Glenmore Causeway Upgrades Project

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Paper prepared for presentation

At the Bridges - Links to a Sustainable Future (A) Session

of the 2008 Annual Conference of the
Transportation Association of Canada
Toronto, Ontario

Abstract

Innovative bridge construction techniques employed to remove and replace an existing expressway bridge and maintain traffic flows of 140,000 VPD as part of the Glenmore Trail Corridor expansion being undertaken by The City of Calgary.

As Glenmore Trail is one of the most important transportation links in the City and southern Alberta, this paper addresses new bridge construction or roadway rehabilitation creating linkages to sustain social and economic development

ISL was engaged by The City to plan, design and supervise the construction of Glenmore Causeway Upgrades between Crowchild Trail and 14 Street SW. Glenmore Trail is the most important east-west expressway through Calgary, and the segment across the Glenmore Causeway is also part of the north-south Crowchild / 14 Street expressway route, designed ultimately to carry of more than 190,000 vehicles per day. The roadway is the busiest roadway operated by The City, and the segment of Glenmore Trail crossing Glenmore Reservoir is arguably the most environmentally sensitive area within Calgary.

The project includes the removal and reconstruction of the existing Causeway Bridge to achieve the joint objectives of accommodating medium-term traffic growth, and satisfying current flood control guidelines through the causeway waterway for the Glenmore Dam. In addition to traffic management, removal and reconstruction of the existing causeway bridge, and construction of a new bridge for the NB-WB Ramp at 14 Street SW, the project included both stormwater management and noise attenuation.

This complex $57 Million project was designed sequentially focusing on the tender and construction of critical path work while the remainder of the design continued. The success of this strategy was based on thorough planning by ISL, which ensured that each component of the separate detailed design packages fit logically within the project as a whole.

Project Overview

The Glenmore Causeway Upgrades is a capital works project undertaken jointly by The City of Calgary, Water Resources and Transportation Infrastructure departments. ISL Engineering and Land Services Ltd. was engaged in 2004 to develop the Preliminary Design and that engagement was extended during 2005 to include the Detail Design and Construction Administration of the project. ISL is responsible for Transportation, Structures, Stormwater Drainage, and Construction Administration. Our design team included Klohn Crippen Berger (Hydrology and Geotechnical), McIntosh Lalani (Materials), ENMAX (Illumination), HFP Acoustical (Noise Attenuation), Hamilton Finn (Road Safety Audit), EBA Engineering (Pavement), BGME (Electrical), Landplan Associates (Landscape Architecture), and Browning Horrocks (Golf Course Design). The project is budgeted at $57 Million with construction occurring on an accelerated staged basis during 2005 – 2008. The breadth of the assignment can be appreciated by the diversity of disciplines on the team. This paper focuses on staged construction of the bridges as it relates to temporary traffic accommodations required to ensure over 140,000 VPD pass through the project along what is the most significant transportation corridor operated by The City of Calgary over the drinking water supply for half the City.

Project Constraints

Glenmore Trail is the main continuous East - West route through south Calgary and the only bypass route through Calgary from Provincial Highways along with being the only major crossing of the Elbow River west of downtown (Fig. 1.). Currently approximately 80,000 VPD commute in a north- south direction towards downtown and 75,000 VPD transverse across south Calgary in an East – West direction. With heavy traffic on all links the Forecast to 2023 Horizon had over 190,000 VPD traveling along Glenmore Trail over the Causeway (Fig. 2.). The future 2023 roadway will require nine lanes comprised of four eastbound and five west bound. At 14th Street the EB lanes split in a two-two configuration and 3 – WB lanes are joined by 2 – NB-WB via a ramp. (Fig. 3.).

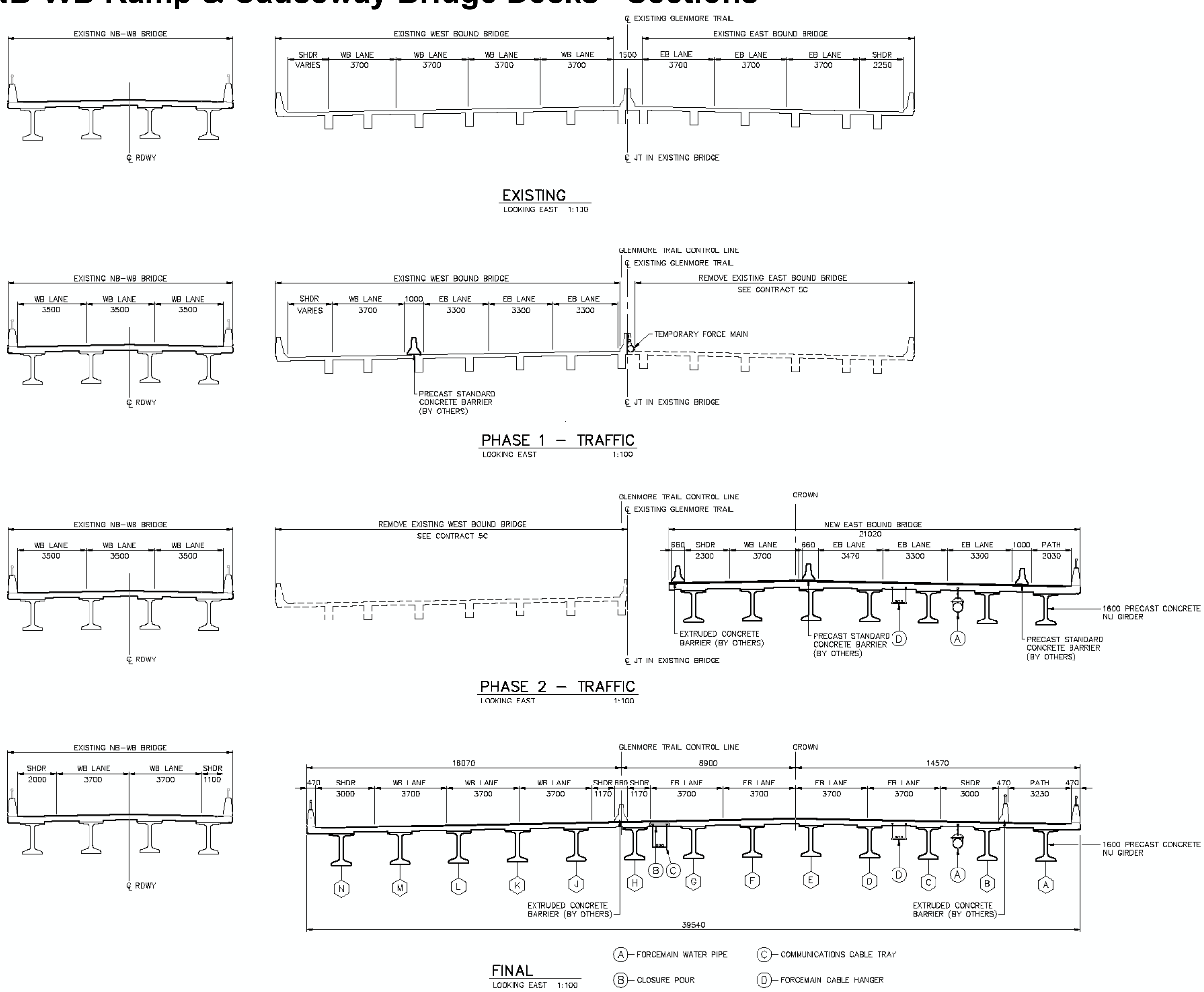
This part of Glenmore Trail is influenced and constrained by many geographic and civic features in the area. Most prominent among these is Glenmore Reservoir retained by a concrete dam built in 1932 that is 20m high by 320m long and 22m wide at base. The current seven lane roadway crosses the reservoir via a causeway and two bridges set side by side. The causeway was completed in 1963 and features a waterway/bridge flood capacity 1490 m3/sec (1:750 year). The roadway was widened in 1979 with an existing bridge being twinned to accompany construction of the 14th St. Interchange. The waterway armouring was improved in 1988 and 1990. As it is only 500m upstream of Glenmore Dam and Water Treatment Plant (WTP) intakes, current dam safety standards required the water passageway or bridge flood capacity to be upgraded to pass a Probable Maximum Flood of 2500 m3/sec (1:125,000 year) event (Fig. 4.). This necessitated increasing the water passing capacity of the existing channel. Preliminary concepts considered were: large culverts, building a second bridge, widening the existing opening and building a parallel box tunnel (Fig. 5.). After consideration of the requirements, widening the existing channel with removal and replacement of the existing bridge and adding a new bridge for the NB-WB Ramp was the preferred option.

