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TITLE	GMC Bridge Options Summary of Considerations - DRAFT
DATE	29 November 2019
TO	Darryl Matson, GMC Technical Lead
COPY	Hendrik Westerink, Anne-Marie Langlois
FROM	Don Bergman, GMC Bridge Lead
PROJECT NO	A127810

1 Introduction

In July 2019, COWI North America Ltd. and Stantec (CST) were awarded an assignment to provide as & when technical services to the BC Ministry of Transportation and Infrastructure (Ministry) for the George Massey Crossing Project. The assignment was to provide technical support in response to questions asked by the Ministry (or the Mayors Task Force through the Ministry).

The purpose of this memo is to document the technical work completed for the assessment of the bridge options for the George Massey Crossing Project.

The options considered and the key considerations in determining the preferred layout and concept for the replacement bridge option are discussed. The work on the bridge options is based upon input secured and terms of reference developed by the Province and the regional stakeholders. The work for the bridge option also draws significantly upon work completed by COWI as part of the previous George Massey Tunnel Replacement (GMTR) Project.

2 Chronology of The Assessment

From the outset the bridge form selected was cable stayed as this form has proven to be the most economic bridge for the range of spans under consideration for the George Massey Crossing.

The initial phase of the assignment comprised a high-level assessment of all viable six and eight lane cable stayed bridge options for the tunnel replacement.

The proposed six-lane bridge option makes use of the existing tunnel for dedicated bus lanes, and the proposed eight-lane option does not utilize the existing tunnel.

A profile for the bridge crossing was selected based on assumed horizontal and vertical navigation clearances (for the purpose of our work, we assumed the same clearance envelope as that required for the GMTR project, but if the bridge option is carried forward, this will need to be verified with Transport Canada). Property considerations and highway connections on the north and south ends lead to the selection of an upstream alignment arranged with an acceptable separation between the existing tunnel portals and the foundations required for the replacement bridge.

Consideration was initially given to two different span arrangements for the replacement main span bridge over the Fraser River:

i) A short span bridge option with main towers in-river just clear of the horizontal navigation envelope, and

ii) A long span option with main towers clear of the river.

In order to assess the cost differences between the longer and shorter span bridges, we performed a concept design of the foundations for both. The longer span bridge piers do not need to resist ship collision loads, while the shorter span bridge does need to resist ship collision loads. Based on our current work on the Pattullo bridge, we anticipate that the design ship at Massey will be at least 60,000 DWT, and this is the vessel that we did the preliminary design for. The lateral loading caused by ship impact turned out to be quite significant, and in the case of the six-lane option, we estimated that the cost savings associated with the shorter cable-stayed bridge were less than the added foundation cost – so the shorter six-lane cable-stayed bridge would actually cost more than the longer one. For the eight-lane option, the foundation cost increase was slightly less than the cost savings associated with the shorter cable-stayed portion, so the shorter eight-lane option looked marginally cheaper. However, due to the risk of Transport Canada wanting a larger design ship, as well as the delay to the project associated with the permitting, it was decided that the bridge options should assume that the cable-stayed bridge clear spans the main channel of the Fraser River.

A general layout, typical cross-sections, and estimated areas of ground improvement were developed for the six and eight lane long span bridge options.

As directed by the Ministry in September 2019, the six-lane bridge option was abandoned and the eight-lane bridge option was further refined. The typical cross-section for the eight-lane option was refined and geometry of the main towers and foundations were determined. Required ground improvement for the preferred bridge option was developed. For general arrangements of two variations of the eight-lane bridge option, refer to drawings BR011 and BR012 in Appendix A. For structural details of the eight-lane bridge option, refer to drawings BR102 and BR103 in Appendix A.

3 Description of Bridge Options Considered

The six-lane and eight-lane bridge options for the George Massey Crossing both initially featured an open composite steel and concrete deck cable-stayed main span across the Fraser River with multi-girder composite bridges for the north and south approaches.

The bridge is proposed to be located upstream of the exiting tunnel, with the north abutment located south of the Steveston Highway interchange and the south abutment located north of River Road. The proposed upstream alignment of the proposed bridge options is shown in Figure 1 below. The proposed alignment places the closest piles for the new bridge approximately 10m from the existing tunnel portal.

Figure 1 – Upstream Bridge Alignment

Figure 2 below shows the in-river bridge arrangement for the short cable-stayed option, with in main towers and foundations just clear of the 325 m navigation window. This resulted in a main span length of 370 m.

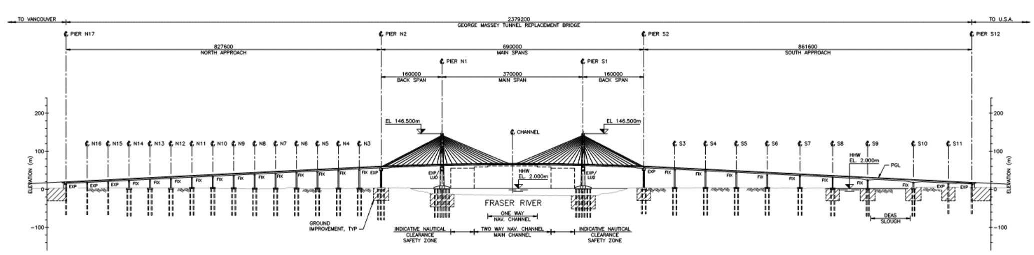


Figure 2 – Short Span Bridge Option

Figure 3 below shows the long cable-stayed bridge option with main towers and foundations clear of the river, resulting in a main span of 634 m.

