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# Hamilton Rapid Transit Preliminary Design and Feasibility Study

## B-LINE

### RED HILL VALLEY PARKWAY STRUCTURAL DESIGN BRIEF

Version:2.0

METROLINX

An agency of the Government of Ontario

RAPIDTransit

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# 1.0 Introduction

The Hamilton B-Line Rapid Transit project is the provision of rapid transit between McMaster University and Eastgate Square along the Main Street/King Street corridor.

The alignment of the LRT line passes on the existing bridge of Queenston Road over the Red Hill Valley Parkway (See Figure 1). This report outlines the current condition of the Queenston Road Bridge, a structural evaluation of the impacts the LRT may have on the bridge structure, the various alignment options and their feasibility, and a recommendation of the preferred alignment option.

It is to be noted that is an evaluation based on current information provided by the City of Hamilton from their PRISM database, and a preliminary design of the bridge is recommended to be undertaken in the next design phase.

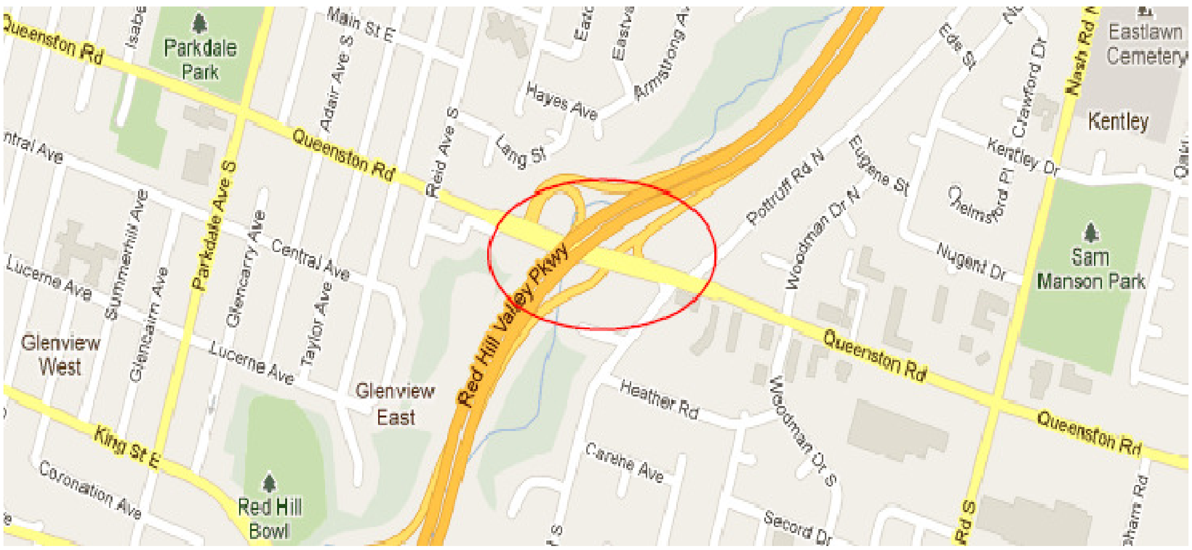



**Figure 1 Location of Queenston Road Bridge**

# 2.0 Existing Queenston Road Bridge

## 2.1 Description

The existing bridge is a three-span structure (See Figure 2). The span lengths are 37.0 m, 29.0 m and 39.5 m respectively. The bridge consists of two hollow slab deck structures which sit side-by-side, accommodating six 3.5m wide traffic lanes (3 westbound lanes and 3 eastbound lanes), two 0.5m wide shoulders, two 2.5m sidewalk, and two 2.5m median/left turn lanes, cumulating to a total deck width of 31.9m including barriers. A minimum vertical clearance of 4.8 m from the Parkway Road surface to the underside of the superstructure is provided.

The existing bridge has a total span length of 105.5m and a superstructure depth of 1.6 m. The bridge superstructure consists of a cast-in-place post-tensioned concrete voided deck which is overlay with 90mm thick asphalt and waterproofing system. Expansion joints are placed at the east and west abutments.