The widened water channel needed to accommodate construction detours, integrate waterway hydraulics, optimize constructability and presented the least cost. At the same time it could protect water supply and avoid constraints on reservoir storage.

Temporary Traffic Accommodations

Stage 1 (Fig. 6) was construction of the NB-WB Ramp Bridge occurring from September 2005 to October 2006. This was required first to provide “more” roadway so there was space available crossing Glenmore Reservoir in which the detours could be staged.
At this point traffic along Glenmore Trail was relatively unimpeded as most construction occurred off the roadway to the north. A work zone speed reduction was posted and the existing numbers of lanes were maintained with periodic closures. Trucks entering and leaving the jobsite caused the greatest disturbances to traffic. Construction of the new bridge necessitated that the existing pedestrian pathway be closed and detoured.

NB-WB Ramp & Causeway Bridge Decks - Sections



Stage 2 (Fig. 7) which removed the existing and enabled construction a new Eastbound Causeway Bridge occurred from November 2006 through October 2007. During this time construction activities were by and large confined to a work zone on the south side of the remaining westbound half of the existing bridge. The number of lanes available

were matched the pre-construction condition by creating an “isolated” WB “contra-flow” lane on the north side of the westbound half of the existing bridge. Reducing lane widths from 4.57m to 3.3m with the corresponding speed reduction provided opportunity to for the detour to work effectively within the TAC design envelope.

Stage 3 (Fig. 8) which removed the existing and enabled construction a new Westbound Causeway Bridge occurred from October 2007 through September 2008. Construction activities occured between the new NB-WB Ramp Bridge and re-built EB Causeway Bridge. The “isolated” WB “contra-flow” lane was moved onto the EB Causeway Bridge and the work zone in between is access from the east or west at either end. The pathway is now available on the south side of the new EB Bridge and is re-opened.