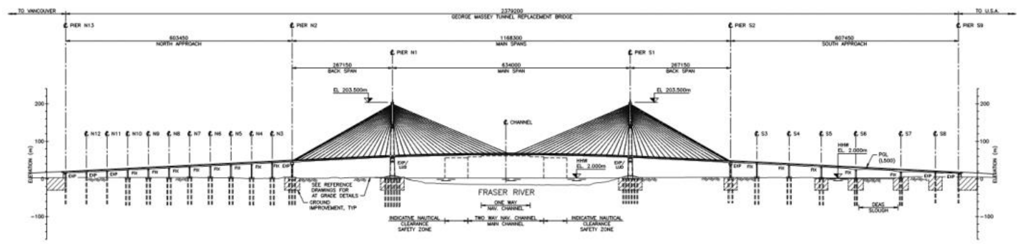


Figure 3 – Long Span Bridge Option

Both Figure 2 and Figure 3 above show Bridge Option 1, which includes a multi-girder bridge over Deas Slough with piers located in Deas Slough. Upon further consultation with the Ministry, Bridge Option 2, with a clear-span cable-stayed bridge across Deas Slough was added. Bridge Option 2 is described in Section 4.1 and illustrated in Figure 9.

The main tower foundations for the in-river option must be designed for ship impact from a 60,000DWT vessel, whereas the foundations for the out of river option do not require vessel impact design. As a result, the foundations for the in-river option will be substantially larger than those required for the out of river option. This fact combined with the anticipated environmental issues associated with the in-river option offset the cost advantages of the shorter cable stayed bridge span and lead to selection of the out of river option as the preferred span arrangement.

Figures 4 and 5 below show the composite steel and concrete cable stayed decks initially considered for the six and eight land configurations respectively. Both configurations allow for 3.7 m lanes widths, 1.0m shoulder for the eight-lane and 1.5 m shoulder for the six-lane, 1.0 m shying strips each side of the central median barrier and 3.5 m wide multiuse paths (MUP's) outboard of the stay cables.

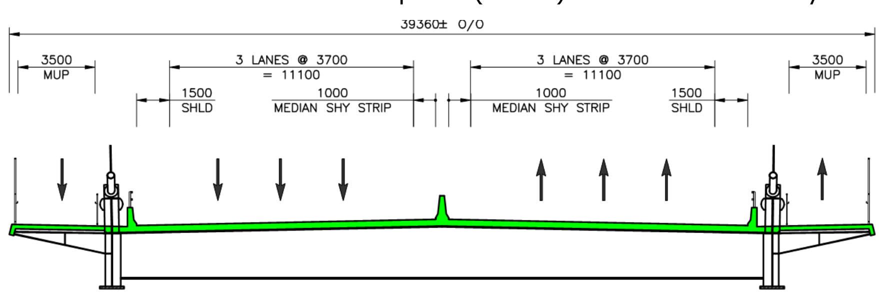


Figure 4 – Initial Six-Lane Bridge Configuration

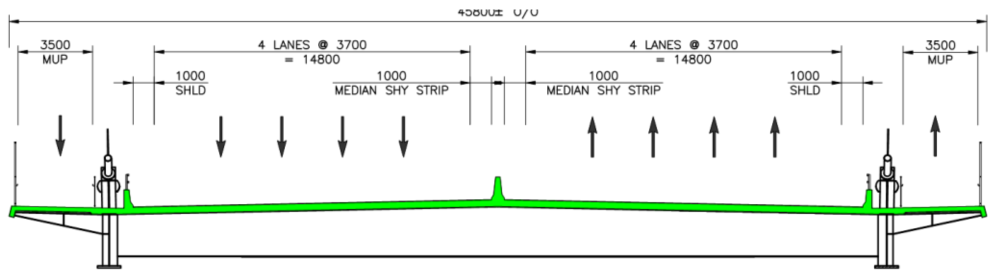


Figure 5 – Initial Eight-Lane Bridge Configuration

Aerodynamics is a critical design issue for long span cable stayed bridges. As a result of the decision to select the longer span out of river bridge option, further assessment of the narrow six-lane deck with respect to aerodynamics indicated a need for a torsionally stiff box girder section. The revised proposal for the six-lane deck section is shown in Figure 6 below.

