50 Street / Canadian Pacific Rail Grade Separation in Edmonton

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Abstract

50 Street is an important goods movement and commuter corridor in the City of Edmonton (City), providing access to adjacent developing industrial areas and functioning as a major north-south commuter route. Currently, the at-grade Canadian Pacific Railway (CP) crossing along 50 Street north of Sherwood Park Freeway ranks as the top priority location for grade separation in the City based on delays, number of vehicles impacted, frequency of train crossings and other factors. With ongoing development along the 50 Street corridor, particularly in the industrial and residential areas south of Sherwood Park Freeway, traffic volumes and congestion at this crossing are predicted to continue to increase.

The City, along with ISL Engineering and Land Services Ltd. (ISL), recently completed a concept validation study for the grade separation of the CP crossing of 50 Street NW near 82 Avenue NW. The scope of the project was to review, validate and update the previously completed grade separation feasibility study (2008) and subsequent 50 Street Corridor study (2010), which both recommended a tight urban underpass.

The project complexities included being situated in a fully developed and built up area of the City with existing residential, commercial and industrial land uses abutting the corridor, existing at-grade accesses within the grade separation area, complex underground and aerial utilities, a high water table, sand lenses in the sub-surface, and numerous daily train movements across 50 Street both from the CP mainline and from shunting in and out of CP's Lambton staging yard, which also abutted 50 Street

This paper will present the process that the City and the project team undertook to explore feasible and viable options, both overpass and underpass, as well as the decision making processes that were used to select the preferred option. This paper will highlight the issues, opportunities, challenges and constraints that resulted with the overpass and underpass options, as well as the sub options that were explored to reduce costs and present a viable, constructible project.

In addition, the paper will present the implementation approach along with the risk assessments, value engineering, and multiple account evaluation process that were undertaken. The paper will demonstrate how the City and the team undertook the exploration of options for a complex project in a constrained corridor and ultimately recommended a refined underpass option that met stakeholder concerns, respected access needs (both during and post construction), and minimized land acquisition and overall costs.

1.0 Project Introduction

As part of its ongoing transportation network development, the City has plans to upgrade the 50 Street NW Corridor between Whitemud Drive and 90 Avenue. As a next step in the development of the 50 Street corridor, the City has retained ISL to complete a Concept Validation and Preliminary Design for the widening of the 50 Street corridor from four to six lanes from 76 Avenue to 90 Avenue, including the provisions for a grade separation of the CP Railway near 82 Avenue as well as the replacement of the Sherwood Park Freeway overpass.

These identified upgrades will enhance the serviceability and reliability of the 50 Street corridor by eliminating a major bottleneck associated with the rail crossing near 82 Avenue. In addition, these upgrades will enhance safety, improve walking and cycling along the corridor, and increase the functional capacity of the corridor to serve the increasing industrial traffic that uses 50 Street as a key goods movement route. Within the project limits, 50 Street services the Davies East, Weir, Gainer, Morris and Lambton Industrial areas as well as the residential neighbourhoods of Kenilworth and Ottewell as shown on Exhibit 1.1.

The key objectives of this study included a review of the proposed roadway cross sections, grades and profiles for the project, validation of the Sherwood Park Freeway overpass replacement approach, validation of the CP underpass approach, and validation of the overall constructability of the project with the associated required detours. The overall concept validation also included validation of the stormwater and drainage requirements of the project for flood mitigation and resiliency as well as the validation of the land requirements, access modifications and utility impacts. Design criteria reflecting the project requirements were developed and shown on Table 1.1.

1.1 Subsequent Steps

The original scope of work for the project was to validate the previously completed 2010 functional planning study for the widening of 50 Street and validating a roadway underpass option at the CP rail crossing. During the preliminary concept validation of the underpass the following key items triggered the need to investigate an over option and refine the underpass concept to ensure the most appropriate solution was recommended:

- Initial explorations into detouring CP to facilitate the construction of new CP bridges proved to be more difficult due to the proximity of the Lambton railyard to the east. The rail yard track is affected due to the widening of 50 St and will require the railyard to be modified. Buy in from CP proved to be more difficult than anticipated due to reluctance to disrupt operations to modify the railyard. As such, it was postulated that if a train detour/yard reconfiguration agreement could not be reached between the City and CP, then the under option would not be viable.
- The initial subsurface geotechnical investigation near the tracks indicated deep sand pockets and a relatively high water table which needs additional design requirements for managing water during and after construction. The City expressed concerns with the overall long-term water drawdown effects of the area by constructing the under option and wanted to understand the effects (settlement) and risks to surrounding buildings etc. The City also requested additional geotechnical investigation to minimize risk for construction claims as a result of contractors suggesting unexpected ground conditions.

50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 1.1 : STUDY AREA MAP

March 27, 2018

ISL Engineering and Land Services

	50 Street	Sherwood Park Freeway One- Lane Ramp	Two-Lane Ramp	76 Avenue	Morris Road	82 Avenue	84 Avenue	90 Avenue	Source
Design Controls									
Designation	UAD	n/a	n/a	UCU (west) / UAU (east)	UCU	UCU	UCU	UCD (west) / UCU (east)	
Design Speed	70 km/h	70km/h	70 km/h	60 km/h	60 km/h	60 km/h	60 km/h	60 km/h	
Posted Speed	60 km/h	60 km/h	60 km/h	50km/h	50km/h	50km/h	50km/h	50km/h	
Stopping Sight Distance	116 (-6%) 110 (-3%) 105m (flat) 100 (+3%) 97 (+6%)	116 (-6%) 110 (-3%) 105m (flat) 100 (+3%) 97 (+6%)	116 (-6%) 110 (-3%) 105m (flat) 100 (+3%) 97 (+6%)	92 (-6%) 87 (-3%) 85m (flat) 80 (+3%) 77 (+6%)	92 (-6%) 87 (-3%) 85m (flat) 80 (+3%) 77 (+6%)	92 (-6%) 87 (-3%) 85m (flat) 80 (+3%) 77 (+6%)	92 (-6%) 87 (-3%) 85m (flat) 80 (+3%) 77 (+6%)	92 (-6%) 87 (-3%) 85m (flat) 80 (+3%) 77 (+6%)	TAC Tables 2.5.2 and 2.5.3
Decision Sight Distance	200m - 275m	250m - 275m	250m - 275m	175m - 235m	175m - 235m	175m - 235m	175m - 235m	175m - 235m	TAC Table 2.5.6
Design Vehicle	WB-21	WB-21	WB-21	WB-21	WB-21	B-12 **	WB-21	B-12 (west) / WB-21 (east)	City Design Standards Table 3.3
Control Vehicle	WB-36	WB-36	WB-36	WB-36	WB-36	WB-21	WB-36	WB-21 (west) / WB-36 (east)	City Design Standards Table 3.3
Horizontal									
R_{min}	190m (e=0.06)	190m (e=0.06)	190m (e=0.06)	130m	130m	130m	130m	130m	TAC Table 3.2.3; City Design Standards Appendix C
Access Spacing ($_{min}$)	400m	n/a	n/a	60m (west) / 200m (east)	60m	60m	60m	60m	TAC Table 2.6.5
Vertical									
Grade ($_{max}$)	5%	5%	5%	8% (west) / 6% (east)	8%	8%	8%	8%	City Design Standards Table 3.14
Grade ($_{target}$)	4%								
Grade ($_{min}$)	0.60%	0.60%	0.60%	0.60%	0.60%	0.60%	0.60%	0.60%	City Design Standards Table 3.14
Crest K ($_{min}$)	17	17	17	11	11	11	11	11	TAC 3.3.3.2
Sag K ($_{min}$)	10	10	10	8	8	8	8	8	TAC 3.3.3.5
Curve Length ($_{min}$)	70	70	70	60	60	60	60	60	TAC 3.3.5
Vertical Clearance ($_{min / des}$)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	City Design Standards 3.2.7.1
Cross-Section									
Basic ROW	Match existing								
Median Width	5.6m *	n/a	n/a	n/a	n/a	n/a	n/a	Match Existing	City Design Standards
Median Type	Grass	n/a	n/a	n/a	n/a	n/a	n/a	Grass	
Inside Shoulder	n/a	Match Existing		n/a	n/a	n/a	n/a	n/a	
Inside Curb and Gutter	250 STD	Match Existing		250 STD	250 STD	250 STD	250 STD	250 STD	
Travel Lanes	6 Basic	1	2	2 (west) / 4 (east)	2	2	2	4 (west) / 2 (east)	
Travel Lane Width	3.65m turn, 3.95 curb, 3.7 center	Match Existing		Match to existing					City Design Standards
Outside Shoulder	n/a	Match Existing		n/a	n/a	n/a	n/a	n/a	
Outside Curb and Gutter	250 STD	Match Existing		250 STD	250 STD	250 STD	250 STD	250 STD	
Parking Permitted	no	no	no	no	no	no	yes	no (west) / yes (east)	
Basic Boulevard	4m	Match Existing		Match to existing					
Clear Zone	5.5m - 6.0m	7.5m - 8.5m	7.5m - 8.5m	3.5m - 4.5m	3.5m - 4.5m	3.5m - 4.5m	3.5m - 4.5m	3.5m - 4.5m	TAC Table 7.3.1
Shy Line Offset to Retaining Wall	3.0m	n/a	n/a	n/a	n/a	n/a	n/a	n/a	TAC Table 4.10.1 and 7.8.4
Shy Line offset to Pier	1.4m	n/a	n/a	n/a	n/a	n/a	n/a	n/a	TAC Table 4.10.1
Shared-Use Trails (both sides of Arterial as per City Design Standards 3.3.4.1)									
Multi-Use Trail	3.0	n/a							City Design Standards Table 3.2
Shlyline to curb of driving lane	0.5m	n/a							City Design Standards 3.1.3.2
Shline to curb of parking lane	0.6m	n/a							City Design Standards 3.1.3.2
Shyline to vertical obstacle - 100mm to 750mm in height	0.2m	n/a							City Design Standards 3.1.3.2
Shyline to vertical obstacle >750mm in height	0.6m	n/a							City Design Standards 3.1.3.2
Grade ($_{max}$)	5%	n/a							City Design Standards 3.2.7.2
Grade ($_{min}$)	0.60%	n/a							City Design Standards 3.2.7.2
Vertical Clearance (min)	3.6m	n/a							City Design Standards 3.2.7.2
Cross-slope	2% -3%	n/a							City Design Standards 3.2.7.2

* City Design Standards Table 3.12 has 4.5 (min); however due to the turn requirements on the SPF bridge, and the connections at the project limits, the median will never be narrower than 5.6m. 5.6m is based on a 1.5m pier + 0.62m for barriers (x2) + 1.4m shyline (x2)). At the CP Rail bridge 7.5m is needed from edge of travel lane to edge of travel lane to accommodate the perpenicular bridge pier and related pier protection to ensure vertical clearance of the bridge pier cap.

