\PROJCAD\48216\096\AU096C03

TAB

XREF FILES

SCALES N.T.S.

ORIGINAL SIZE A1

DESIGNED

DRAWN PH

CHECKED

PROJECT MANAGER BR

DATE OCT 2003

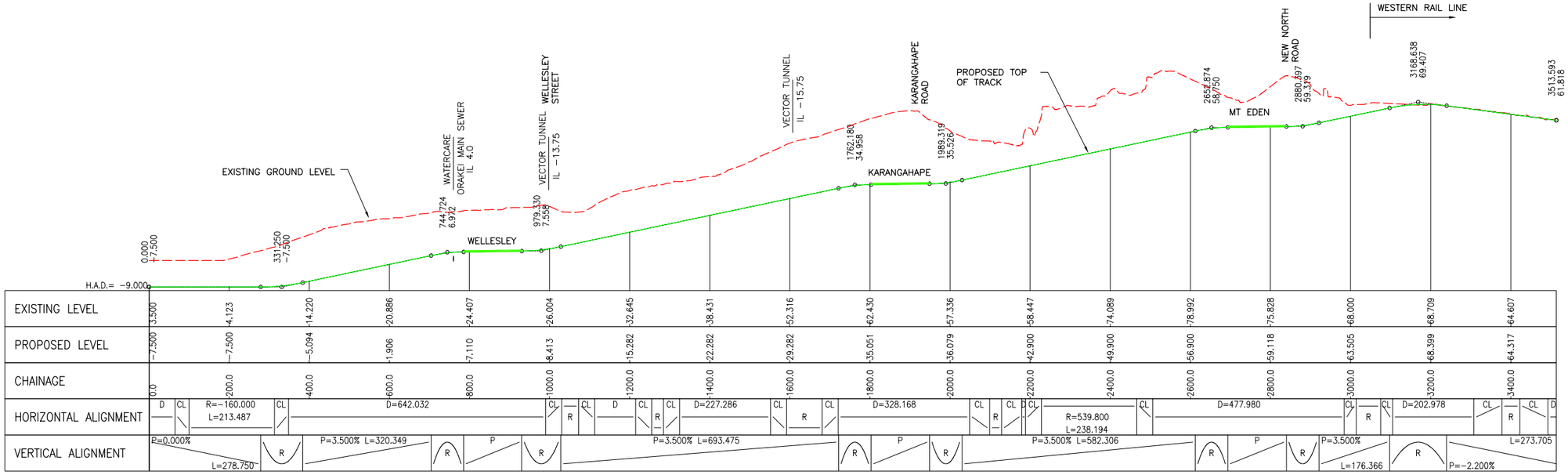
BRITOMART WEST RAIL EXTENSION

ALIGNMENT OPTIONS

STATUS FINAL

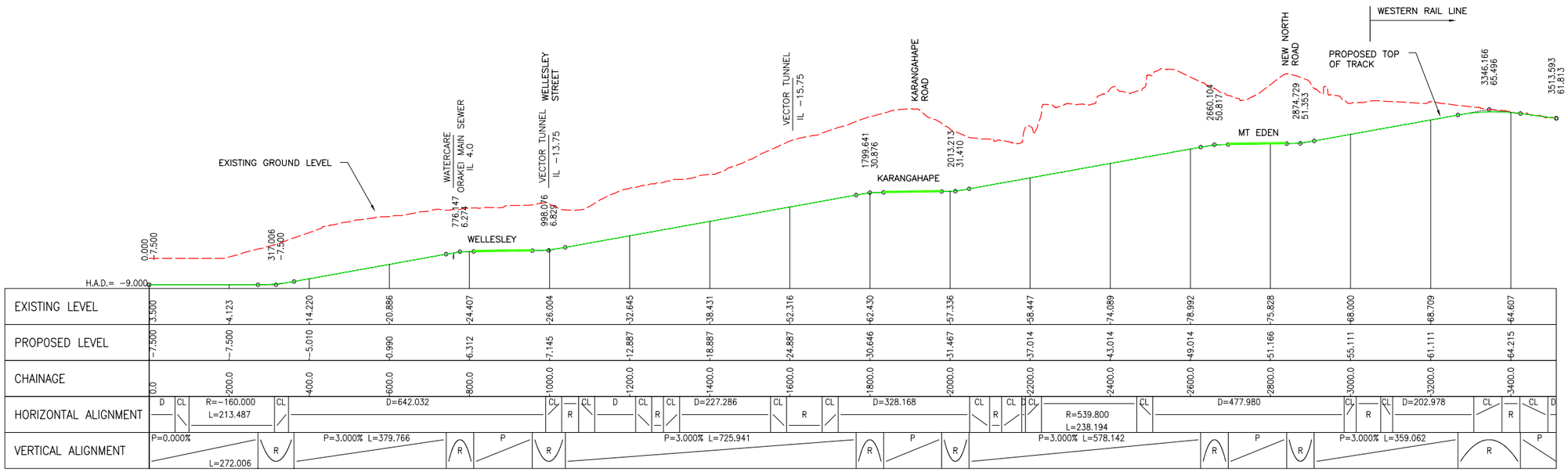
REVISION B

DRAWING NUMBER C01



LONGITUDINAL SECTION AT 3.5% MAXIMUM GRADIENT – OPTION 2B

SCALES: 1:6000 Horiz. 1:1000 Vert.