Traffic Analysis and Requirements

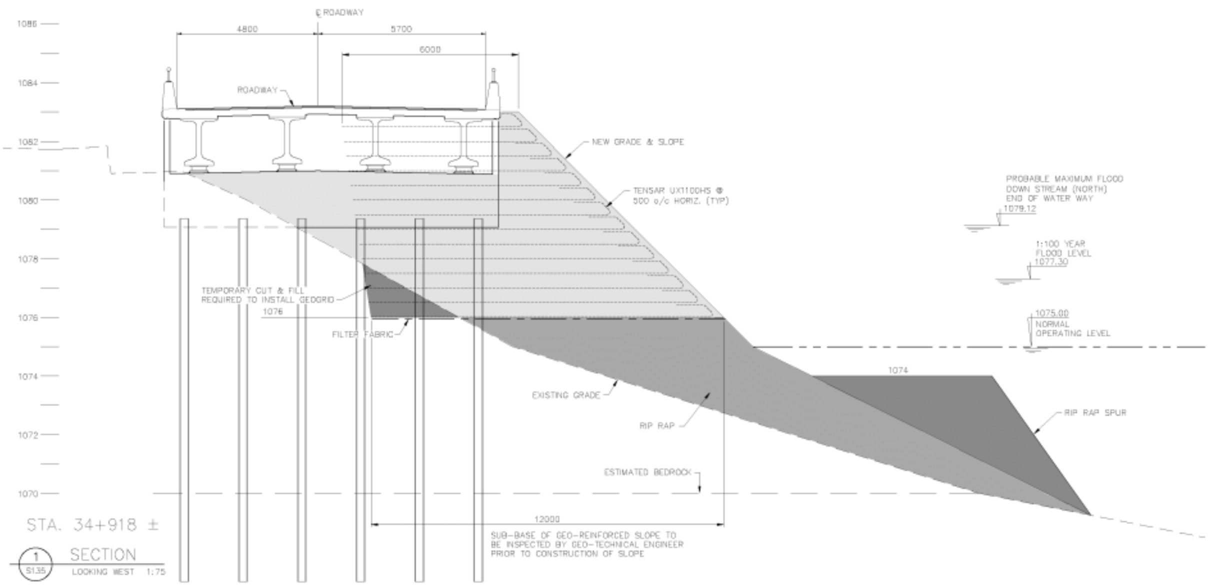
Glenmore Trail is a vital part of Calgary’s transportation network for both commercial truck traffic and perk-hour commuters. It provides a preferred alternate truck route to Trans Canada Highway connecting via Provincial Highways 8 and 22 on the east and west side of Calgary to Highway 1. Virtually all truck traffic traveling east and west through Calgary or turning east and west at Calgary use Glenmore Trail inside the City. Over 100,000 commuters use Glenmore Trail to travel to and from work. Sustaining this level of use during construction was an absolute economic and political necessity. For this reasons detours were subject to Route/Travel Time Analysis utilizing VISSIM 4.10, a multi-modal microscopic simulation modeling software that moves and tracks the performance of every vehicle using “car following logic” and no “set” criteria. Possible travel routes for commercial trucks and commuters are described in Figure 9. Ideally there would be no significant difference between the pre-construction travel times and the detour travel times along these routes. The results of the analysis are summarized in Figures 10 and 11 for the AM and PM Peak Periods, respectively. The modeling showed very little difference between the pre-construction and detour travel times.
The impact of single lane closures was evaluated using VISSIM and the results are presented graphically in Figure 12. It was apparent that closing a single lane during a peak period had a severe delay impact on traffic and that the impact would extend well beyond the peak hours causing commuters nightmares. Based on this analysis Lane Closure Specifications were developed with “Lane Closures” allowed only from 8:00 PM to 5:00 AM with a provision to extend the end time until Noon on weekends. For cases where the Contractor judged it was an absolute necessity to close a lane outside the permitted times a $750 cost to the contractor per occurrence Lane Rental Fee was inserted into the tender schedule of prices with a “Closure Number” the bid item. As a consequence there were only ~110 closures over 3 years bid versus the usual ~250 per year on a typical City project resulting in avoiding over 600 potential lane closures.

Bridge Design Requirements

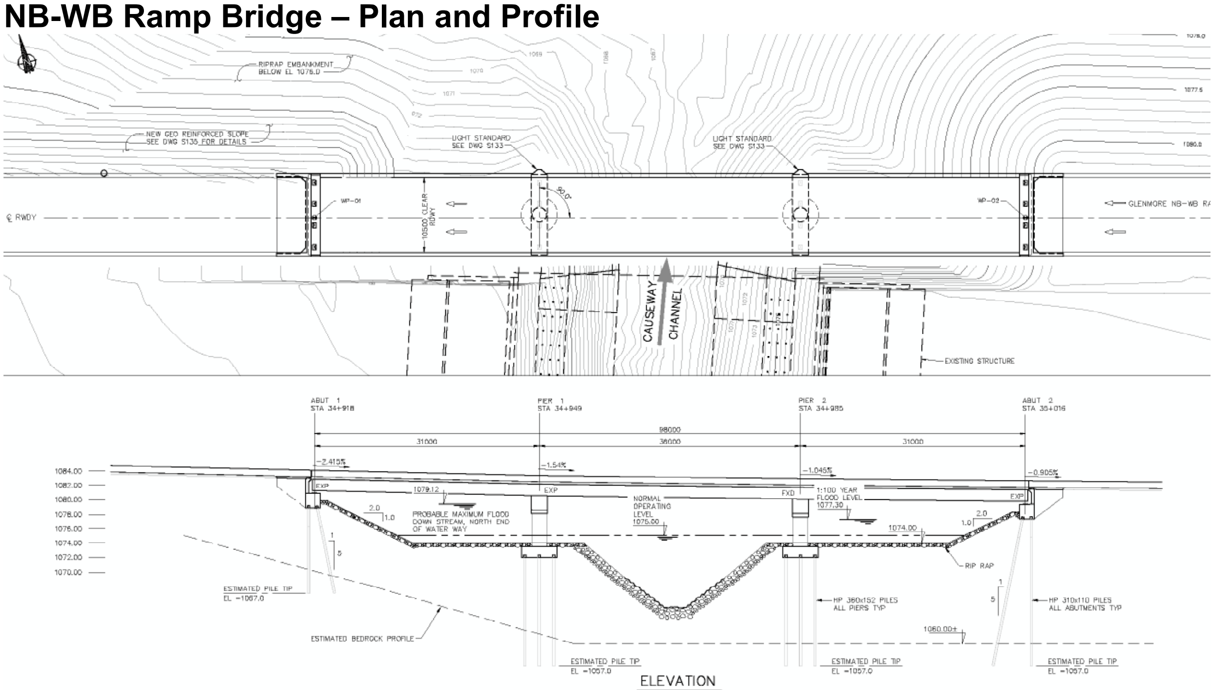
Design Criteria for the new structures are the City of Calgary Design Guidelines for Bridges and Structures which incorporates national requirements by reference. The design vehicle is the CL-800 and the design life of the structure is 75 years. The GCU project has been designed to City of Calgary and TAC geometric standards for an Expressway facility with a 90 km/h design speed, as confirmed with Calgary Roads.

The horizontal and vertical alignment for the bridges was considered during the Pre-Design Phase, then determined and refined during the development of the various alternatives. The structural cross-section illustrated in figure was derived to accommodate the ultimate traffic. For the NB-WB Ramp Bridge this was two 3.7m lanes with shoulders and the interim three 3.5m lane detour configurations for a total width of 10.5m curb face to curb face. For the Causeway Bridge this was seven 3.7m lanes with shoulders for a total width of 37.9m curb to curb and the interim four 3.3m lane detour configurations. Bridge configurations are shown in drawings below.