** Turn radius for a B-12 is 12.9m. The turn radius for a City Fire Truck is 12.8m. The turn radius for a WB-21 is 15.0m.

Table 1.1: Design Criteria

2.0 Background

This at-grade crossing is denoted by CP as Mile 169.70 on the Scotford Subdivision, previously the Willingdon Subdivision. The railway line at this point is a single track, crossing 50 Street at a skewed angle of 40° from the right and uses flashing lights, cantilevers, bell, gates and a concrete crossing surface. Immediately to the east of the crossing, the railway line splits into over 20 tracks for storing rolling stock as part of CP's Lambton Park Yard. The first separation of the tracks is located approximately 5 m from the current edge of pavement. According to previous correspondence between the City, CP and Transport Canada, the City is senior at this established crossing.

Official correspondence from CP from 2008 stated that every day, there are on average 4 x 6,000 ft. trains travelling at 15 mph, 6 x 4,000 ft. trains travelling at 10 mph and also numerous switching movements with shorter trains. A 9-day survey carried out by the City in 1990 saw an average of 27 crossings per day. Based on recent discussions with CP, train operations currently produce on average 8 trains per day with additional 25 or more assignments/switching operations that activate the railway's active warning system. Based on the cross product of train movements and daily traffic volume, the 50 Street CP crossing is well over the Transport Canada cross product guideline of 200,000 (vehicles per day x train movements per day) for grade separation, which is a key driver for the completion of the grade separation.

2.1 CP Train Volumes

As a supplemental data collection exercise, the City of Edmonton undertook a 7-day video recording of several intersections within the study area to better understand the existing traffic conditions in support of its Transport Canada grant application. As part of this exercise, the City was able to view and assess train movements at the CP crossing to determine the frequency and duration of train crossings and the impacts that these movements have on vehicle traffic. The following table is a summary of train activities at 50 Street and 82 Avenue from October 16, 2018 to October 22, 2018.

Table 1.1 CP Train Activities from 24-hour Video Data Collection

	Total Train Movements	Total Blockage Time	Average Blockage Time	Max Blockage Time
October 16, 2018	64	5:14:52	0:04:55	0:24:47
October 17, 2018	42	3:53:37	0:05:34	0:33:33
October 18, 2018	48	4:26:06	0:05:33	0:16:09
October 19, 2018	38	3:51:28	0:06:05	0:14:29
October 20, 2018	42	3:36:43	0:05:10	0:28:21
October 21, 2018	35	3:14:48	0:05:34	0:18:40
October 22, 2018	42	4:32:29	0:06:29	0:18:06
7 Day Total	311	28:50:03	0:05:34	0:33:33

3.0 Option Evaluation and Assessment

A due diligence evaluation on the overall costs and implementation impacts of both the over and underpass options for the 50 Street CP Grade Separation was completed prior to reaching a conclusion on the most appropriate infrastructure investment for the City. To assist with the due diligence evaluation and the assessment of proposed options, an extensive option exploration exercise was initiated to ensure all possible options for constructing and implementing the 50 Street CP Grade Separation were tabled and assessed during this phase of the project. This assessment resulted in the following key tasks and activities being completed prior to the development of a preferred overpass and underpass option.

3.1 Value Engineering and Risk

To assist with option evaluation and assessment, the City retained SMA Consulting Ltd. (SMA) to provide supplementary engineering services including workshop facilitation, risk assessment and risk register creation, value analysis and value engineering as well as decision support services.

As a key part of the project evaluation, a risk analysis study was completed. This process started with the creation of an initial risk register, which was updated and revised during the initial risk workshop as held on March 29, 2018. SMA facilitated this workshop and the risk analysis study with the support of ISL through the provision of technical information.

As a fundamental step in the evaluation of the grade separation options, a two day value engineering (VE) session was held in August 2018. In preparation for the VE session, the project team reviewed and analyzed several overpass and underpass profiles and cross-sections along with their respective plans, detour scenarios, land impacts and drainage requirements. While variations of each the overpass and underpass option were considered, it was important for the project to establish a preferred over and underpass option, based on all of the input, such that a single over and single under option could be presented at the VE session.

Discussion on the two day VE session process and the subsequent refinements to the options that were generated and explored is included in section 4.0 of this report. However, for completeness in the discussion of the overpass and underpass option explorations below, the options that were generated as a result of the Value Engineering session are also included in the descriptions of options in sections 3.1.1 and 3.2.2 with the note (Post VE). This inclusion serves to illustrate the depth and the breadth of the option explorations that were completed for this project.

3.1 Overpass Explorations

The overpass option for the CP grade separation was proposed due to the advantages that it has related to the accommodation of CP during and post construction. As an overpass, no shoofly would be required to temporarily detour the railway to enable the construction, fewer constraints with construction were also anticipated and the subsurface geotechnical conditions (high water table and sand lenses) were thought to be less impactful on the project during construction. As the construction benefits of the overpass option were significant, considerable effort on the design team was required to explore multiple overpass options such that a true assessment of equals, or like to like comparisons of the overpass and underpass option could ultimately be completed.

Five overpass plan options were considered, which were put forward to test and evaluation for differing impacts on access (both during and post construction), plan footprint and land impacts, utility impacts and accommodation, operational impacts for road users, as well as operations and maintenance impacts. Three initial plans were developed for discussion and assessment purposes to better understand the project requirements and impacts of an overpass option that was elevated and supported by retaining walls, 1:1 steepened slopes as well as traditional earth fills. Subsequent the creation of the three initial plans, it was determined, as an outcome of the VE session that the most appropriate solutions for the plan of the overpass option would be a hybrid of Options 1 and 2 that were considered the most desirable elements of these two plan options. As such, two subsequent hybrid options were developed after the VE session.

3.1.1 Overpass Profile Options

Over the course of the option exploration exercise, 15 distinct profiles were considered for the overpass option. These profiles varied with respect to design speed, road grade north and south of the CP railway, bridge grade at the CP railway, bridge grade over the Sherwood Park Freeway, and overpass bridge structural depth and vertical curve crest location.

Each of these profiles was proposed and considered to reflect the differing aspects of the project details that each influenced the overall profile of 50 street for the overpass options. Assessment of the impacts associated with these profile options included the review of access provisions, fill heights, adherence with desired design criteria and general operational considerations. It is noted that Options 1 through 7 were the primary options developed prior to the VE session and Options 8 through 11 were developed after the VE session. Options 12 through 15 were developed as secondary options and were included for the comparative value that they provided. An overview of each profile option is included in the subsequent sections along with a high-level summary of the profile option.

Option 1: 70 km/hr, 2.3 m Structure – 5.0 % Grade, Summit South

Option 1 fully met all of the desired design criteria. Discussion of Option 1 follows in the following sections as Option 1 is compared to other profile options considered.

Option 2: 70 km/hr, 2.3 m Structure – 5.0 % Grade, Summit North

Option 2 also fully met all design criteria and differed from option 1 only in the location of the summit of the Sherwood Park Freeway bridge. Profile options with a south summit location lessened the fill requirements on the north side of the Sherwood Park Freeway and reduced the access impacts at Morris Road but the fill requirements on the south side of the bridge consequently impacted other parcels. Consolidation of impacts to areas north of the Sherwood Park Freeway over dispersion of impacts along a larger proportion of the project area was recommended.

Option 3: 70 km/hr, 1.5 m Structure – 5.0 % Grade, Summit North

Option 3 was similar to Option 2 and was considered to assess the impacts of a narrower CP crossing. In this option, the clearance box underneath the overpass was assessed with only two tracks to be provided. This enabled the team to ascertain the look of a basic grade separation and was only considered for discussion purposes.

Option 4: 70 km/hr, 2.3 m Structure – 4.0 % Grade, Summit North

Option 4 was similar to Option 2 in all regards with the exception of the approach grade being changed to 4%. This option was developed to demonstrate the difference between the 5% road grade and the desired 4% road grade for 50 Street. With this option intersection elevation at Morris Road would be increased to approximately 4.2 m and that run out to the north would extend approximately 150-200 m north of 90th. Due to the grading impacts, this option was not explored further.