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B	FINAL DRAFT ISSUE			
A	DRAFT ISSUE	PH	BR	14/10/03

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GHD

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Engineering and Environmental Management

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ORIGINAL SIZE A1

DESIGNED

DRAWN PH

CHECKED

PROJECT MANAGER BR

DATE OCT 2003

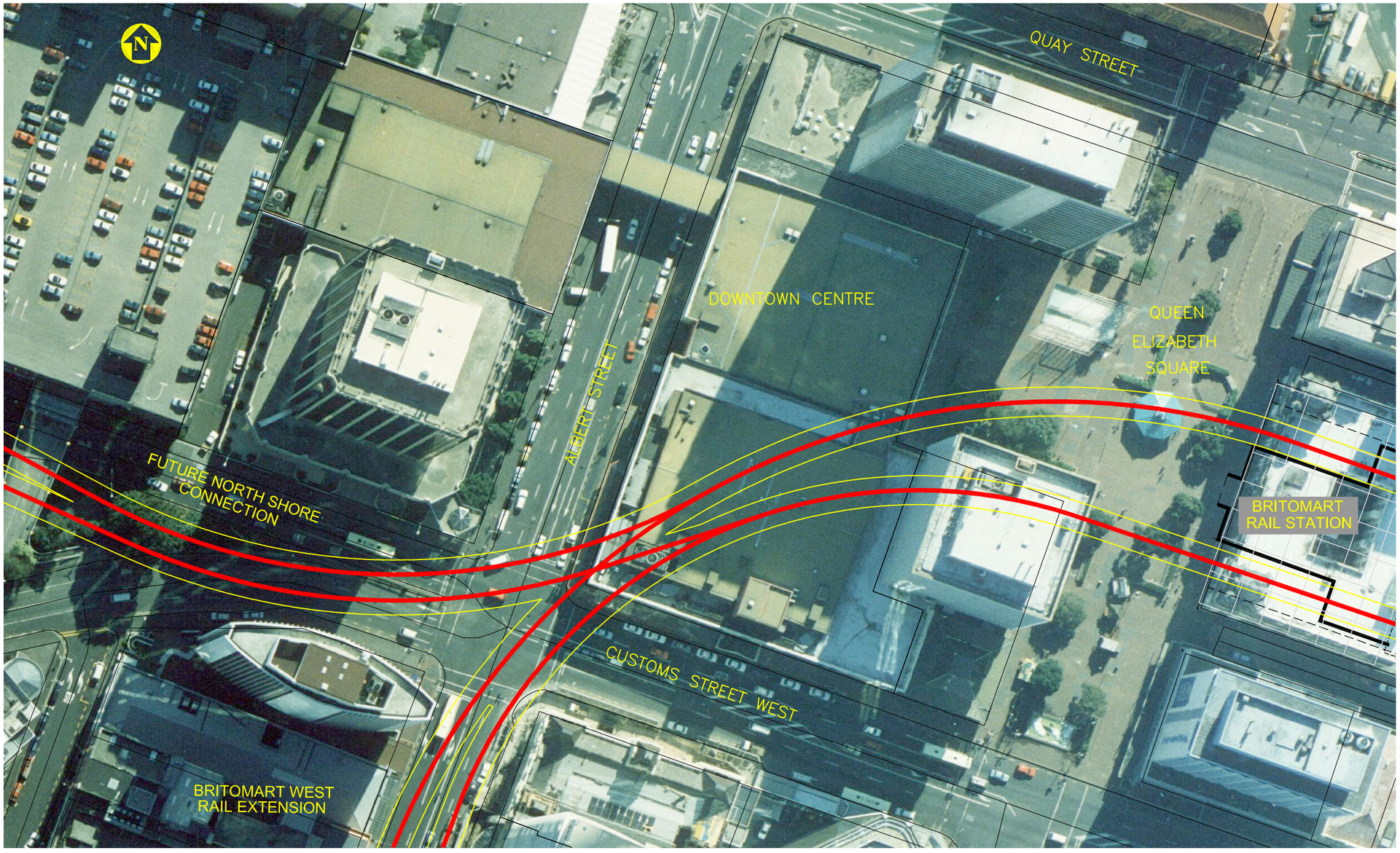
BRITOMART WEST RAIL EXTENSION

OPTION 2
LONGSECTIONS

STATUS FINAL

REVISION B

DRAWING NUMBER **C02**