NB-WB Ramp Bridge West Abutment - Section

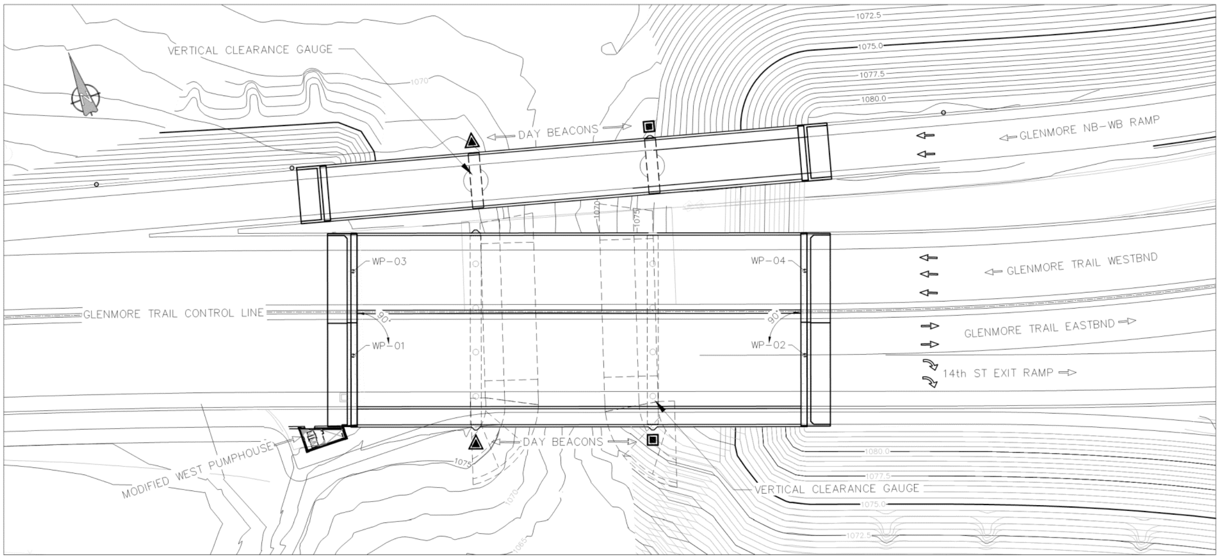


NB-WB Ramp Bridge – Plan and Profile

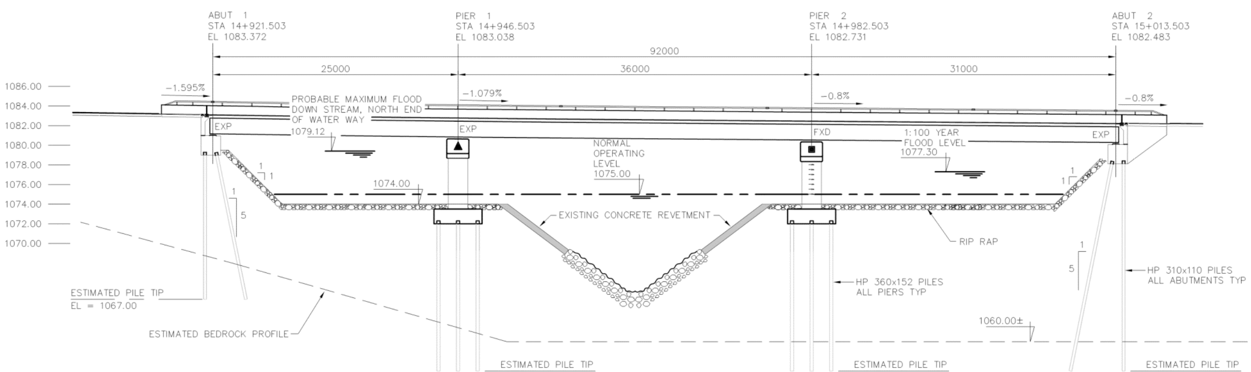


The two bridges are essentially the same in profile with the difference being shortening the west span to avoid conflicting with the West Pumphouse as illustrated below.

Causeway Bridge – Plan and Profile



PLAN
1:500



ELEVATION
LOOKING NORTH 1:250

The west abutments were set in a location where they can be suitably founded with side slope embankment impact minimized and not to conflict with the West Pumphouse foundation. The west abutments also need to miss the gore between the NB-WB ramp and the mainline, and facilitate positive drainage of the bridge structures. The east abutment is located to provide the shortest crossing of the opening that still allowed for the passage of the PMF flows. Both east abutment locations are ahead of the low point sag of the roadway alignment. There are slight curves in the horizontal alignment accommodated by using regular girders and curving the edge of the slab. Piers are located outside the notch area of the existing causeway bridge, where flows would reach their highest velocity, to avoid costly work “in stream”.

Choices between cast-in-place concrete caisson and driven steel pile foundations were evaluated. This resulted in selection of driven steel piles for the foundation. Large boulders placed randomly at the toe of the original causeway fill and concerns about effects on the causeway fill of conventional methods of installing large caissons lead to the conclusion that groups of H-piles preferred for founding the substructure.

Flow velocities in the v-notch channel range of 5.3 m/s for the current configuration and 4.6 m/s after construction is complete are predicted for the PMF flows for the bottom and sides of the Causeway Water Passageway so Class 3 Rip-rap was used in the notch. Along the sides or shoreline of the causeway, Class 1M Rip-rap was placed for protection from wave action and to match the existing finish slope.

To sustain the bridge over design life various materials and details were incorporated into the final bridge design enhancing durability of the structure including:

- Use of High Performance Concrete for the deck and barriers;
- Use of galvanized rebar in the deck and barriers;
- Use of pre-cast concrete girders;
- Post-tensioning the pre-cast concrete girders on short bridges;
- Utilizing a Polymer Modified Asphalt (PMA) overlay on the bridges;
- Coating exposed concrete surfaces with silane sealers; and
- Roadway grades that allow storm water to drain off of the bridge.

Bridge Construction

The existing Causeway was constructed by end-dumping pit-run gravel sourced from nearby pits and the banks were lined with Rip-rap from mountain quarries (Fig. 13). The existing bridge rested on footings set on the causeway embankment and was actually of two steel girder bridges with concrete decks set side by side with a 50mm gap between the Structures. NB-WB Bridge was constructed during the Stage 1 Detour between September 2005 and October 2006. The first step (Fig. 14) was widening the Causeway by placing approximately 140,000 T of granular fill in the reservoir. To minimize the impact on Reservoir and Water Treatment Plant a silt curtain was installed around the perimeter of the in water work zone. Additionally a floating oil absorbent boom was tethered in front of the silt curtain in case of a hydrocarbon spill on the reservoir from construction activities. Spills on the roadway are controlled by an existing system that intercepts all storm drainage and pumps it downstream of the WTP or holds it in storage in case of a roadway spill. This system was maintained intact without interruption for the duration of construction and so the risk of potential roadway spills was addressed early in the project planning.