Option 5: 70 km/hr, Close Morris at 50 Street

Option 5 is a derivative of Option 2 with the exception of the road grade north of the grade separation being developed at 3%. With this option, the project explored removing access onto Morris Avenue from 50 Street. While this option enables a much smoother transition from the Sherwood Park Freeway bridge to the CP overpass, due to the potential access closure, this option was not explored further.

Option 6: 70 km/hr, 1.2 m Structure – 5.0 % Grade, Summit South

Option 6 is similar to Option 1 except the structure has been reduced from 2.3 m to 1.2 m. This option was prepared to demonstrate the impact of an alternate bridge design type as reducing the size/depth. It is noted that the idea of an alternate bridge type was revisited later in the project during the VE session.

Option 7:70 km/hr, 2.3 m Structure – 5.0 % Grade, Summit South, 300 mm Additional Clearance

Option 7 considered the same features as Option 2 with an additional 300 mm of vertical clearance. This option was prepared at the request of CP to assess additional flexibility that the additional 1 foot of clearance underneath the structure to track grade could afford. This request came with a cost premium of approximately $2 million in that it added an additional 300 mm of wall and fill height over the length of the project.

Option 8: 70 km/hr, 1.0 m Structure – 4.5% Max Grade, *(Post VE)*

Option 8 resulted from the VE session under the premise of an alternate structure type. Option 8 was similar to Option 1 with the exploration of a proposed thin structure, such as a tied arch or truss type structure. In this option, the grade of the road could be reduced to 4.0% south of the grade separation and 4.5% north of the grade separation.This option had a cost premium of $9 million and was not advanced past the option exploration phase.

Option 9: 70 km/hr, 2.3 m Structure on Crest, *(Post VE)*

Option 9 explored moving the crest vertical curve onto the overpass and flattening the curve on the bridge structure as opposed to requiring a continuous 1% across the entire length of the bridge structure.

Option 10: 70 km/hr, 2.3 m Structure on Crest – 4% Grade, *(Post VE)*
Option 10 is similar to Option 9 with a further modification of having the crest vertical curve centered on the overpass structure as opposed to simply starting the crest vertical curve on the structure. This option enabled the achievement of the desired 4% grade without an expense bridge type.

Option 11: 70 km/hr, 1.0 m Structure on Crest – 4% Grade, *(Post VE)*
Option 11 was proposed as a hybrid of Options 8 and 10, to have the crest vertical curve centered on the overpass structure and reducing the structural depth of the bridge by using an arch or truss type structure.. However, as with Option 8, Option 11 also came with a cost premium and was not advanced further.

Option 12: 60 km/hr, 1.5 m Structure, 6% Grade, Summit North
To maintain an elevation change of less than one meter at Morris Road and 9.0 m clearance over the tracks, the road grade must be 6.0 %. To achieve this profile, the design speed was reduced to 60 km/hr. This option provided access benefits but had a negative operational impact due to the 6% grade.

Option 13: 60 km/hr, 1.5 m Structure, 5.5 % Max Grade, Summit South
Similar to option 12, the design team explored a second profile at 60km/hr. design speed to achieve a one metre grade change at Morris Road. In Option 13, the profile of the Sherwood Park Freeway Bridge was configured so the high point was on the south side of the bridge, further reducing the elevation change at Morris Road. Option 13 provided access benefits but had a negative operational impact higher grade.

Option 14: 70 km/hr, 1.5 m Structure, 5.0 % Grade, Summit South
Option 14 is similar to both Options 12 and 13 with the exception of the design speed being maintained at the desired 70 km/hr. This option was not further explored past the option exploration phase as other profiles were deemed more acceptable.

Option 15: 70 km/hr, 1.5 m Structure, 5.0 % Grade, Summit South
Option 15 is similar to Options 12, 13 and 14 with the exception of the design speed that was increased to 80 km/hr., so that the impact of this change could be quantified. This option was also not further explored past the option exploration phase as other profiles were deemed more acceptable.

3.1.2 Overpass Bridge Options¶

In conjunction with road profile options, 13 overpass bridge options were explored. Bridge options explored directly corresponded with a change to the road profile due to number of spans and structural depth required for bridge span length. Each overpass option considers a single bridge which accommodates both northbound and southbound lanes. Transport Canada's Standards Respecting Railway Clearances for vertical and horizontal clearances were recognized and respected for the majority of the options. Crash walls to protect the bridge structure are considered for all options where railway tracks are within 7.62 m (25 feet) of bridge substructures with the exception of the options where the abutments and/or piers are to be designed to handle impact loads.

In general, the overpass option created significant roadway geometric challenges with respect to grades, height of fills and overall length for the roadway to cross above the tracks. To minimize the elevation of the roadway over the railway tracks (approximately 10-11 m of fill) and minimize structural bridge depth, various span arrangements were considered. It was assumed that each additional track would match the elevation of the existing track.

3.1.3 Retaining Wall / Fill Options¶

Various options for elevating the overpass were considered, which included considerations for both sideslopes and bridge approach embankment fill under the bridge. Options included all retaining walls, steepened slopes (1:1), standard slopes (3.5:1), and hybrid options. Bridge approach fill options were considered along with the development of the Profile and Bridge Options to find the most economical solution while considering land impacts, adjacent land access, project design criteria, and construction staging options. The project proposed a bridge to cross only the projected CP right-of-way, with the remaining elevated section of roadway supported by retaining walls and steepened slopes (1:1 slopes).

3.2 Underpass Explorations

As part of the option exploration exercise, additional underpass options, beyond the initial underpass option that was reviewed and explored during the preliminary concept validation phase, were proposed and considered to ensure a fair and balanced assessment of the more appropriate underpass and overpass options could be completed. This process enabled the project team to propose modifications and refinements to the underpass option that were not initially considered during the preliminary concept validation phase and to incorporate feedback from stakeholders into the concept as it related to access.

3.2.1 Underpass Plan Option

As the underpass plan had been previously reviewed and vetted during the preliminary concept validation phase, less effort in option generation was required for the underpass options as the allocation of more effort was required to develop and assess overpass options. Based on feedback provided notable changes and amendments to the plan included the provision of northbound right-in access with a turn bay to 84 Avenue, provision of southbound right-in access to 82 Avenue, review of islands and sidewalks at 90 Avenue and modifications to the alignment and lane configurations at 76 Avenue.

3.2.2 Profile Options

Over the course of the option exploration exercise, five underpass profiles were reviewed and evaluated for the underpass option. These profiles varied with respect to road grade north and south of the CP railway, CP bridge structural depth and bridge type and bridge grade over the Sherwood Park Freeway.

Each of these profiles was proposed and considered to reflect the differing aspects of the project details that each influenced the overall profile of 50 Street for the underpass options. Assessment of the impacts associated with these profile options included the review of access provisions, fill heights, adherence with desired design criteria and general operational considerations. It is noted that Option 1 and Option 2 were the primary options developed prior to the VE session and Option 3 and Option 4 were developed after the VE session. The preliminary profile option is included for comparison as the initial underpass profile considered during the preliminary concept validation phase.

Preliminary Profile – Through Plate Girder Bridge

The preliminary profile explored during the initial concept validation phase is included here for comparison to highlight the difference noted as a result of the change in bridge type. This profile fully met the City's design criteria and desired maximum road grade. The initial profile concept was based on a through plate girder bridge which had the effect of raising the road profile by placing some of the structural depth of the railway bridge above the rail. As a result of discussions with CP, this bridge type was removed from consideration as it would not enable the construction of a bridge that allowed CP full access to an unencumbered right-of-way. As such the remaining profiles were are all based on a deck plate girder bridge which enables an ultimate construction of a continuous unobstructed bridge.

Option 1: 2 Span Deck Plate Girder Bridge, Summit North

With the change in bridge type the structural depth increased to 3.35 m, which deepened the excavation of the underpass and steepened the roadway profile. All desired design parameters could be met, with the exception of the road grade south of the grade separation. In this case, the road grade increase from 4% to 4.75%; a change, which still held the road grade below the desired maximum road grade.

Option 2: 2 Span Deck Plate Girder Bridge, Summit South

Profile Option 2 sought to maintain as many of the parameters from profile Option 1 to evaluate the effects of the change in Sherwood Park Freeway Bridge grade. In Option 2 the summit of the Sherwood Park Freeway bridge was placed to the south of the overpass. With this configuration, the road grade decreased from 4.75% to 4.1%. This minor grade change was not deemed significant in comparison to the negative access and fill placement impacts.

Option 3: 4 Span Deck Plate Girder Bridge, Summit North, *(Post VE)*

Option 3 was developed after the VE session based on a 4 span railway bridge. This bridge configuration was not initially considered due to the uneven span lengths. The structural depth of the railway bridge was reduced from 3.35 m to 2.25 m. This change enabled raising the road grade and the softening of road profile to 4.25% south of the grade separation and was held to 4% north of the grade separation.

Option 4: 4 Span Deck Plate Girder Bridge, Summit North, Minimized Grades, *(Post VE)*

Option 4 was also developed after the VE session based on a 4 span railway bridge as a modification to Option 3. In this option the road grade was further flattened north of the grade separation to minimize the slope while maintaining access at 84 Avenue. Access could be maintained with a 3.5% road grade north of the grade separation.

3.2.3 Bridge Options

In conjunction with road profile options, 12 underpass bridge options were explored. Bridge options explored directly corresponded with a change to the road profile due to structural depth required for bridge girder type as well as span length. Each underpass option considers options, which accommodate from three (3) up to five (5) tracks within the projected right-of-way. Transport Canada's Standards Respecting Railway Clearances for horizontal clearances were recognized and respected for the majority of the options. A minimum vertical clearance from the road surface to the underside of girders remained a constant 5.6 m following the project requirements.