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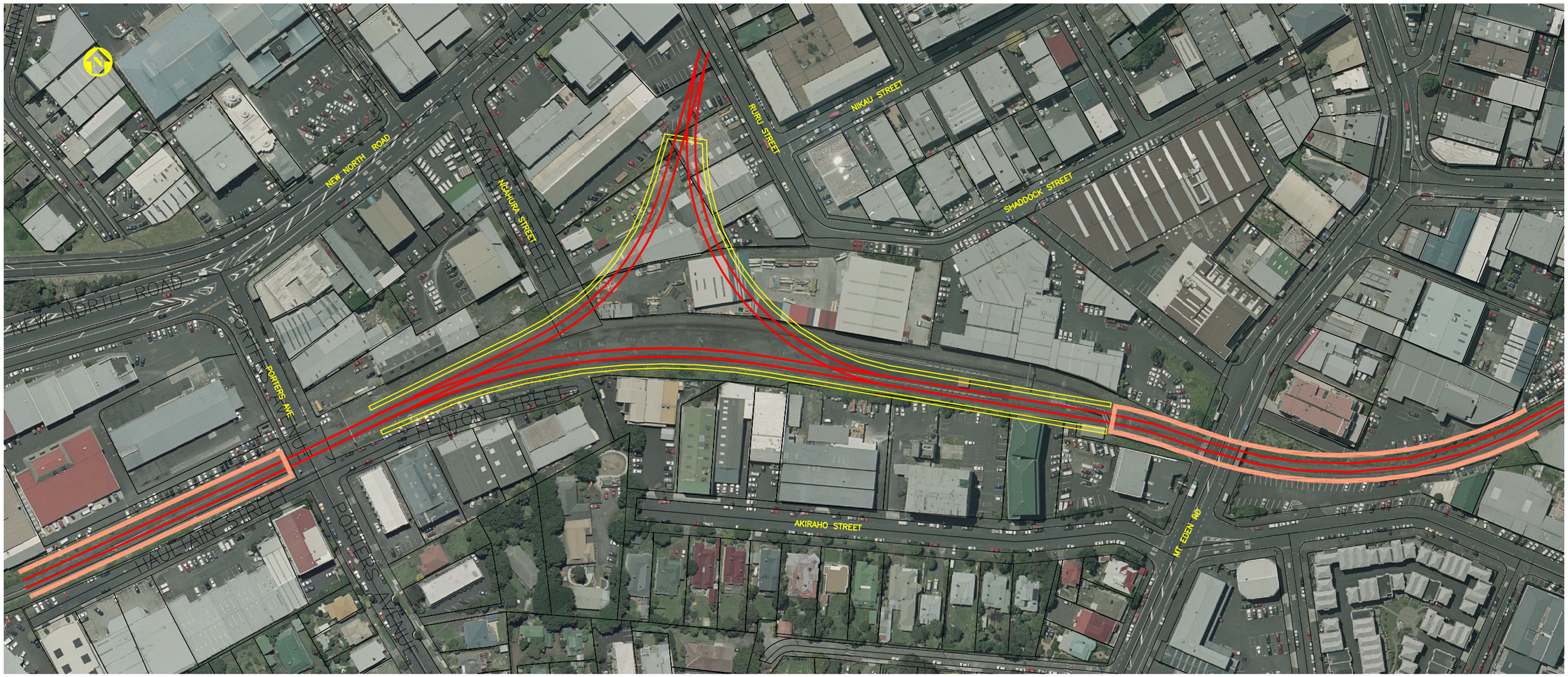
DESIGNED
DRAWN PH
CHECKED
PROJECT MANAGER BR
DATE 10/10/03

BRITOMART WEST RAIL EXTENSION

PROPOSED NORTH SHORE LINK

STATUS FINAL
REVISION B
DRAWING NUMBER C03



LEGEND:

- PORTAL FOOTPRINT OPTION 2A (3.0%)
- PORTAL FOOTPRINT OPTION 2B (3.5%)

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
B	FINAL DRAFT ISSUE			
A	DRAFT ISSUE	PH	BR	14/10/03

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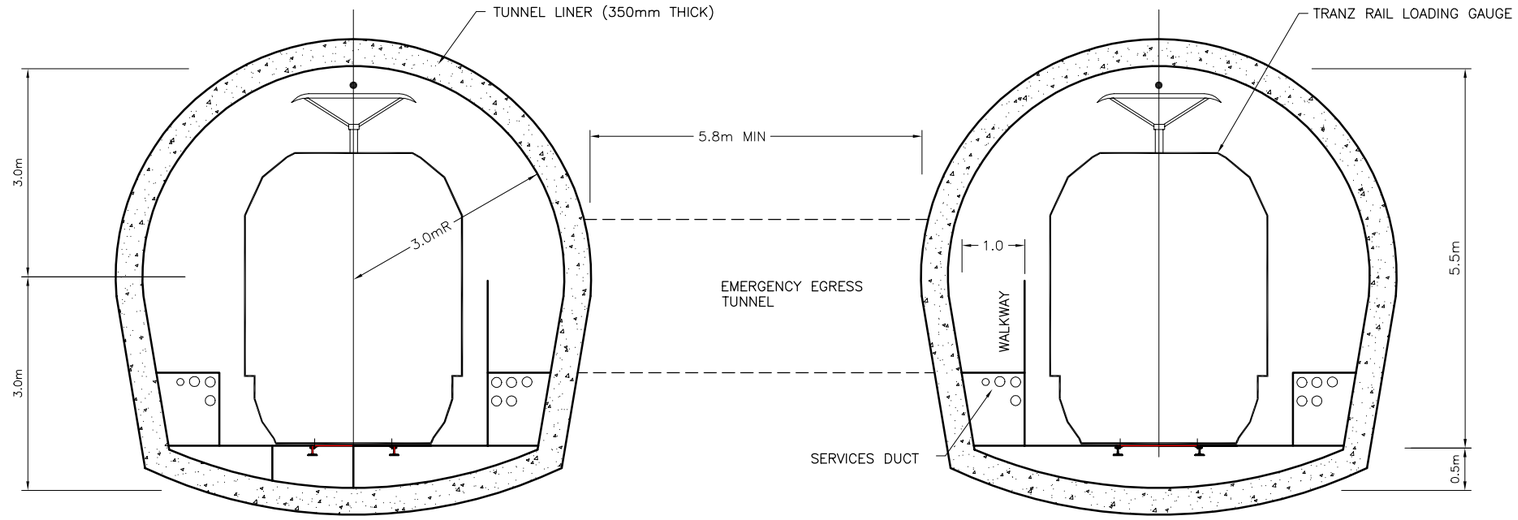
ORIGINAL SIZE A1
DESIGNED
DRAWN PH
CHECKED
PROJECT MANAGER BR
DATE 13/10/03