After evaluating the options and receiving price input from the Contractor, the Design Team adopted a 98 meter long NB-WB Ramp Bridge design employing 1600 deep NU Girders, utilizing four girder lines. The east approach to the bridge will consist of a 144 meter long Causeway Infill placed with the Abutments founded on steel H-Piles driven to refusal in bedrock. The west approach employed an engineered embankment with a steep slope planted with native grasses instead of the usual MSE retaining wall. The bridge substructure is cast-in-place structural concrete consisting of Pile Caps and Piers with a “Tee-Top” supporting the superstructure. The round pile cap design provided opportunity for the Contractor to set a large diameter steel culvert vertically around the steel piles and seal the work space from the reservoir water by placing concrete slab via tremie methods below the pile cap. This approach was adopted for building the piers.

As can be seen in Figures 15 and 16 the superstructure bridge deck system consists of galvanized reinforcement with a High Performance Concrete (HPC) deck. To this is added a Polymer Modified Asphalt (PMA) roadway surface. The barrier rails are HPC topped with steel bridge rail. The completed NB-WB Bridge can be seen in Figure 17.

Figure 18 illustrates construction of the Stage 2 Detour November 2006. Again the first step was widening the Causeway to the south by placing approximately 70,000 T of granular fill in the reservoir. And again a silt curtain with a floating oil absorbent boom were installed around the perimeter of the in water work zone. Seen in the lower right hand corner of the figure are a previously completed cut slope and the required golf course renovations to accommodate the roadway widening. The West Pumphouse, which is part of the Causeway storm drainage system, can also be seen nearby.

Figure 19 shows the start of the removal of the eastbound half of the existing bridge. To minimize the chance of debris falling into the reservoir the bridge deck was saw cut and removed in pieces instead of more traditional demolition techniques. Due to restrictions on what could fall into the reservoir a false deck was constructed on the lower flange of the existing steel girders to catch any debris or deleterious fluids that might slip down from the deck. Figure 20 shows the Stage 2 Detour in place a working while the bridge substructure is being constructed. Note the “isolated” WB “contra-flow” lane on the north side of the WB half of the existing bridge working effectively and the widened causeway used as a staging area for bridge construction. In Figure 21 the foundations are ready with the Piers and Abutments being constructed. Also the West Pumphouse is under renovation with a corner cut off to accommodate the new road. Figure 22 shows the galvanized rebar in place just prior to the deck pour. On the east bridge abutment, two tanks to capture the curing water run-off are in place to prevent it from entering the reservoir. The nearly complete West Pumphouse can be seen in the lower left of the figure. The silt curtains are effective, in this case, keeping the silt laden spring run-off water separated from the relatively cleaner water inside the work area.

Figure 23 shows the Stage 3 Detour under construction with the “isolated” WB “contra-flow” lane being shifted to the north side of the EB half of the new bridge. In Figure 24 the traffic has been shifted to the Stage 3 configuration and removal of the existing WB bridge is beginning. In figure 25 the concrete deck has been removed and the steel girders are waiting to be hoisted out of position and hauled away. Figure 26 is a picture taken behind the soon to be demolished former east abutment with the west abutment ready for pile driving in the background.

Figures 27 and 28 show the substructure under construction during early spring when flows are most reliably at their lowest and the reservoir has been drawn down over winter. In Alberta flows generally remain low on uncontrolled rivers originating in the Rocky Mountains until about Victoria Day and so work on the substructure should ideally be completed prior to mid-May. After that river elevations can vary dramatically with spring run-off and precipitation and it is best to be working on the superstructure.

Figures 29 and 30 show the bridge deck being formed between the pre-cast girders. The false deck was required to prevent anything from falling into the reservoir during construction and is also used for access to strip the deck formwork after it is poured. Starting at 8:00 PM on Thursday, May 29, 2008 the WB Causeway Bridge Deck pour began and continued over night until completing about 5:00 AM the next morning. Figures 31 and 32 are taken shortly after starting. Afterward the City hosted a thank-you breakfast for all involved and work continued to finish-out the westbound bridge. At the time of writing this paper, work is beginning on finishing the roadwork and the project is expected to be completely finished on schedule during October 2008.

Conclusion

The Glenmore Causeway Upgrades Project was designed and constructed to sustain commercial and commuter traffic for the next 25 years. The design life of the new bridge structure is 75 years. The existing 45 year-old bridges that were removed and replaced could have easily lasted another 30 years as well, but required removal and replacement to satisfy current and future traffic volumes, as well to be upgraded for modern dam safety standards. The challenge is then to make provision for future uses and configurations for traffic volumes, vehicles and situations that we can imagine and are most certain to wrong in predicting. Please take a moment to reflect on whether the designers in the 1960's could have imagined current volumes and vehicles? Probably not and neither could they have predicted it would be worthwhile to accommodate a 1:125,000 year flood. Nonetheless the basic design decisions made back then were reasonably renovated and capacity expanded to suit current needs. It is no coincidence that the pathway is the exact width required to accommodate another lane. Nor is it happenstance the bridges are founded on bedrock and could easily be widened. The challenge then is for engineers to design efficiently for today to sustain future needs.