The underpass option created significant staging challenges with respect to the proximity CP's Lambton Park Yard and requires changes to existing track alignments. To minimize the excavation of the roadway under the railway tracks different girder depths were considered along with span arrangements. It was assumed that each track would match the elevation of the existing track.

One of the design criteria that was reviewed during the course of the project was the outside shoulder width within the underpass. Initially a 3.0 m outside shoulder following Figure 4.10.1 of Transportation Association of Canada's (TAC) Geometric Design Guide for horizontal clearance at bridges on urban arterial roads. Alternatively, other options used a 1.7 m outside shoulder following TAC Table 7.6.4 for Suggested Shy Line Offset. The City requested that the larger shoulder (3.0 m) could be utilized for road maintenance crews and for emergencies as necessary however the narrower shoulder minimized the structural span length. Ultimately a wider shoulder was selected to ensure 4 traffic lanes, in a detour scenario, could be accommodated on each of the bridge openings.

3.2.4 Rail Detour and Staging Strategy

In order to build the underpass, various railway track alignment staging plans were reviewed and evaluated that would allow the various options of railway Ballasted Deck Plate Girder bridge configurations to be constructed. Four rail detour strategies were reviewed with CP as described below.

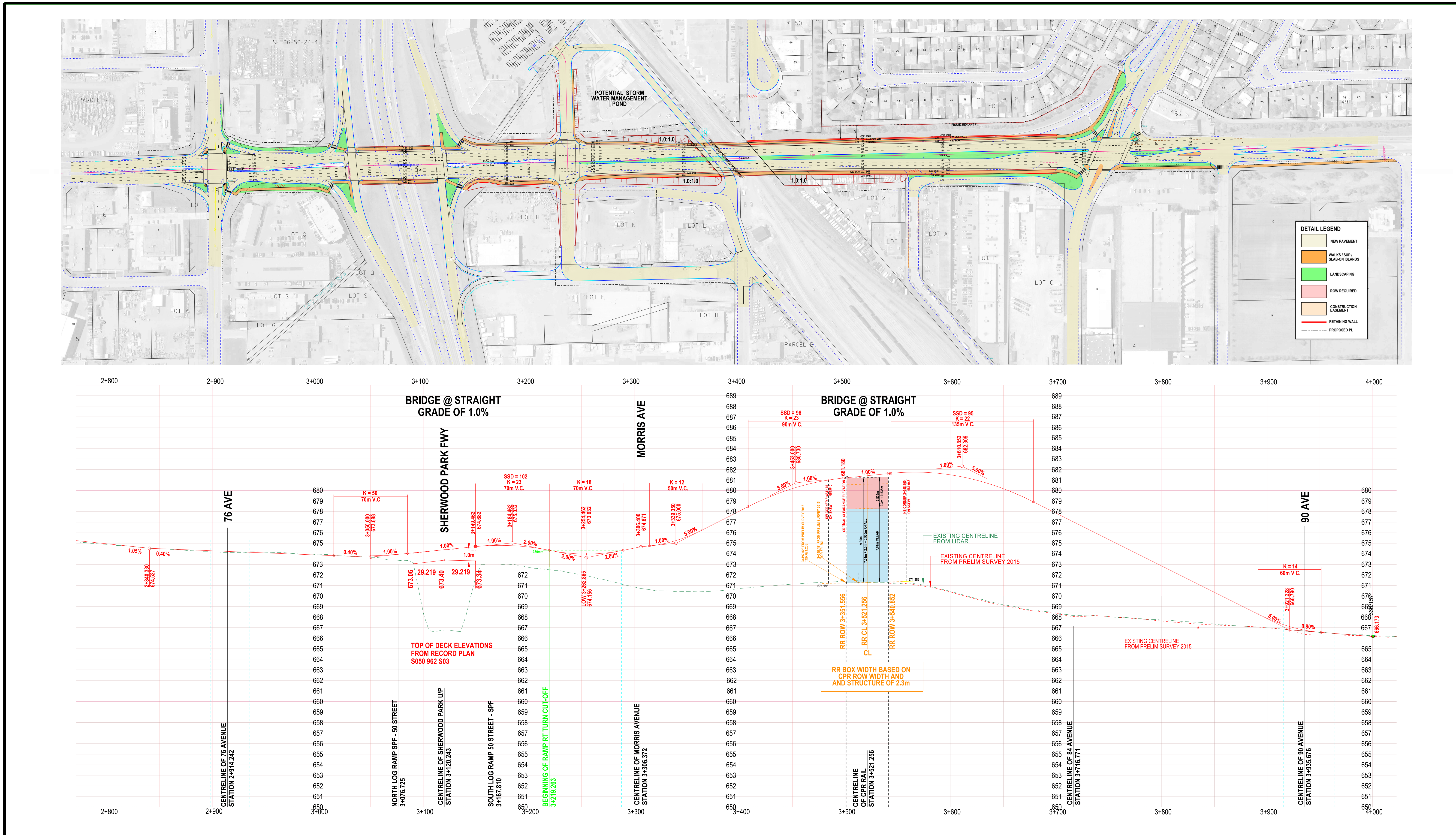
Option A: Rail Detour to North
Option A redirects the mainline and yard access track to the north (at-grade) and maintains access to the existing CP Lambton Park Yard. This option requires track realignment work, a temporary shoring wall along the southern track realignment, and a temporary bridge span (approx. 30 m) to maintain the yard lead. This option would require time blocks for the complex staging and is assumed to increase the scheduled length of construction as time blocks are not guaranteed. There is minimal track work required relative to other options and therefore less risk to CP Operations in that context.

Option B: Rail Detour to South
Option B redirects the mainline and yard access track to the south. This option requires yard work (including multiple switch reconfigurations) and a temporary shoring wall along the northern track realignment. Once the bridge is built, the yard needs to be re-configured again to put the tracks onto the new bridge. This option requires more CP yard work and outages in comparison to Option A. However, during construction of the grade separation, there are minimal delays/track blocks required. There is a loss of capacity in the tracks for CP due to the shortening of leads. Due to the multiple configurations and time required to build them, CP did not prefer this option.

Option C: Maintain Existing Mainline, Realign to North and South
Option C maintains the existing mainline track using a temporary retaining wall north and south of the track and re-configures the yard allowing bridges to the north and south to be built concurrently. This

option enables construction staging with presumed minimal disruptions to CP during the grade separation construction. This rail detour staging includes modification to the Lambton Park Yard switches using a compound ladder to utilize the new bridges in the long-term. This modification reduces the construction schedule.

Option D: Maintain Existing Mainline, Realign with Ladder Reconfiguration
Option D varies from Option C in that it modifies the yard to a simple ladder track to better utilize the track arrangement when the bridges are built. Both Option C and Option D are viable solutions for construction staging of the bridge.¶