At both east and west abutments, the two structures share a single abutment with a construction joint. The substructure consists of a 600mm thick abutment wall with a 1800 mm abutment seat (See Figure 3). On the piers the substructures are separated and each consists of a 1,000 mm thick trapezoidal shape pier wall system. The abutment seats are supported by 1,000mm deep pile caps which are supported by 310 x 110 HP piles. The pier walls are supported by 1,750mm deep pile caps which are supported also by 310 x 110 HP piles.

## 2.2 Structural Evaluation

To understand the feasibility of placing the proposed LRT system on the existing bridge, the effects of longitudinal and transverse joints have been investigated. The conclusions of the structural evaluation of the existing bridge are listed below:

1. The longitudinal joint between the eastbound and the westbound bridges is a construction joint, not an expansion joint. Therefore linking the two bridge decks together to form a single track bed for the LRT should not be an issue. However, the structural capacity of the cantilever portion will not be sufficient and will need to be upgraded to carry the LRT loads, as the LRT loading will be approximately 10% over existing structure capacity. The loadings from the proposed B-Line will include the weight of the LRT vehicles, track work, catenary and other loads (snow, wind, etc.). The prototype LRT rolling stock is a 100% low-floor articulated vehicle with a length of 32m and a width of 2.65 m running on 1,435 mm gauge tracks. The empty vehicle weight is 49.5 tonnes and the loaded vehicle weight is 70.1 tonnes. The vehicle has 3 bogies with 2 axles each and the maximum axle load is 11.8 tonnes. A train with an AW2 load should be capable of pushing or towing a disabled train with AW2 load of equal length to the next station.

2. The transverse joints are fixed at the east pier and free at the west pier at both abutments. The span lengths are 37-29-39.5. Placing rail fasteners adjacent to the joints is feasible, although the skew angle of the joints may pose a challenge to the arrangement of the fasteners.

3. Upon close review of the prestressing drawings as found on the City's website, the minimum top concrete cover to the steel is 75mm at piers. This room could be utilized to drill in shear connection dowels for a concrete overlay. It is insufficient however for the embedment of rail fasteners.

FIGURE 2 - BRIDGE PLAN

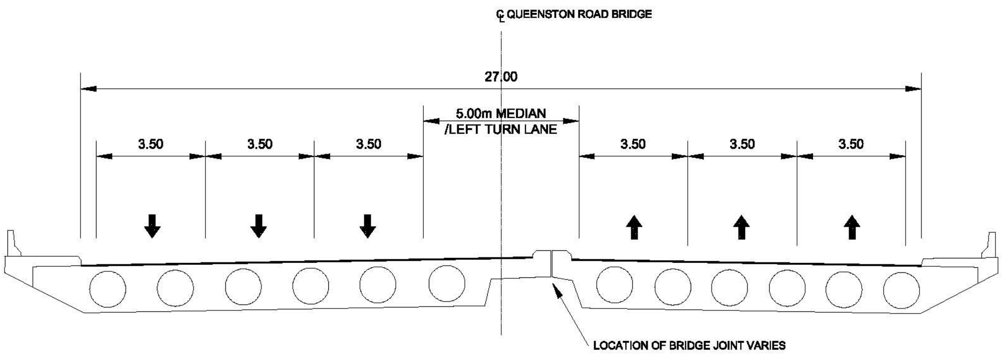



Figure 3.
CROSS SECTION OF EXISTING BRIDGE
OVER THE RED HILL VALLEY PARKWAY

**Figure 4 Underside of the Superstructure**

# 3.0 Evaluation of Alignment Options

There are three possible alternatives being considered for the placement of the LRT guideway as listed below. These alternatives assume no structural modifications to the existing bridge.