6. Figures

Figure 1 – Location Key Map

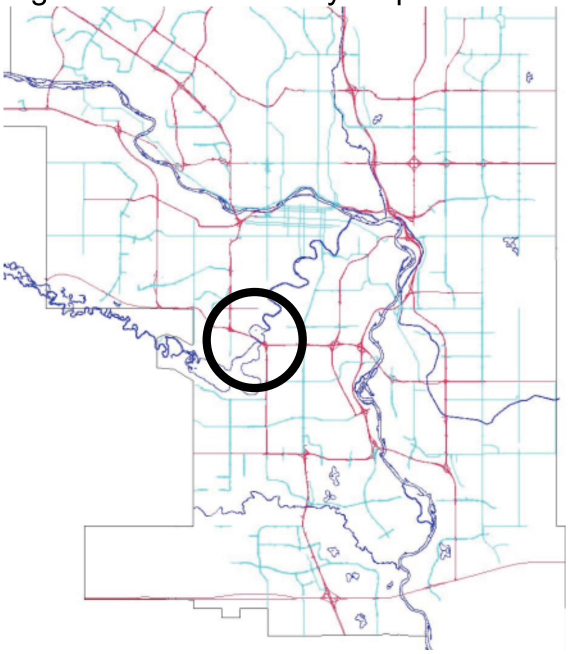


Figure 2 – Traffic

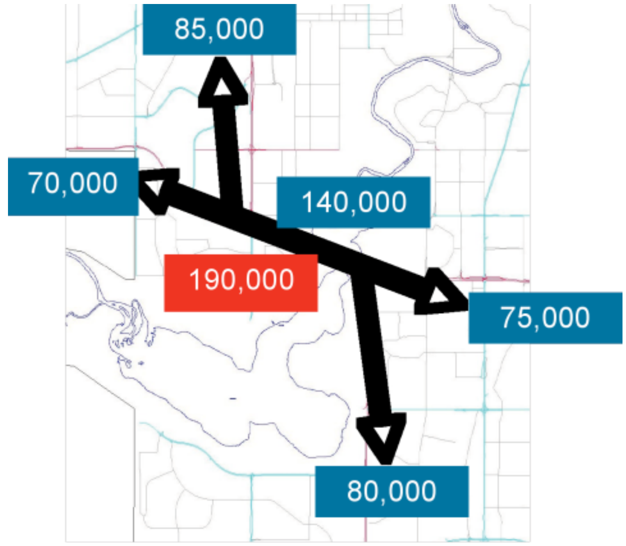


Figure 3 – Lane Configuration

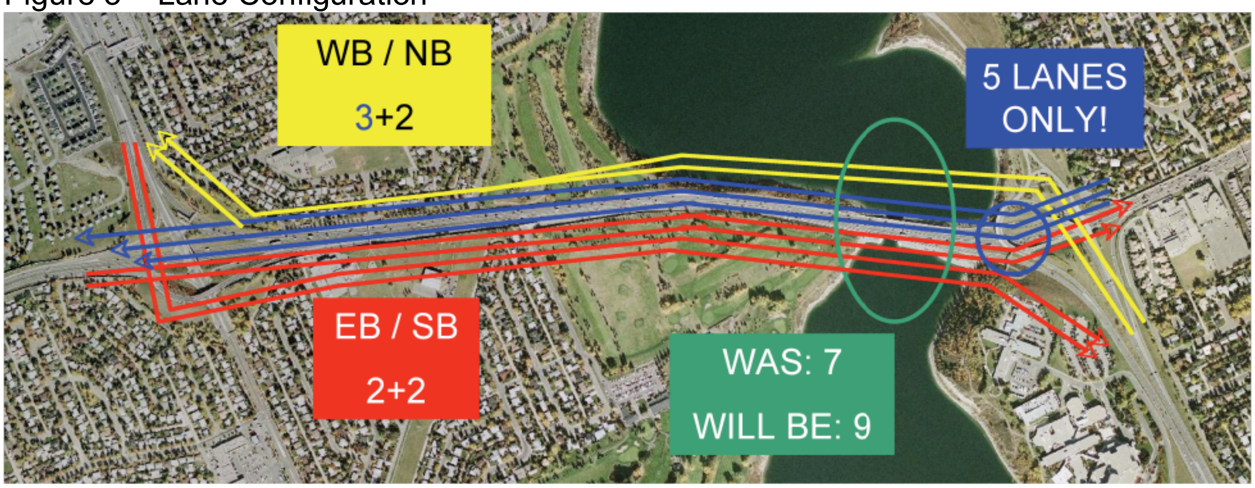


Figure 4 - Probable Maximum Flood

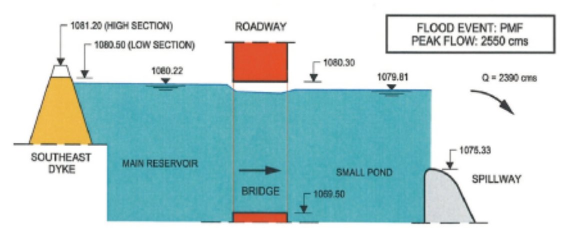


Figure 5 – Channel Widening Concepts

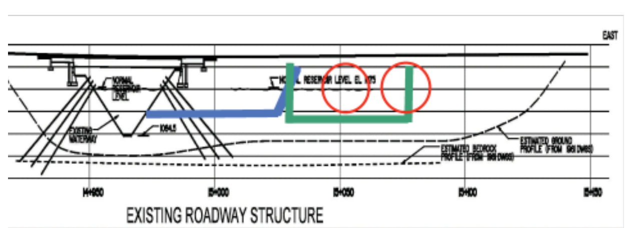


Figure 6 - Stage 1 – Construct New NB-WB Ramp Bridge

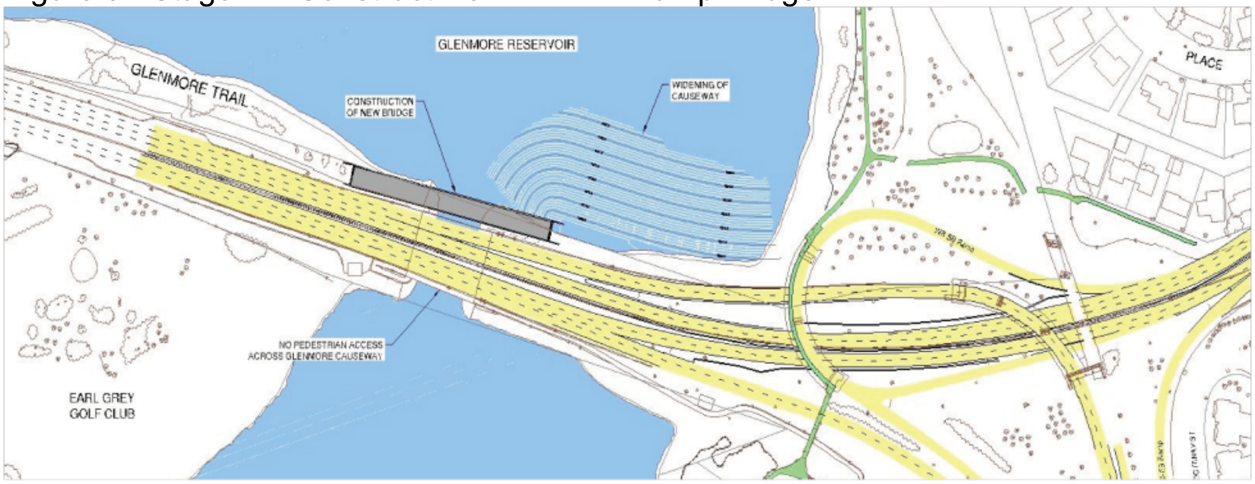


Figure 7 – Stage 2 – Remove and Construct EB Half of Causeway Bridge

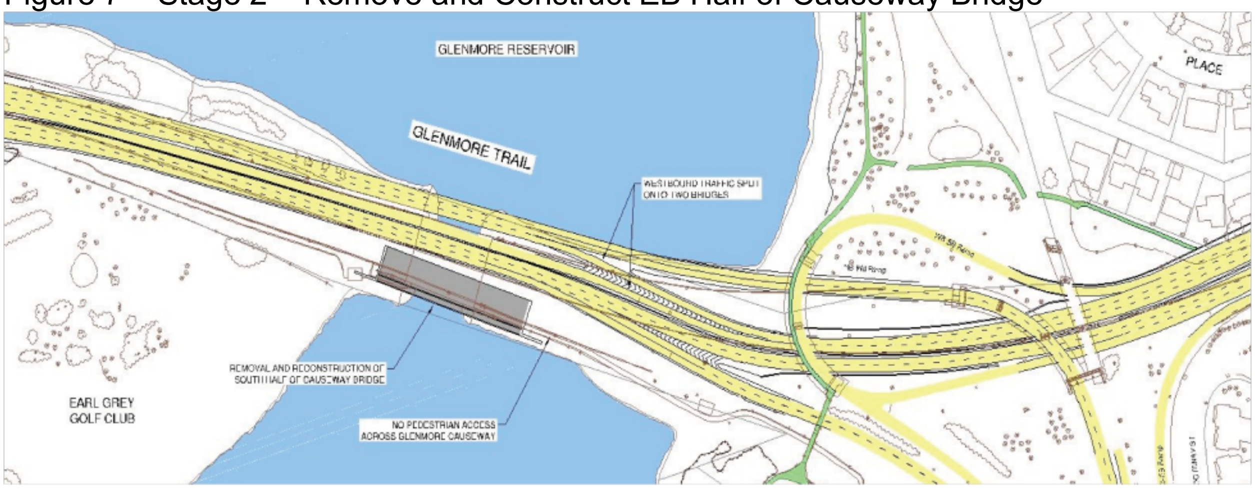


Figure 8 – Stage 3 – Remove and Construct WB Half of Causeway Bridge