BRITOMART WEST RAIL EXTENSION

MT EDEN JUNCTION PORTAL FOOTPRINTS

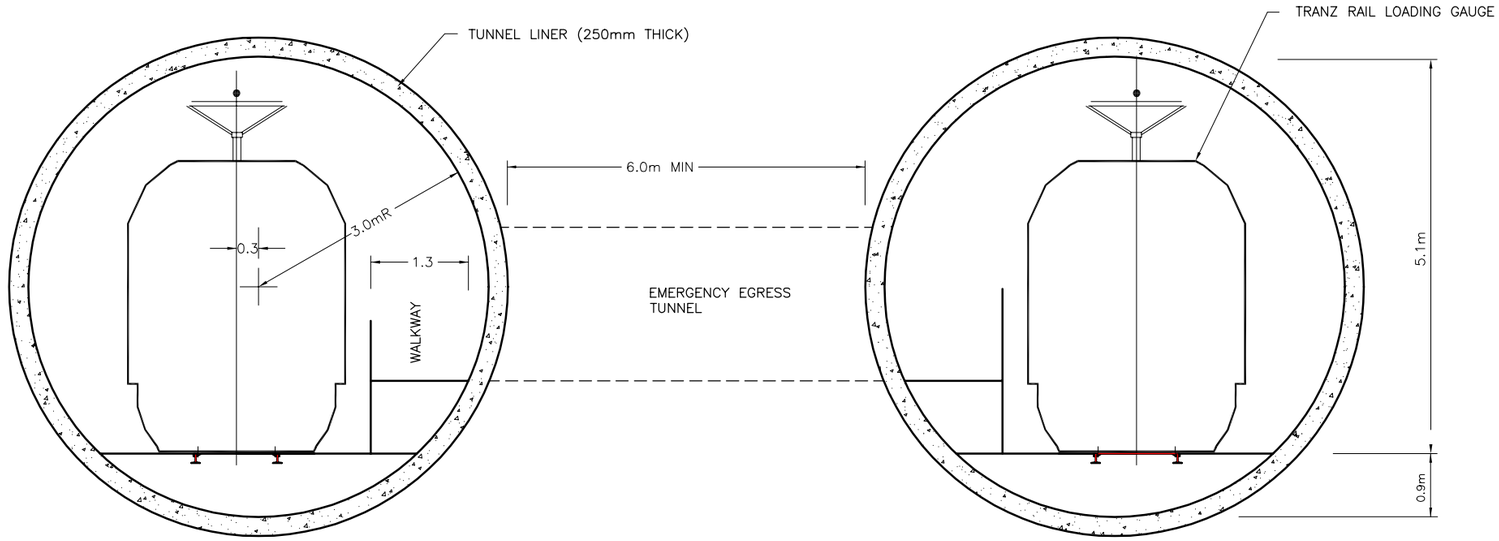
STATUS FINAL
REVISION B
DRAWING NUMBER C04



MOUNT EDEN BOUND TUNNEL

BRITOMART BOUND TUNNEL

ROAD HEADER CONSTRUCTION



MOUNT EDEN BOUND TUNNEL

BRITOMART BOUND TUNNEL

TBM CONSTRUCTION

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
B	FINAL DRAFT ISSUE			
A	DRAFT ISSUE	PH	BR	14/10/03

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SCALES N.T.S.