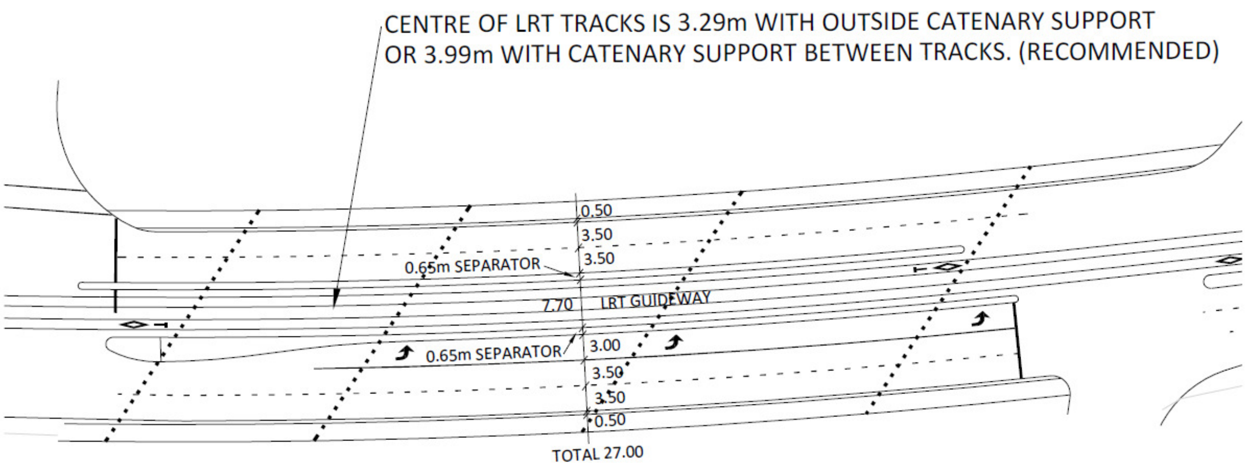
a) Accommodating the guideway in the centre of the bridge with active road lanes on either side;

b) Accommodating the guideway at the south side of the westbound structure;

c) Building a new LRT structure south of the existing bridge

## 3.1 Accommodating the guideway in the centre of the bridge with active road lanes on either side

The design configuration as proposed in the Design Workbook 2 is shown in Figure 5. One of both eastbound and westbound road lanes is eliminated to accommodate the guideway. Figure 5 and 6 show the proposed position of the LRT guideway on the bridge. The sidewalks remain at 2.5 m each. As mentioned in the Structural Evaluation in Section 2.2 above, placing the proposed LRT guideway on the existing bridge without structural reinforcement is not feasible.




Alternative 'A'

Figure 5.
PROPOSED HAMILTON LRT "B" LINE ON QUEENSTON ROAD
OVER THE RED HILL VALLEY PARKWAY.

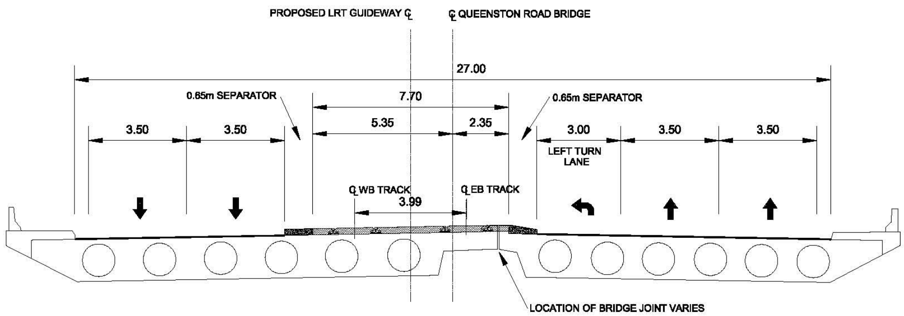



Figure 6.

PROPOSED CROSS SECTION RECONFIGURATION OF EXISTING BRIDGE

**IN ALTERNATIVE 'A'**

## 3.2 Accommodating the guideway at the south side of the westbound structure

For the purpose of this analysis, the guideway width will be reduced to 6.50 m and the catenary supports are to be placed on the sidewalks. Also, the road lanes on the westbound bridge will be reduced to 3.30 m each and the offset of the curb lane is eliminated. Also eliminated is the 0.85 m separation between the guideway and the roadway (See Figure 7).

The loading analysis shows that with full loading on both tracks on the bridge, the combined load of the road and LRT vehicles will exceed the carrying capacity of the bridge. This alternative will require restrictions on the LRT operations: only one loaded LRT vehicle can operate on both tracks at a time. While this is possible to implement with signalization, it will cause delays in the vehicle schedules. This alternative also causes reduction in the traffic lane widths and takes away the safety separations between both the sidewalk and road and the road and LRT guideway.