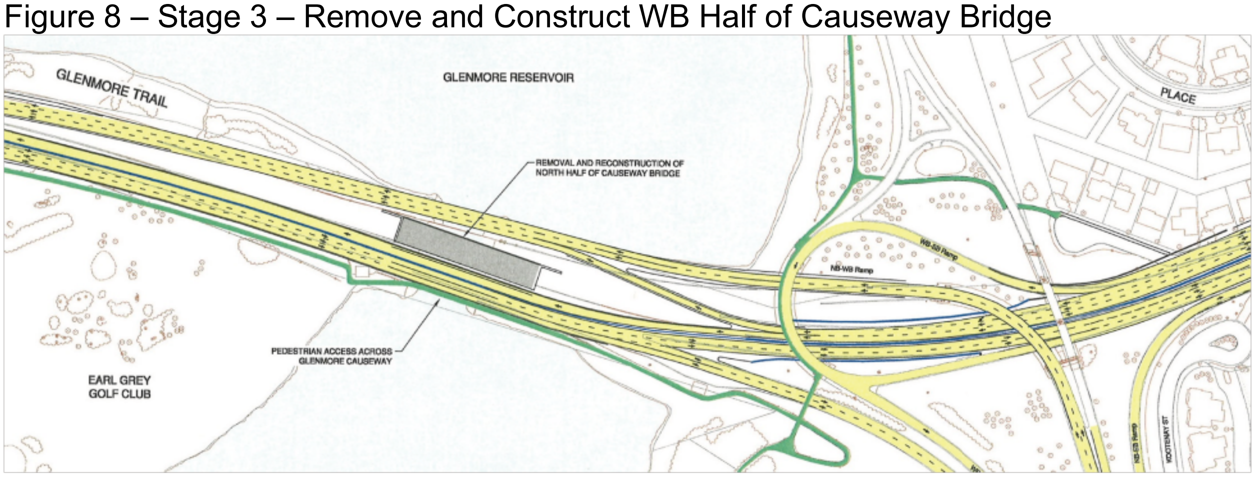


Figure 9 – Routing / Travel Time Analysis

Figure 10
Travel Time Comparison at AM Peak

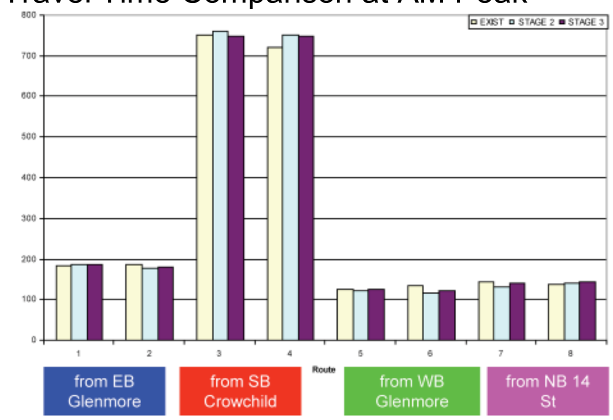


Figure 11
Travel Time Comparison at PM Peak

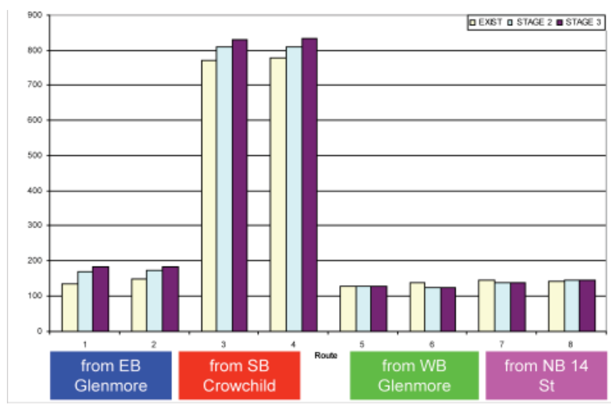


Figure 12 – Lane Closure Analysis

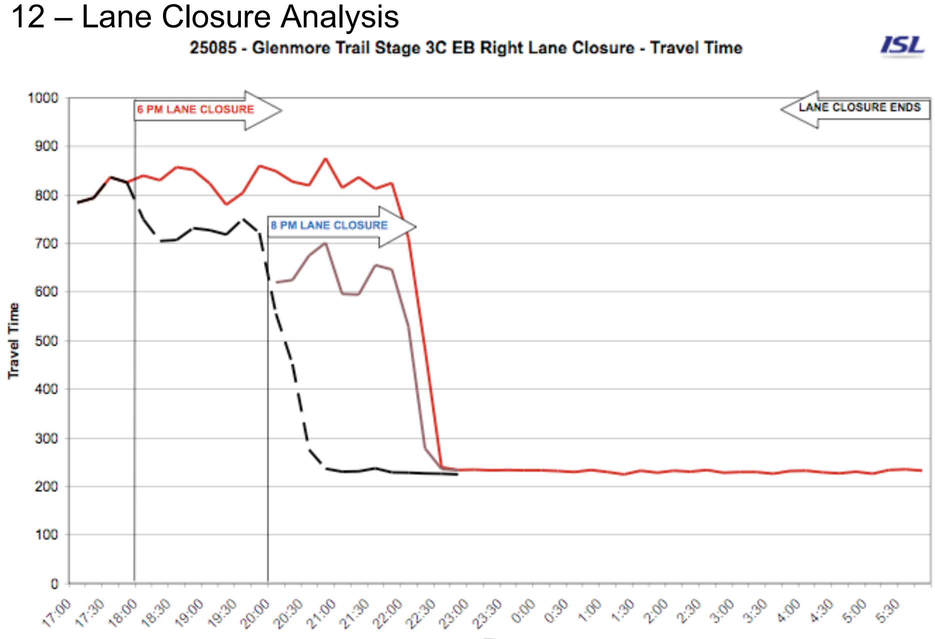


Figure 13 – Existing Glenmore Causeway

Figure 14 – Stage 1 Detour & Widening

Figure 15 – NB-WB Bridge Construction

Figure 16 – NB-WB Deck Pour

Figure 17 – NB-WB Bridge Complete

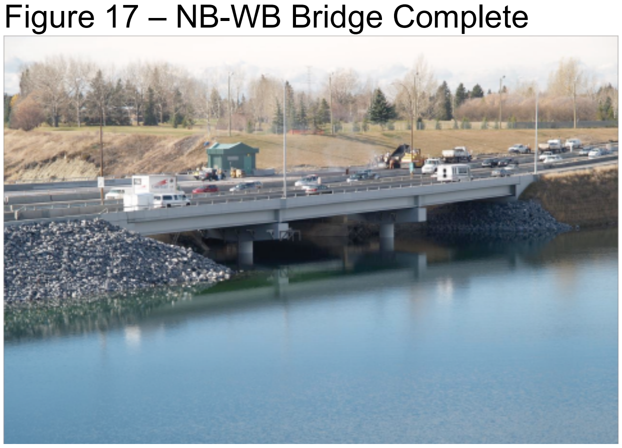


Figure 18 – Stage 2 Detour Construction