ORIGINAL SIZE A1

DESIGNED

DRAWN BR

CHECKED

PROJECT MANAGER BR

DATE 13/10/03

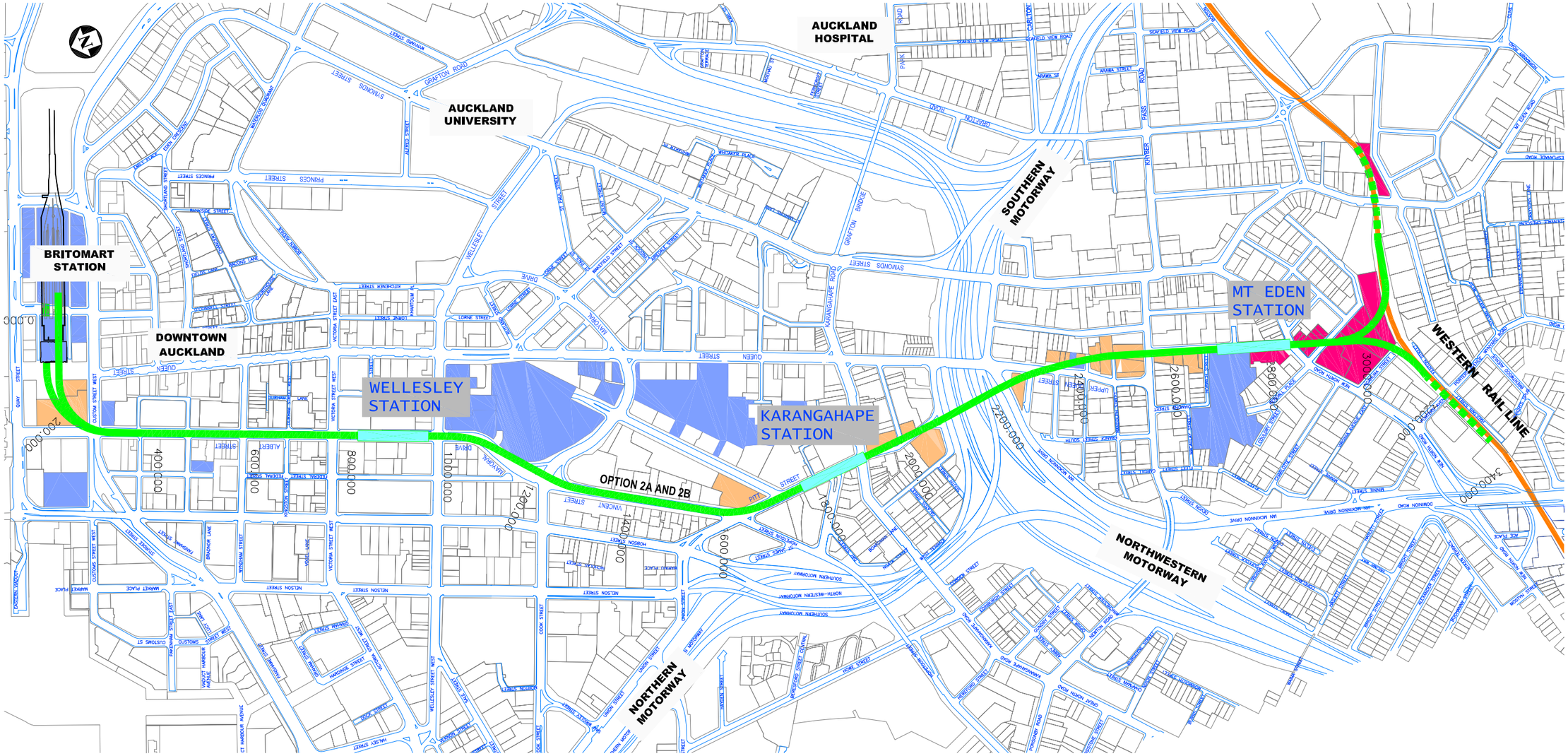
BRITOMART WEST RAIL EXTENSION

TWIN TUNNEL CROSS SECTIONS

STATUS FINAL

REVISION B

DRAWING NUMBER **C05**



LEGEND:

- ALIGNMENT OPTION 2A (3.0%)
- ALIGNMENT OPTION 2B (3.5%)
- PROPOSED STATION LOCATION
- WESTERN RAIL LINE
- LAND AFFECTED
- LAND REQUIRED FOR JUNCTION/STN
- ACC OWNED PROPERTIES

NUMBER OF PROPERTIES AFFECTED OPTION 2A = 33
(INCLUDES SUBSURFACE TITLE ENCROACHMENT)

NUMBER OF PROPERTIES AFFECTED OPTION 2B = 34
(INCLUDES SUBSURFACE TITLE ENCROACHMENT)

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
B	FINAL DRAFT ISSUE			
A	DRAFT ISSUE	PH	BR	14/10/03

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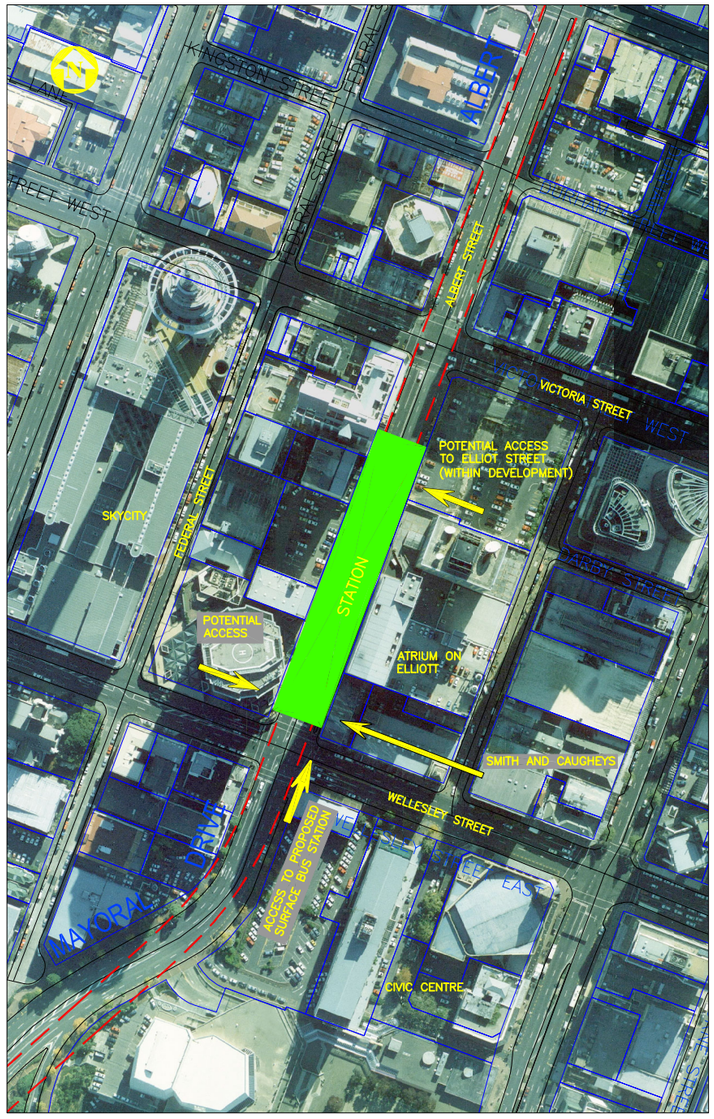
ORIGINAL SIZE A1
DESIGNED
DRAWN PH
CHECKED
PROJECT MANAGER BR
DATE OCT 2003