Since no more than one vehicle should be on the bridge at any given time, it makes sense to consider a signal-controlled single bi-directional track operation on the bridge. This will allow the bridge to have 3.50 m lane widths and to have comfortable separations, as well as allowing for central catenary poles.

While this alternative has a very low construction cost, it is not recommended for further consideration due to the constraints of the LRT operations and the reduced reliability of the system in case of failure of one of the switches reducing the two tracks to one on the bridge.

## 3.3 Building a new LRT structure south of the existing bridge

This alternative, as shown in Figure 8, will require modifications to the signalized intersections to accommodate the LRT and crossings of the Eastbound Queenston Road. It will impact 3 homes in the South-West quadrant and will cost between $10 and $15 million. A profile raise of the S-E/W ramp from the parkway will also be required.

Due to the relatively high cost of this option, as well as the impact on property and construction scheduling, this option is not recommended.



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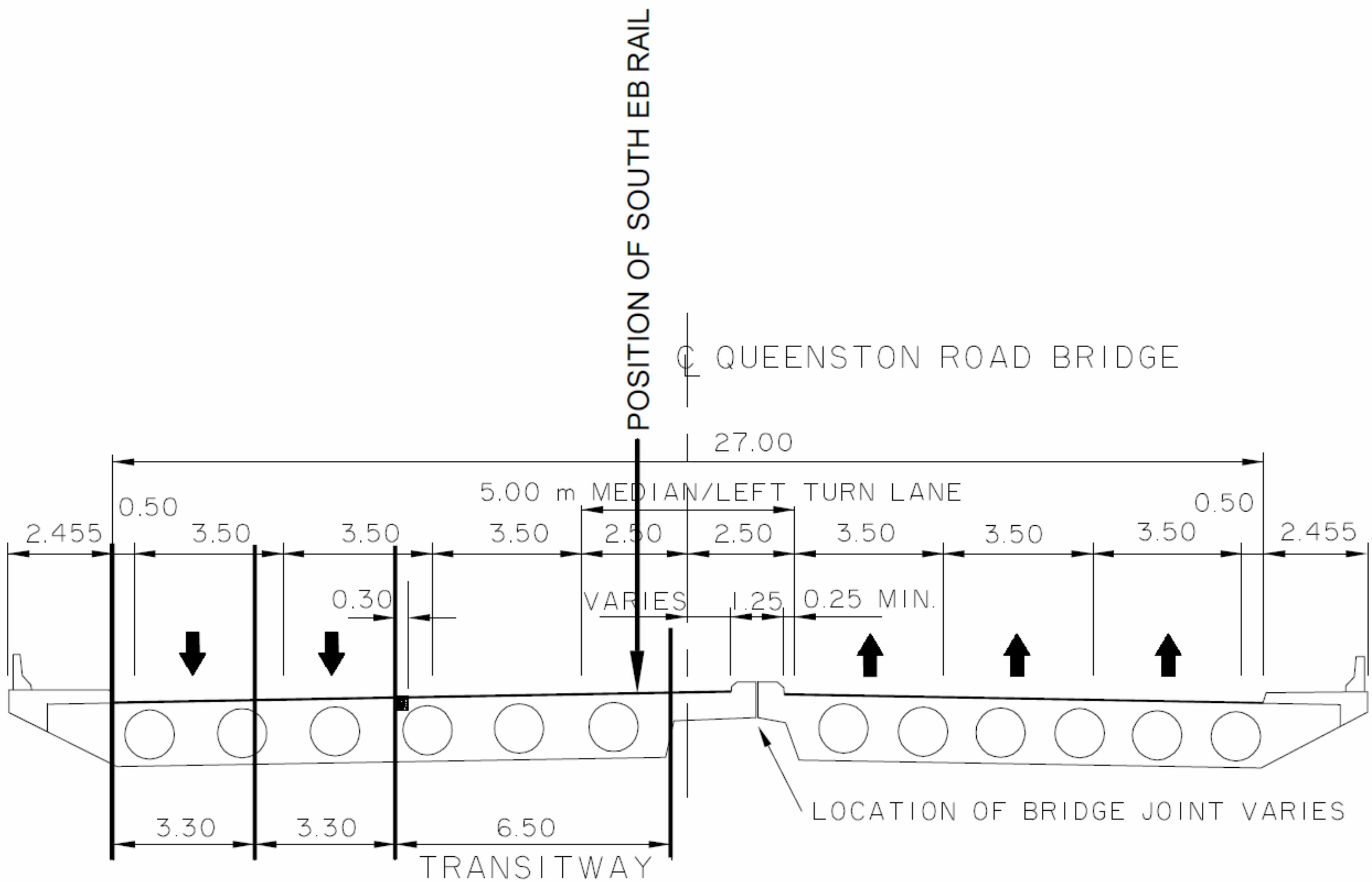