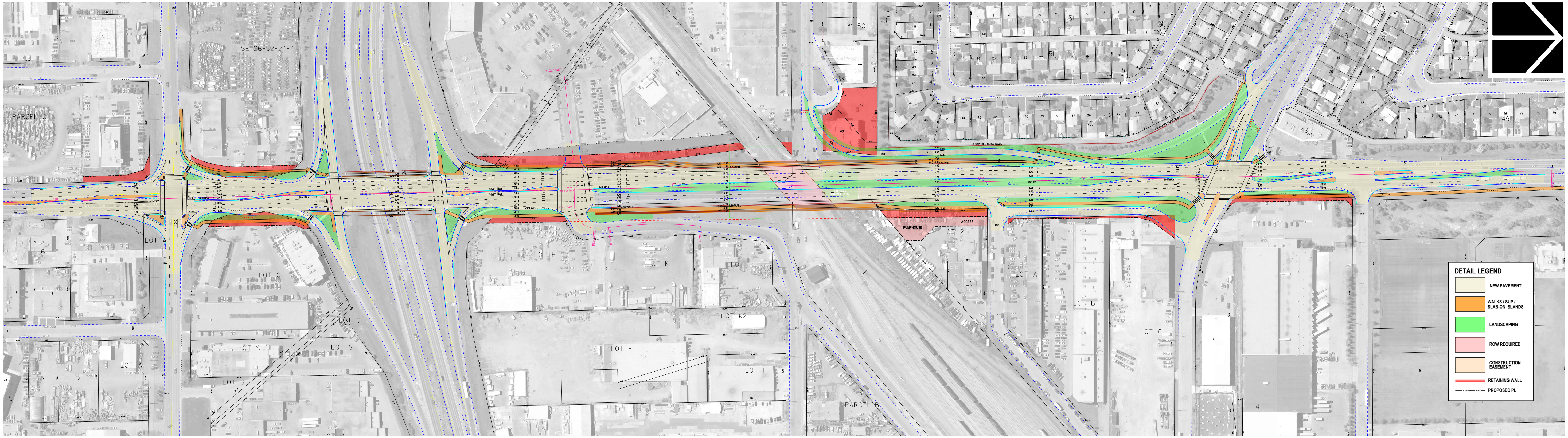


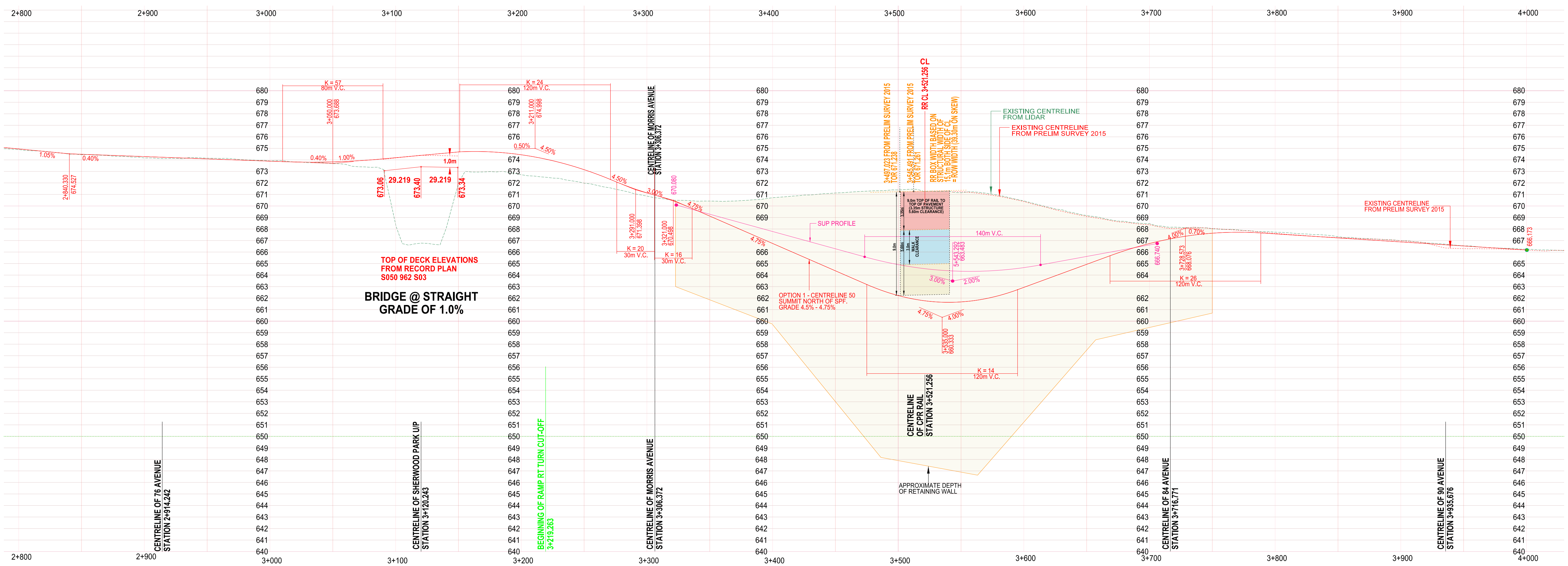
50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 3.1

PREFERRED OVERPASS PLAN AND PROFILE FOR VALUE ENGINEERING

August 16, 2018





50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 3.2

PREFERRED UNDERPASS PLAN AND PROFILE FOR VALUE ENGINEERING

June 18, 2018

4.0 Value Engineering and Risk

As mentioned in section 3.0 of this report, VE had a pivotal role to play in the assessment and refinement of options for the overpass and underpass. In addition, the VE process was fundamental in the ultimate evaluation and selection of a preferred option. The following sections outline the discussion that occurred, the ideas that were generated, the advantages and disadvantages of each option as well as the risk assessment, for both cost and duration, that was completed for each of the preferred options.

4.1 Two Day Value Engineering Session

Day 1 of the VE session focused on two key activities: information sharing and idea generation. With the information sharing component, the project team provided an overview of the project work to date, explained the history and evolution of the overpass and underpass options, and completed an overview of the package of information that was provided to the session participants. This enabled healthy discussion and debate as part of the idea generation and evaluation portion of the VE session.

Approximately 30 ideas were generated for consideration with the overpass option whereas approximately 15 ideas were generated for consideration with the underpass option. These 45 ideas underwent a two-stage assessment as part of the evaluation phase. In the first stage, the VE session participants reviewed these ideas for merit. This reduced the ideas moving forward for consideration to 15 and 7 for the overpass and underpass options respectively. The VE session participants further reviewed these 22 ideas as part of the second stage evaluation, and ideas that were more broadly identified by the majority of the participants at the VE session were put forward as the key ideas to consider and the ideas most likely to have the greatest impact. The second-stage review further refined the list of ideas to consider to 7 and 3 for the overpass and underpass options respectively.

As a key part of the second day of the VE session, participants discussed the advantages and disadvantages of the options and suggestions, discussed the risks associated with the options and discussed an evaluation framework for the revised options. This framework considered the areas of cost, short-term public disruption, long-term operational performance (for the roads and traffic), impact to major stakeholders, as well as, impacts to operations and maintenance of infrastructure. It was noted that cost may be an overarching decision maker and as such it was not ranked against the other criteria. *It is further noted that the VE session participants ranked long-term operational performance for the roads and traffic as most important followed by impacts to operations and maintenance of infrastructure, short-term public disruption, and impacts to major stakeholders*.

4.2 Refined Overpass Option

Following the VE session, the design team reviewed key ideas to consider and modified the overpass option with the following key changes in the design:

- Remove stepped slopes to reduce project footprint and avoid purchase of land.
- Accept crest vertical curve on the overpass structure to reduce road profile and achieve desired maximum grade.

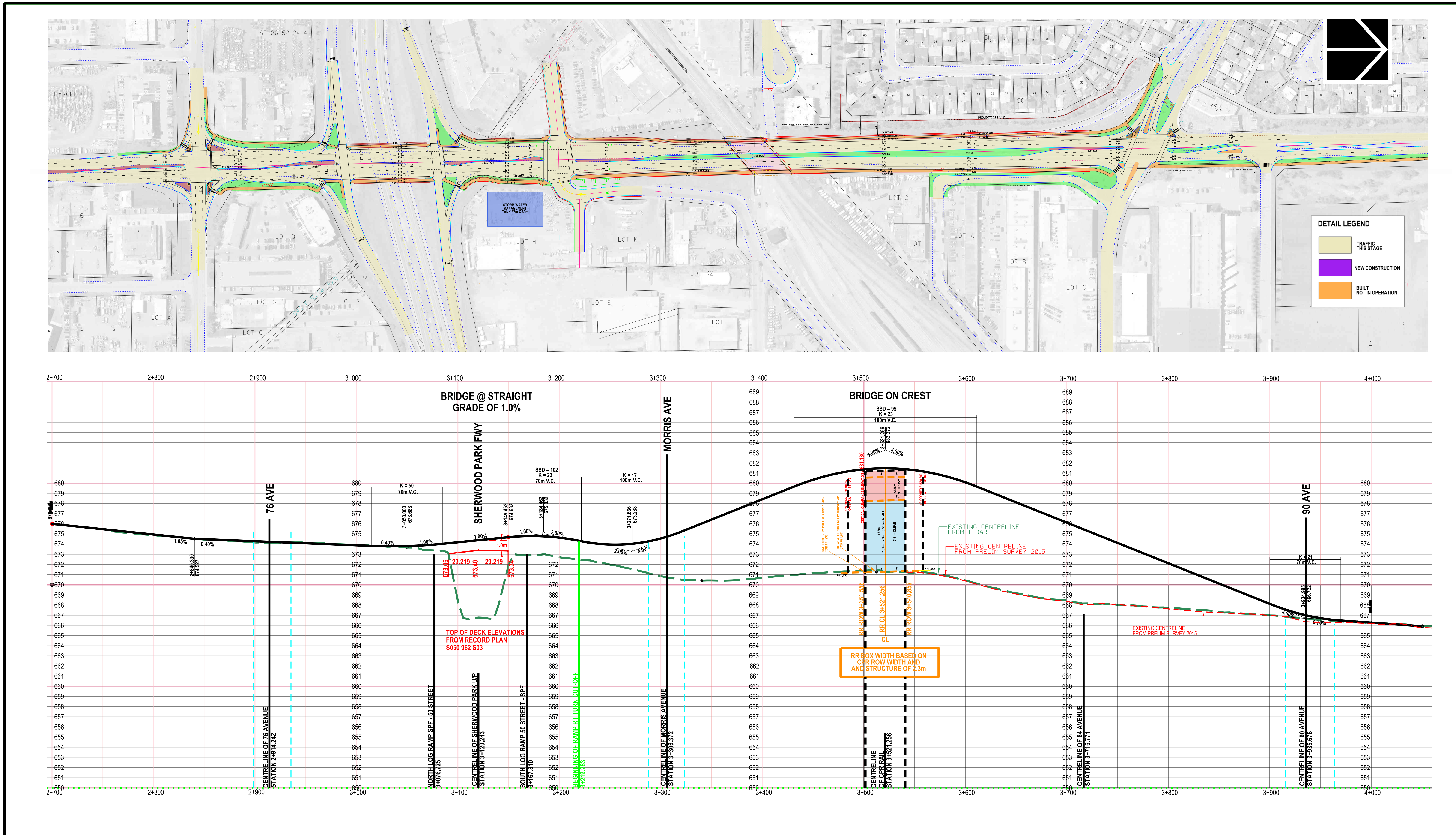
- Remove proposed 2-span bridge and permanent second connection to Plaza 50 in favour of a temporary connection on CP property.
- Remove proposed realigned Morris Road and proposed detours east of 50 Street to utilize the temporary connection on CP property for partial movements.
- Relocate the proposed stormwater management facility from the Plaza 50 site to the Herc Rentals site.

Based on these changes, the plan and profile for the preferred overpass option were refined to show the following:
- No land requirements from Plaza 50.
- No land requirements from additional parcels in the Morris Industrial Area, other than the Herc Rentals site.
- Achievement of a 4% grade north and south of the grade separation.