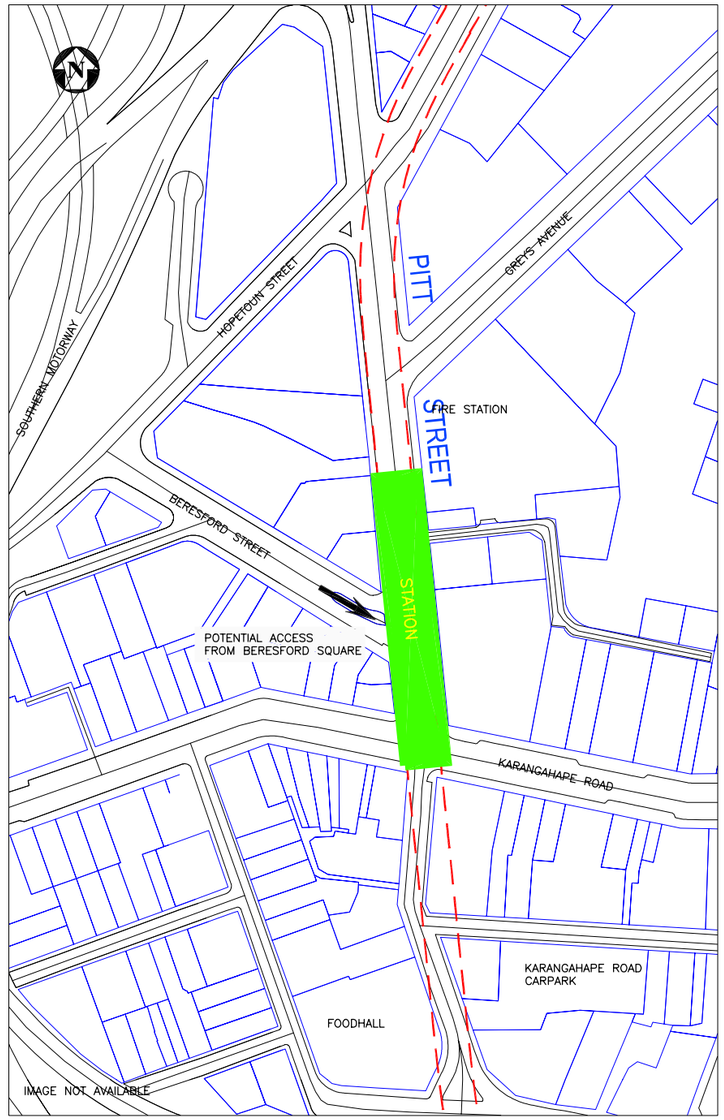
BRITOMART WEST RAIL EXTENSION

PROPERTY AFFECTED

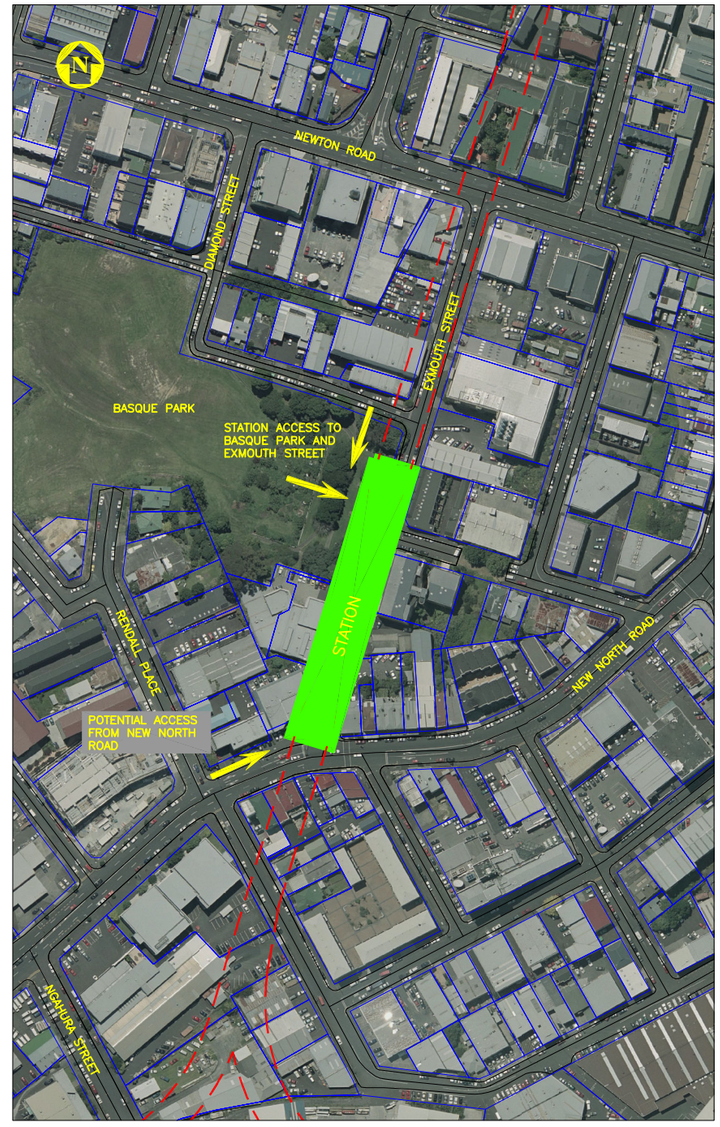
STATUS FINAL
REVISION B
DRAWING NUMBER C06



WELLESLEY STATION



KARANGAHAPE STATION



MOUNT EDEN STATION

LEGEND:

- EXTENT OF TUNNEL LIMITS
- STATION AREA
- PROPERTY BOUNDARIES

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
	FINAL DRAFT ISSUE			
A	DRAFT ISSUE	PH	BR	14/10/03

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CHECKED
PROJECT MANAGER BR
DATE OCT 2003

BRITOMART WEST RAIL EXTENSION

STATION LOCATIONS

STATUS FINAL
REVISION B
DRAWING NUMBER **C07**

Appendix B

Risk Register

DRAFT RISK REGISTER **BRITOMART WEST RAIL LINK**

URS GHD

Reference	What events can prevent us from achieving the outcome	Risk Analysis		Management of Risk	Comments
		How likely is the event	What are the consequences		
Note This Risk Register is based on Previous Engineering Studies with the addition of "Show Stoppers" (in bold) identified from the client workshop in August 2003. It is intended to provide the nucleus for a full Risk Register at later stages of the project as it progresses.					
Function/Activity:	**Funding and Economics**				
Funding	Funding policy changes	likely	major		Project Stalls
Funding	**Not understanding the long term nature of the payback. Not enough funding to maintain and/or renew**	**likely**	**major**	**Noted at this stage only. Not addressed in feasubility study apart from proposing the least cost solution, except for possible station development**	**Developer contributions are important 20-25 year timeline, 2008/09 decision point**
Project Cost Blowout	**Changes over a long project lead-time, including time & cost escalation**	**likely**	**major**	**Reponsibility of ACC**	**Need to get estimates right in the feasibility study. Expect accurracy of +/- 30% in the feasibility study**
Political Climate	**Change of politicians (city, regional, national)**	**likely**	**major**	**Currently reponsibility of ARC**	**ARC will lobby and address through their management strategy**
Patronage	**Patterns of patronage change over time, patronage targets not met**	**likely**	**major**	**ACC and Land Transport Strategy**	**Associated economic analysis is a major part of the feasibility study - giving recommendations. Project may still come out winner due to providing missing link**
Underground Stations	Cost may blow out	likely	moderate		
Function/Activity:	**Design Issues**				
Electrification	**Failure to electrify network**	**moderate**	**major**	**Assumption is that electrification needs to occur prior to tunnelling**	**Crucial - Project could not proceed without electrification**
Traffic Demand Management	**Traffic Demand Management (TDM) fails to drive patronage**	**moderate**	**major**	**Assumption is that Traffic Demand Management will succeed in driving patronage**	**Vital to Finances. Revenue & other targets will not be met if TDM fails**
Tunnelling beneath Buildings	Undermining of building foundation, and distress in the building superstructure	almost certain	moderate		Removal and substitution of foundations required - significant cooperation req from land owners - Central Post Office, QE2 sq, Downtown House,

Reference	What events can prevent us from achieving the outcome	Risk Analysis		Management of Risk	Comments
		How likely is the event	What are the consequences		
Underground Stations	Requirements may vary	likely	moderate		Also North Shore link
Tunnelling Rates	May vary	likely	minor		
Settlement	**Varying ground conditions/inadequate investigation/design**	**moderate**	**major**	**Attention during design phase**	
Function/Activity:	**Land Access**				
Tunnelling beneath Buildings	Unable to access private buildings	almost certain	moderate		Removal and substitution of foundations required - significant cooperation req from land owners - Central Post Office, QE2 sq, Downtown House,
Strata Land Acquisition	**Not being able to obtain consent**	**almost certain**	**major**	**Reponsibility of ACC**	**No cost allowance made**
Land Access	**General Issues especially access to the Downtown**	**likely**	**major**	**Responsibility of ACC**	**Reflect technological and economic implications in the feasibility study. Can Mitigate by purchasing. Alternative routes designation**
Function/Activity:	**Operational Safety Requirements**				
Fire Safety Requirements	Inability to meet requirements	unlikely	moderate		Fire Cell provision, regular escape routes, integrated ventilation and fire supression sustems, full fire suppression capability
Security	Inability to meet requirements	unlikely	moderate		
Communication systems	Inability to meet requirements	unlikely	moderate		
Lighting	Inability to meet requirements	unlikely	moderate		
Emergency Escapes	Inability to meet requirements	moderate	moderate		Land required for exits
Function/Activity:	**Services**				
Vector Cable Tunnel	Unable to avoid service	likely	moderate		Proposed rail tunnel will cross above Vector Cable Tunnel
Orakei Sewer Main	Unable to avoid service	likely	moderate		Proposed tunnel will cross the path of the Orakei Sewer Main
Albert Street Sewer Main	Unable to avoid service	likely	moderate		Large diameter pipes at a depth close to proposed tunnel
Other Services	Unable to avoid service	moderate	minor		
Conflicting Infrastructure	**Someone "gets in before us"**	**moderate**	**major**	**Noted only**	
Function/Activity:	**Environmental Consultation**				
Land Access	Difficult to obtain	moderate	moderate		May be costly to obtain on Private Land