Figure 7 – Proposed Transitway Position
Alternative "B"

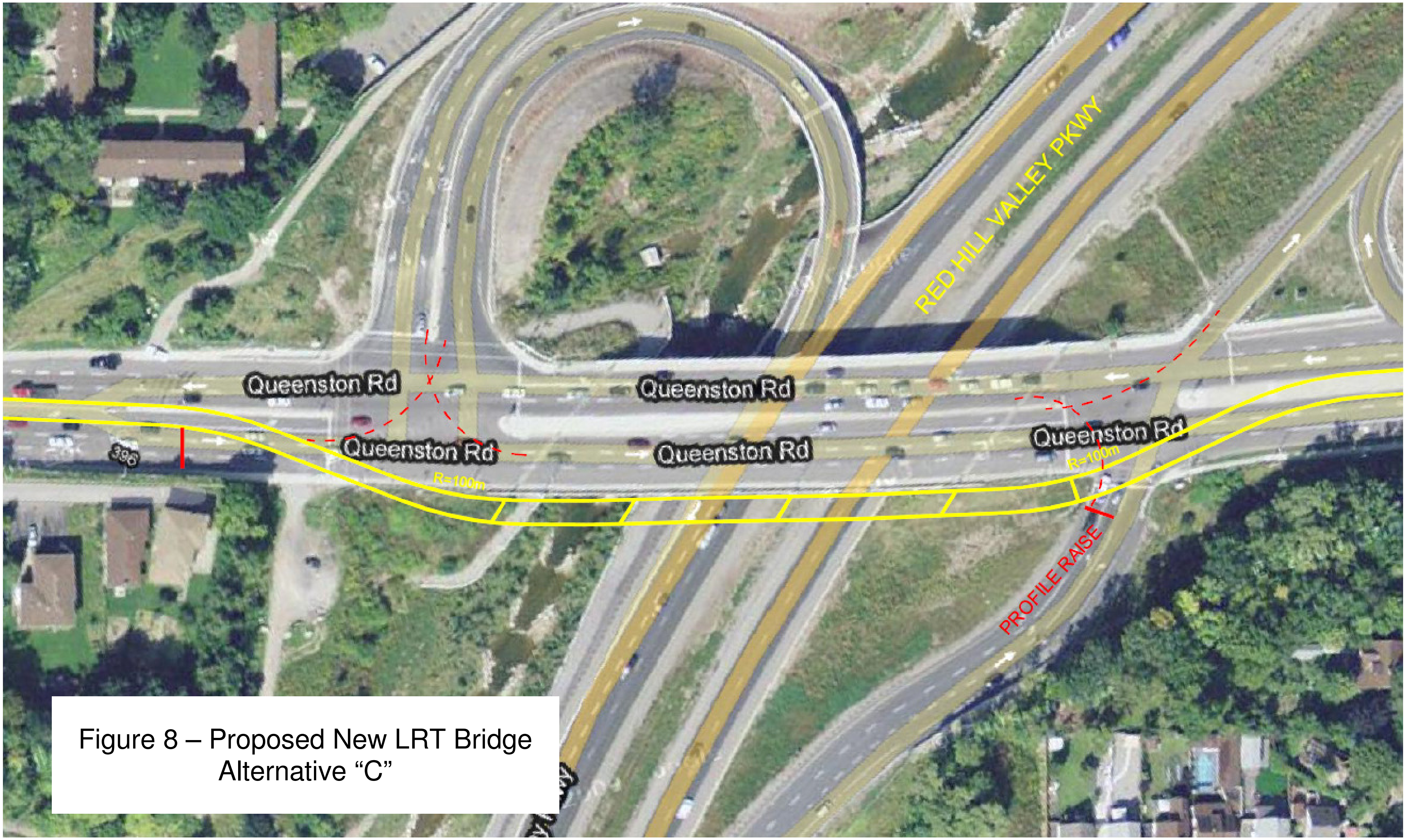


Figure 8 – Proposed New LRT Bridge Alternative "C"