Advantages of the Overpass Option:
- Construction less complicated and lower risk.
- 50 Street detour road generally requires adding two additional lanes.
- Detour traffic over the railway in the fall of 2021 and 2022 pending construction schedule.
- Minimal impact and train delays.
- No construction anticipated to railyard or mainline track.
- No impact to CP 360 fiber communication line.
- Bridges go over the railway, which involves retaining walls and erection of girders and casting of deck where time blocks and CP flagging will be required.

Disadvantages of the Overpass Option:
- Construction of retaining walls and granular fills and road construction is conducive to summer construction.
- No float in construction schedule and susceptible to weather.
- Combined storm line to be relocated under CP right-of-way.
- Access disruption to stakeholder commercial properties
- Detour road along CP mainline track is required or 8 months for access to industrial and commercial parcels

Figures 4.1 and 4.2 show the refined overpass plan and profile and the refined overpass bridge plans.



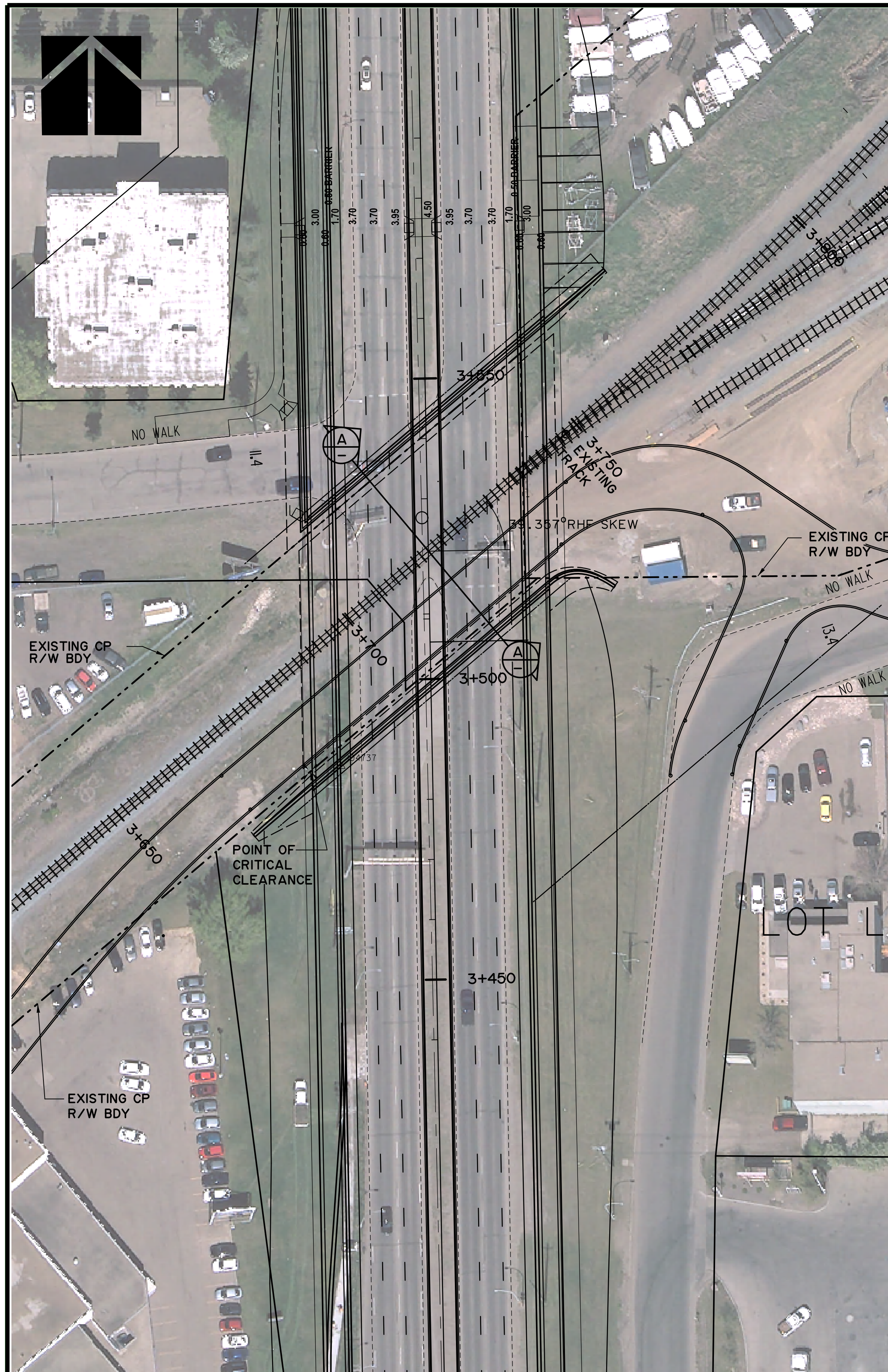
ISL

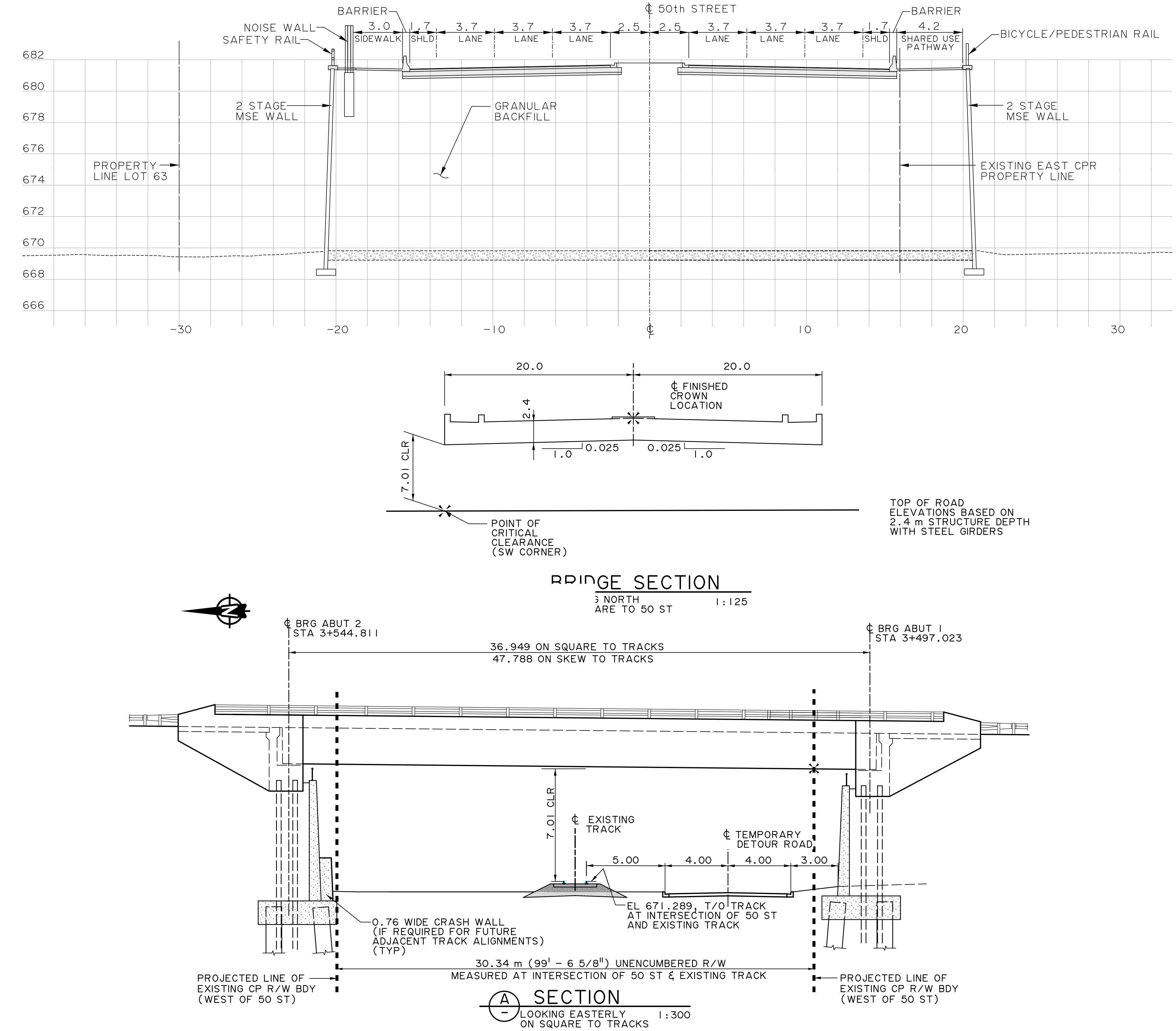
50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 4.1

REFINED OVERPASS PLAN AND PROFILE

September 28, 2018





ISL

50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 4.2

REFINED OVERPASS BRIDGE PLANS

September 06, 2018

4.3 Refined Underpass Option

Following the VE session, the design team reviewed the key ideas to consider and modified the underpass option with the following key directions to reduce land impacts as much as possible, improve detours and reduce overall costs.

Plan, Profile and Cross Section Changes for the Underpass Option

The key changes in the design can be noted as follows:

- Provide a 4-lane detour on the west side by staging the construction and using a temporary retaining wall.
- Utilize a 4-span bridge to reduce bridge depth, thereby improving grades.
- Eliminate impacts to Shipwreck Marine to avoid acquisition (partial or full) of this parcel.

Advantages of the Underpass Option:

- Underpass option is conducive to winter construction for retaining walls, bridge foundations, excavation, and storm tanks/pump stations:
- Construction float in the schedule winter 2021 to 2022.
- Minimal access disruption to commercial properties.