Reference	What events can prevent us from achieving the outcome	Risk Analysis		Management of Risk	Comments
		How likely is the event	What are the consequences		
Land Use Consent	Difficult to obtain	likely	minor		Both city and regional councils involved
Water Take/Diverge/ Discharge	Water Quality	almost certain	minor		Iwi consultation required
Groundwater pH	Consent for pH correction	almost certain	minor		
Groundwater Sediment	Sedimentation facilities required	almost certain	minor		
Groundwater Depletion	**requirement of waterproof tunnel**	**rare**	**major**	**Attention during design phase**	**Buildings may subside**
Vibration	During construction	unlikely	moderate		
Vibration	Rolling Stock	moderate	moderate		
Noise	Portals	unlikely	moderate		
Visual Aspects	Lack of adequate mitigation	unlikely	minor		
Spoil Disposal	Lack of adequate mitigation	unlikely	minor		Both city and regional councils involved
Tangata Whenua	Protracted negotiations	moderate	moderate		Costs increase
Archaeology	Lack of adequate mitigation	moderate	minor		Will need survey, could stall project
Ecological	Lack of adequate mitigation	moderate	moderate		Will need survey, could stall project
Amenity Impacts	Severance and impact	unlikely	moderate		Will need survey, could stall project
Social networks and severance	Severance and impact	unlikely	moderate		Minor impact
All stakeholders	Level of consultation/demands	almost certain	moderate	Could Designate	Time consuming

Date of Risk Review: Oct-03 **Compiled By:** GHD & URS

Date: 0ct-03

Appendix C

Background Information: Vector Tunnel Plans

Information not available in PDF format

Appendix D

Review of Economics by Beca, November 2003

Auckland City Council
Level 1, NSS Building
122 – 124 Quay Street
AUCKLAND

4 November 2003
Our Ref: 8111499/220
L2:12888-MGE3NL01.DOC

Attention: Mr Chris Langstaff

Dear Sir

Britomart West Rail Extension - Review of Economics – Review of Economics

1 Scope of Review

This is a high level review of the economic evaluation contained in the draft report (URS & GHD) dated 14 October, 2003.

2 Overall Conclusions

While the economic evaluation carried out is at a simplistic level, it is nonetheless sufficient to identify that there are substantial benefits in the project and that further investigations into the project are warranted. Based on our high-level assessment, we suggest that the rail extension is potentially economically justified in the medium term.

We believe that the economic evaluation is likely to have a conservative value of benefits, somewhat balanced by underestimation of some of the costs associated with tunnel operation / maintenance and potential additional rolling stock capital requirements.

We suggest that the logical next step in the process should be an evaluation of the project economics with a particular focus on patronage estimates and an estimation of strategic benefits to Auckland City. This evaluation should be done in line with Transfund New Zealand's Alternative to Roading (ATR) evaluation methods so that it can be used in discussions with funding stakeholders to reach a set of agreed assumptions which can be used for project decision making and assessment.

Once this initial ATR model has been developed it will be possible to test different scenarios (including different do-minimums) as well as in essence work backwards to calculate patronage targets that would need to be met in order for the line extension to achieve an Efficiency Ratio (BCR) of over 1.0 .

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Fax +64-9-300 9300
www.beca.co.nz

3 Specific Comments on Assumptions and Risks

These comments do not cover all issues which would be raised in a more in depth review of the economic evaluation but rather relate to those things which at a high level may affect the project economics. [1]

3.1 Project Costs

- The additional operations and maintenance cost of the tunnel section may be a significant annual cost but is not contained in the economic evaluation.
- An evaluation should consider the marginal cost of any extra rolling stock required to operate the services related to the Britomart loop and hence generate the project benefits.

3.2 Benefits

- User Benefits have been set to the estimated value of the passenger fare. This fare level is likely to be the minimum benefit as in almost all cases the user benefit will be higher as this is unlikely to be the maximum fare that a passenger would pay. (The cost of any fare subsidy required should also be included.)
- The estimate of patronage is simplistic and benefits may be overstated if patronage growth cannot be justified. However it is our view that patronage growth is unlikely to be linear but rather grow substantially as soon as the line is opened and be linear from then on. Due to the effect of discounting in economics, this sudden rise in patronage on opening may have a significantly positive effect on the BCR.
- 'Road User Benefits' may increase significantly the total benefits of the scheme in future years (including travel time, vehicle operating, crash reduction, roading maintenance and/or construction savings) as annual cost of regional road congestion increases.

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[1] The version of the economic spreadsheet provided to us by GHD did not produce the same values as quoted in the report. At the time of writing this letter, GHD have just provided an updated version of the Excel Spreadsheet to Beca but this has not been considered in the development of this letter. It is not expected to significantly alter the broad conclusions of our review.

3.3 Assessing Environmental and other Intangible Effects

- As stated by GHD, the intangible benefits of the rail link / loop are likely to be enormous given the opportunity for Auckland City to re-establish the CBD as a place for work, entertainment, recreation, health services and education as well as provide improved standard of amenity for population accessing CBD and North Shore PT Services. It would be possible to estimate the scale of these and include them alongside the project economics.
- Environmental benefits are treated simplistically (only CO_2) and are likely to increase significantly with further investigation.

4 Other Comments on the Analysis

- The analysis doesn't consider public/private investment issues (in essence some benefits and some costs have not been considered).
- The choice of Do Minimum requires close examination, particularly with reference to double tracking and the eventual need for further network improvements.

Thank you for the opportunity to prepare this review to you. If you require any further detail then don't hesitate to contact us.

Yours faithfully
Beca Carter Hollings & Ferner Ltd

Matt Ensor
Senior Transportation Engineer

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Email: mensor@beca.co.nz