# 4.0 Proposed Structural Options

Based on the preliminary evaluation of the structure in Section 2.2 of this report, the alignment option of Alternative 'A' is recommended, with certain structural considerations to retrofit the existing bridge in order to sustain the additional loading demands imparted by the new LRT guideway. The loading demands after adding train live load for two tracks of new LRT guideway on the bridge will be approximately 10% over the existing capacity.

It is considered possible to retrofit the existing bridge to provide the needed capacity by:

- Pouring additional deck and placing the additional post tension for the centre portion between the eastbound and the westbound structures;
- Fill and connect piers and abutments between the eastbound and the westbound structures; and
- Add foundation between the eastbound and the westbound foundations.

This solution will need to be further studied and confirmed during the detailed design stage. More detailed analysis may show that a different level of retrofit is needed to accommodate the new tracks. The additional dead weight (such as the concrete overlay for rail fastener) has not been accounted for in the analysis as the track fixation detail is not yet determined. It will have significant impact on the overall loading.

Disruption of bridge traffic during construction shall be anticipated, although most of the work will be under the superstructure. Lane closures during construction may limit traffic to 2 lanes in each direction and speed limits may have to be enforced. Construction under the bridge may cause environmental impacts and narrowing of the Red Hill Valley Parkway will be required during construction.

When anchoring the catenary supports to the deck Existing rebar and post tensioning in the deck (especially in the transverse direction) must be done. Also, the anchoring becomes challenging if the catenary support is directly above a void in the girder. A second pour slab may have to be poured or the hollow void may have to be filled for adequate anchorage.

Positioning the catenary poles right over the piers, however, will resolve the above problems.

We propose two options to reinforce the slab: 1) With Post Tensioning and 2) With steel beams. Refer to figures 9 and 10.

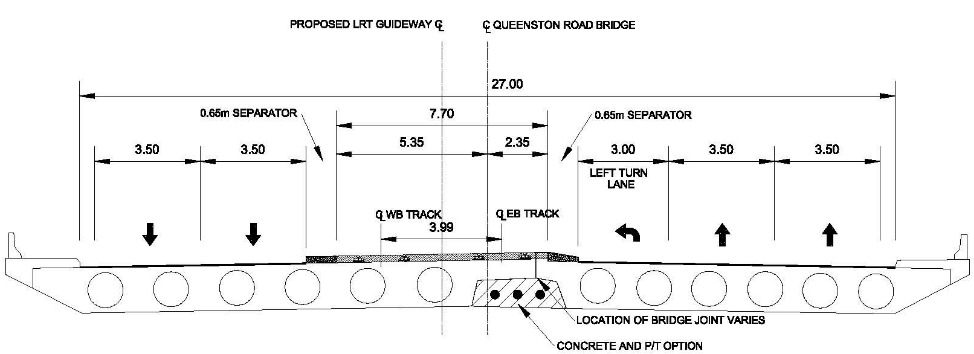


Figure 9.