Disadvantages of the Underpass Option:

- Construction is more complicated and has a higher risk and involvement working around CP tracks.
- Higher CP involvement:
  - Temporary walls to support the tracks.
  - Track yard reconfiguration required.
  - Temporary relocation for CP 360 fiber communication line.

Figures 4.3, 4.4 and 4.5 show the refined underpass plan and profile and the refined bridge underpass plan with detour.

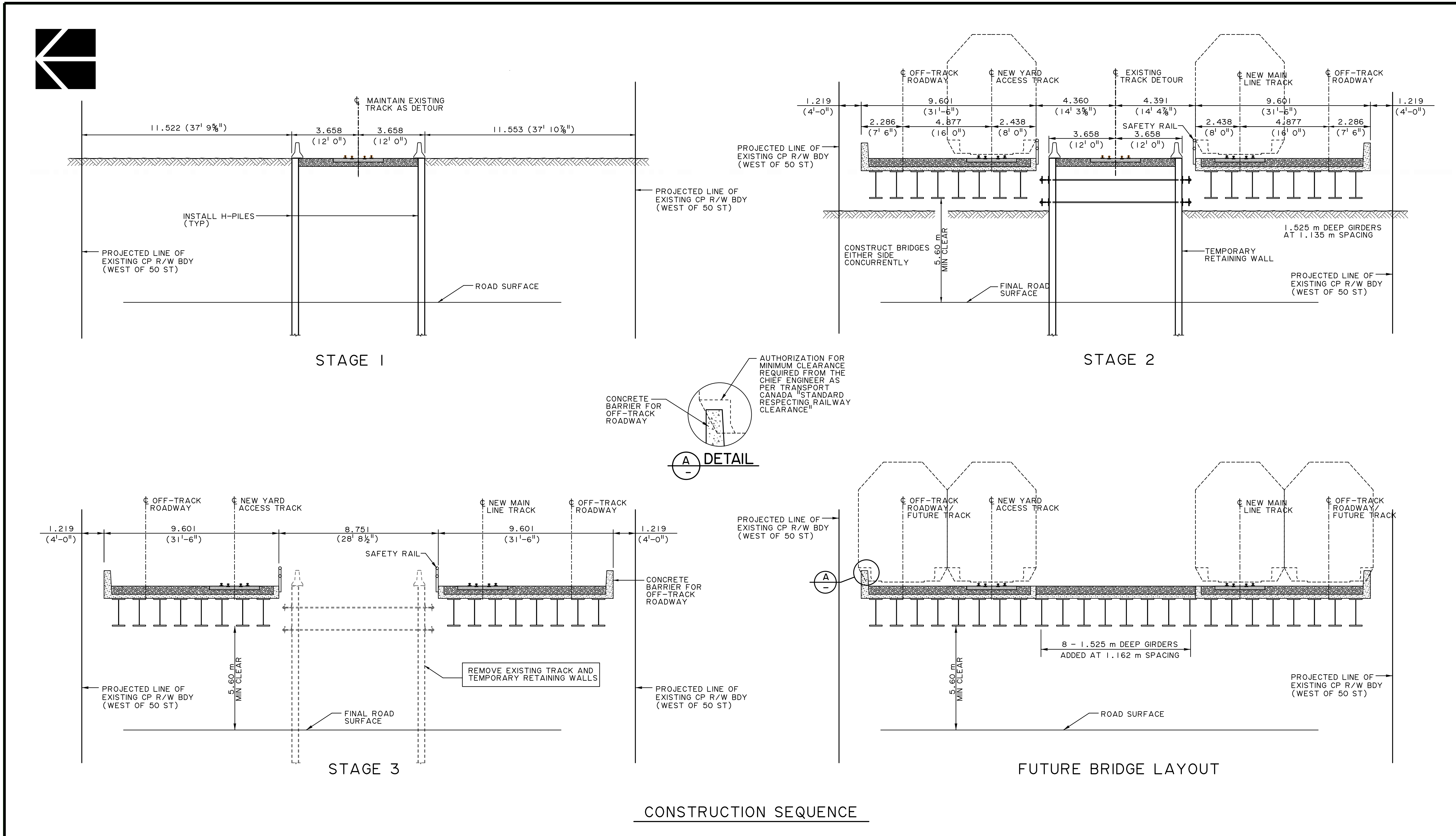
4.4 Revised Risk Assessment

As part of a two day workshop, a risk register review session was held on August 30, 2018. VE participants reviewed the risk register and quantified the added additional risks. This risk register review session and the risk analysis study, was facilitated by SMA Consulting Ltd. with the support of ISL through the provision of technical information. The following tables have been included as a summary of the risk quantification performed by SMA.

Following the workshop, another meeting was held to review the risk register and an updated risk register was then analyzed and the mean impacts to cost and schedule of the project for both options were determined, as shown in Table 4.4. A Monte Carlo simulation was used to calculate the results.

Table 4.4: Mean Cost/Schedule Risks

Option (Section A) Only	Mean Cost	Mean Schedule Impact
Overpass Option	$30.4M	35 Months
Underpass Option	$41.3M	40 Months