Figure 19 – EB Bridge Removal

Figure 20 – E. Abut. EB Causeway Bridge

Figure 21 – EB Bridge Foundations

Figure 22 –EB Causeway Bridge Deck

Figure 23 – Stage 3 Detour Construction

Figure 24 – Start WB Bridge Removal

Figure 25 – WB Bridge Girders Stripped

Figure 26 – West Abutment Removed

Figure 27 – WB Causeway Bridge

Figure 28 – WB Substructure

Figure 29 – WB Bridge False Deck

Figure 30 – WB Bridge Deck Formed

Figure 31 – WB Bridge Deck Pour

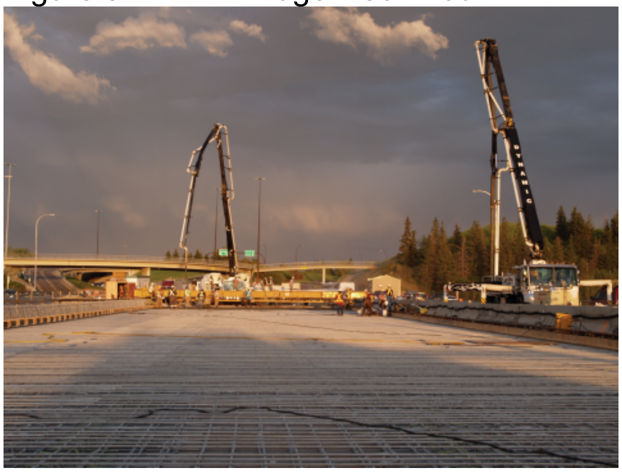


Figure 32 – View Towards Downtown

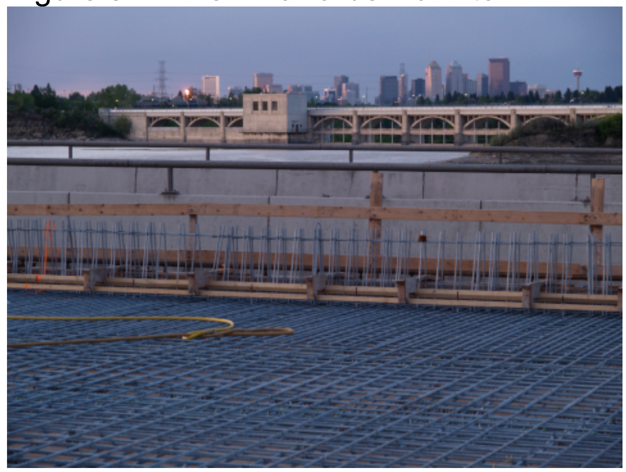


Figure 33 – Aerial View GCU Project Looking Northeast