PROPOSED RECONFIGURATION OF THE EXISTING BRIDGE OVER THE RED HILL VALLEY PARKWAY WITH POST-TENSIONING CONCRETE

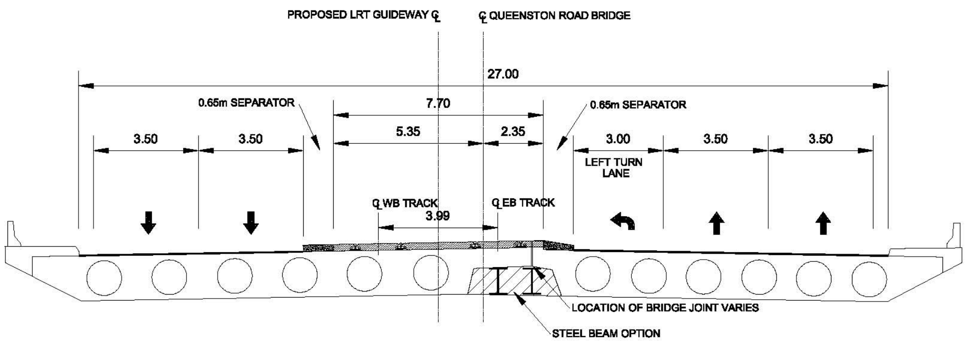


Figure 10.
PROPOSED RECONFIGURATION OF THE EXISTING BRIDGE OVER THE RED HILL VALLEY PARKWAY WITH STEEL BEAM OPTION

Both options will have to span longitudinally across the length of the bridge. Additional dowels will have to be added to bond the new slab with the existing concrete structure.

For the substructure, the area between the eastbound and westbound structures is to be filled with concrete diaphragms at the pier supports. Foundation is also to be added between the existing eastbound and westbound foundations at the abutments and piers as shown in Figure 11 below.

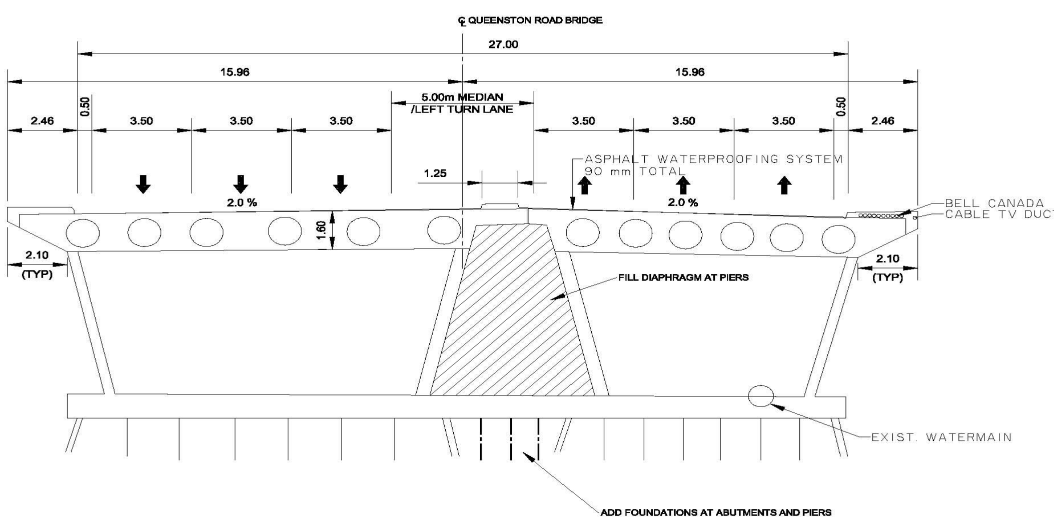


Figure 11.
PROPOSED WORK FOR SUBSTRUCTURE

The bridge works are estimated to cost about $3.5 million.

# 5.0 Recommendations

Based on the operational, structural, and cost analysis of the studied alternatives, it is recommended the LRT be accommodated on the existing bridge, as per Alternative 'A' by retrofitting the structure with an additional deck in the place of the two inner cantilevered parts, filling the gap of the piers between the eastbound and westbound structure and adding the required foundations (see Part 4.0 – Proposed Structural Solutions).

It is also recommended that the retrofit is discussed with the Red Hill Valley Stewardship Board and all concerned parties, to seek an acceptance of the proposed works.

Additionally it is recommended that during the detailed design stage, the possibility to transfer the loads from the in-fill deck to the existing piers with cross-beams should be explored to avoid new foundations work in the valley.

The tracks fixation to the bridge deck is to be developed in the Trackwork Design Brief, under separate cover, taking into consideration the road and rails relative positions and the restrictions on drilling into the post tension deck and placing extra dead load of second pour concrete as described in Part 5.0

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