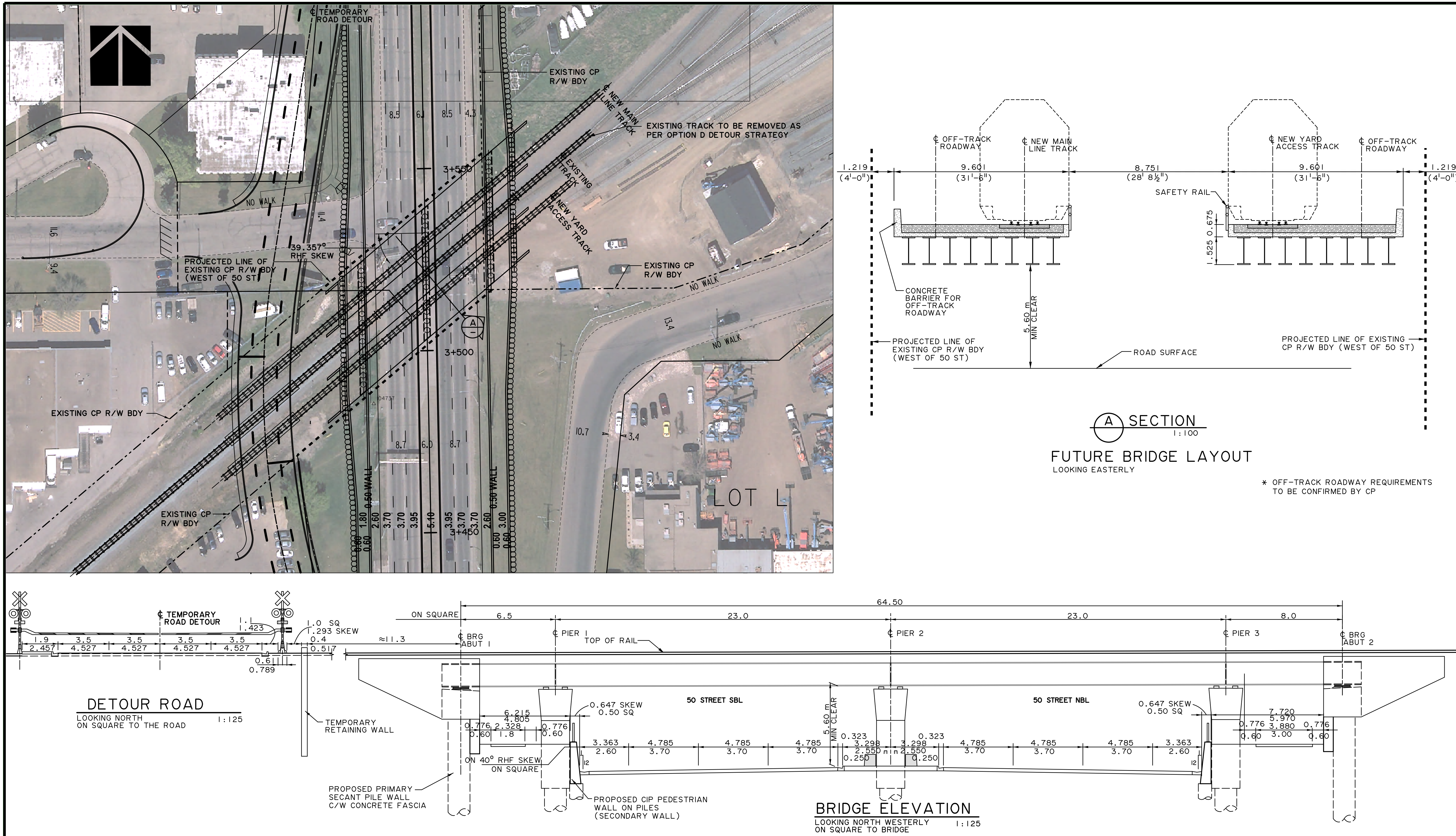


50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 4.5

REFINED UNDERPASS BRIDGE STAGING

September 18, 2018

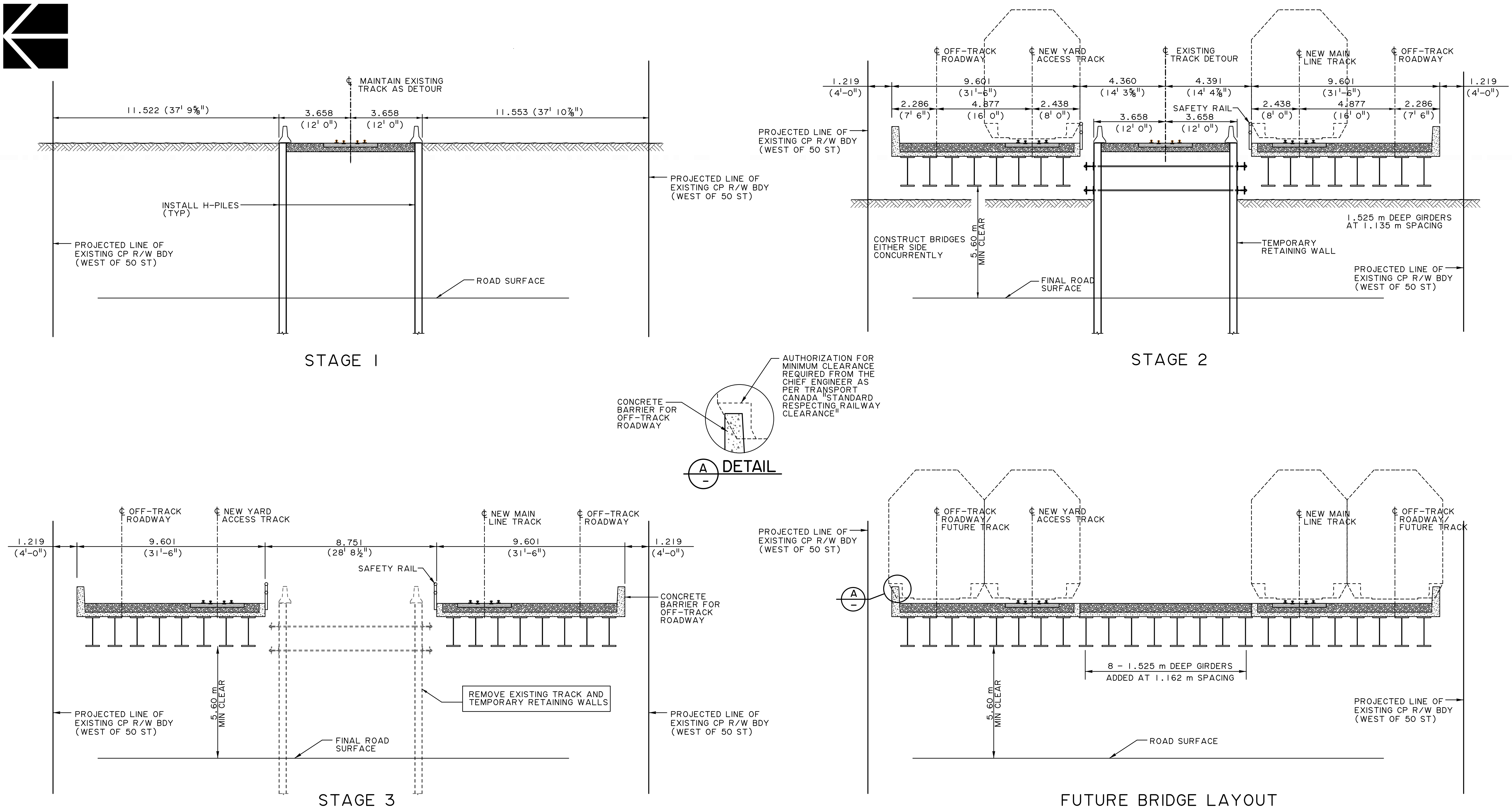


50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 4.4

REFINED BRIDGE UNDERPASS with DETOUR

February 06, 2019



CONSTRUCTION SEQUENCE

ISL

50 STREET WIDENING and CP RAIL GRADE SEPARATION - 76 AVENUE TO 90 AVENUE

EXHIBIT 4.5

REFINED UNDERPASS BRIDGE STAGING

September 18, 2018

5.0 Decision Making

After the design options and risk assessments were completed, a final decision support workshop was held where the refined overpass and underpass options were evaluated and ranked against the evaluation criteria. During the workshop, participants scored the overpass and underpass options against the following four criteria (and weighting) which were previously established at the VE session. The table outlines the criteria, the criteria weightings, the scoring rationale, the raw scores, the weighted scores and the total weighted aggregate scores.

Table 5.0: Criteria Scoring

Criteria		Score (1-10)		Weighted Score (1-10)	
Description	Scoring Rationale	Over	Under	Over	Under
Short-Term Public Disruption (6%)	Over option can provide grade separation earlier than the under option. The under option also has higher construction and schedule risk than the over option, which may mean additional disruption.	7	4	0.42	0.24
Long-Term Performance (52%)	The under option is expected to provide better operational performance for both vehicles and pedestrians due to better vertical grade lines and shorter length in grade changes. There are also fewer accesses that will need to be permanently closed.	4*	7*	2.08	3.64
Impact on Major Stakeholders (13%)	The under option has more potential future impact on utilities through the corridor and east-west.	7	5	0.91	0.65
Operations and Maintenance (29%)	The overpass has easier access but will be harder to rehabilitate. The under option has a pump station which introduces reliability concerns and over-height vehicle collisions with the bridge may cause issues. However, it is a simpler structure to maintain.	7	6	2.03	1.74
Total				5.44	6.27

**Average of scores received*

Based on the results of the evaluation, a Monte Carlo simulation was used to capture and reflect the uncertainty with the evaluation. The results are shown in Figure 5.

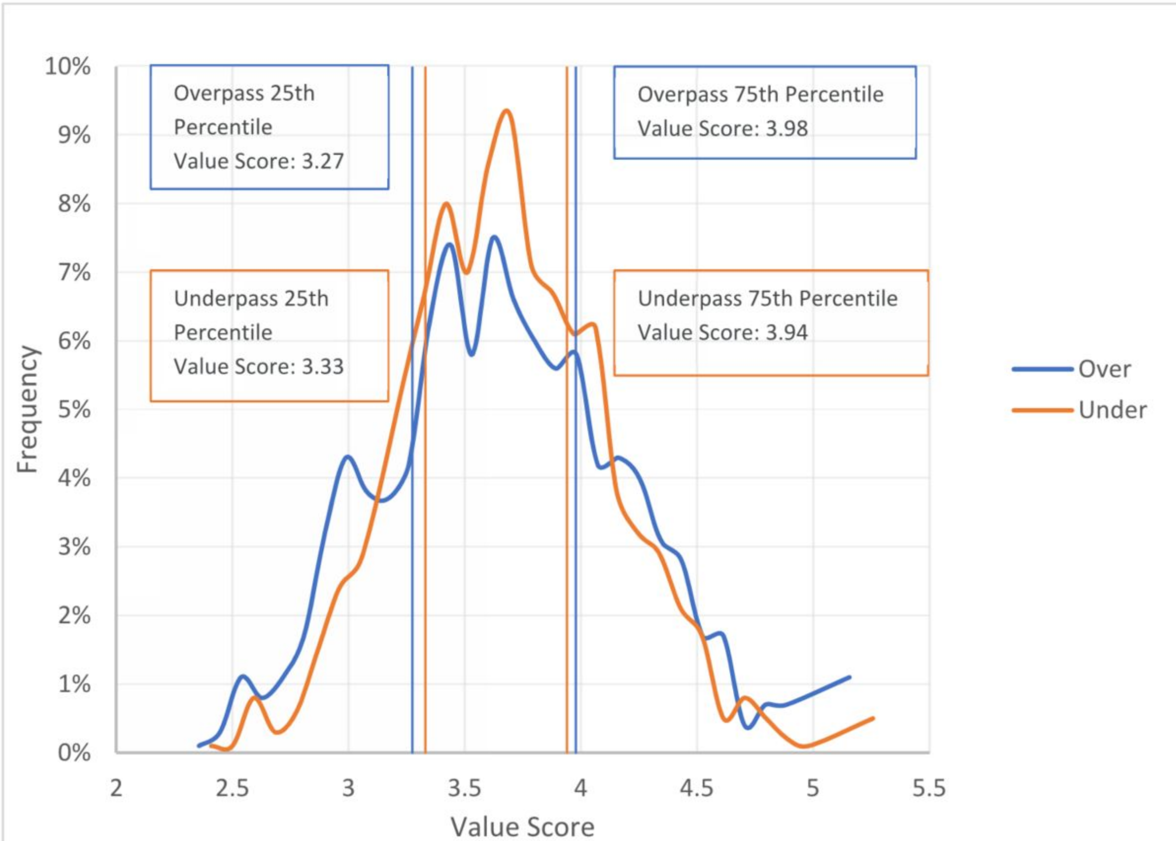


Figure 5: Distribution of Value Scores for the Overpass and Underpass Option with the 25th and 75th percentiles, as provided by SMA

5.1 Recommended Plan

In this exercise, value is the ratio of performance to total cost where the option with the higher value is the option that provides more advantages at a lower cost. Based on the evaluation, the underpass had a higher mean value of 3.61 compared to the 3.57 mean value of the overpass as the underpass was noted as providing better long-term performance. This value differential was noted even though the cost and risk exposure for the underpass is slightly higher. Based on the performance differential, the recommendation from the group was to proceed with the underpass option.

6.0 Conclusion

The project team considered many aspects of the project including right-of-way, utilities, stormwater management, CP impacts, rail detours, roadway detour, CP rail grade separation and CP track requirements, Sherwood Park Freeway bridge replacement, roadway access and connectivity, environmental and geotechnical issues, historical resources as well as overall project staging and constructability. Based on the teams technical review, it was found that the 50 Street widening project with CP rail grade separation, via an underpass, is technically sound, viable and valid.