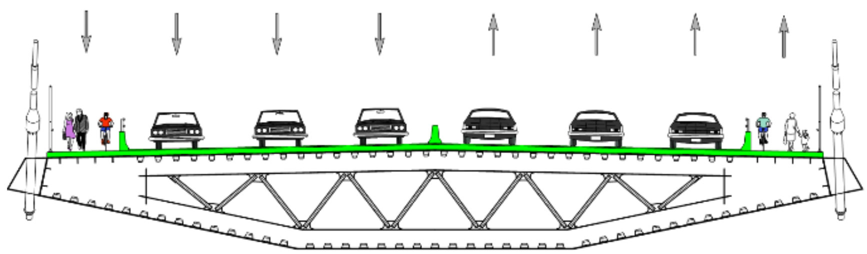


Figure 6 – Revised Six-Lane Box Girder Deck Section

The MUPs were moved in board of the cables as shown in Figure 6.

The revised eight-lane deck section is shown in Figure 7 below. The MUP's have been moved in-board of the cables. A box girder deck is not required for the eight-lane deck as the width of the deck is expected to be sufficient to for aerodynamic stability.

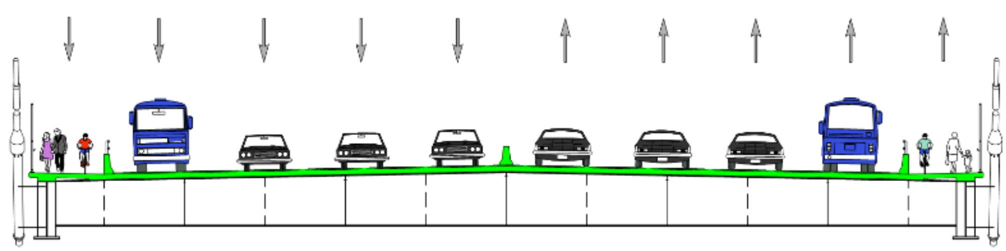


Figure 7 – Revised Eight-Lane Deck Section

The final span arrangement proposed for the bridge option was increased to 650 m to increase the clearance to the existing tunnel portals, to avoid the need for ground improvement in river and to stay clear of the dyke on the north side of the river and the river bank on the south side.

4 Key Considerations

The following key considerations represent important design parameters that have influenced the concepts presented for the bridge options.

4.1 Layout and Geometric Considerations

- Shipping Channel and Clearance Envelope

  The proposed bridge arrangements are based upon the navigation envelope which was required for the previous GMTR project. Figure 8 below shows the assumed navigation envelope.

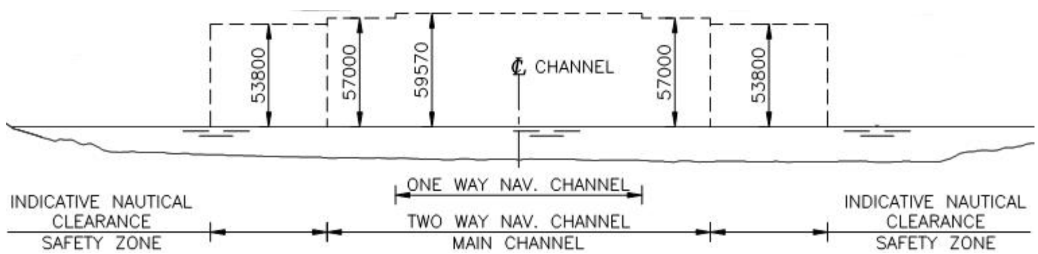


Figure 8 – Assumed Navigation Envelope

  This envelope has not been confirmed with the relevant authorities but is expected to be reasonably representative of the required clearances. Small changes in the envelope would not be expected to have a significant impact on the assessment of the bridge options, but if significant changes are required, it could impact the Steveston Highway interchange.

- Bridge to be Located Upstream of Existing Tunnel

  The location of the new bridge is to be upstream of the existing tunnel. The ability to construct the new bridge off the existing alignment is a significant benefit to the project. Work from the previous GMTR project clearly indicated that the risks and costs associated with constructing the replacement on the existing alignment of the tunnel are substantial.

  Several factors have contributed to the selection of the upstream alignment. The downstream alignment is in close proximity to BC Hydro lines currently in exitance. In addition, the property impacts are lower with an upstream alignment compared to a downstream one.

- Fraser River Bridge Main Span Arrangement

  The cable-stayed bridge option features a 650 m cable-stayed main span that crosses the Fraser River with a single clear span. The Independent Technical

Review indicated that construction cost of the main bridge could be reduced if the main span length is reduced and foundations placed in the river. However, a preliminary costing exercise has shown that the additional foundation costs associated with designing foundations in the river for significant vessel impact forces will not be offset by the corresponding reduction in superstructure cost associated with the span length reduction. The placement of foundations in the river would also have significant environmental implications that can be avoided by staying out of the river entirely.

- North Approach Span Arrangement

The north approach bridge comprises a nine-span steel composite girder bridge. The span arrangement of the bridge includes regular spans that are within the efficient range for a bridge of this type.

- South Approach Span Arrangement and Deas Slough Span

Two options are presented for the south approach bridge and Deas Slough span. Option 1, shown on drawing BR011, comprises an eight-span steel composite girder bridge. The irregular span arrangement is heavily governed by the presence of the 120 m span over Deas Slough. Piers either side of the Deas Slough crossing are located in-water near the shore of the Slough. Haunched steel girders are provided at these piers to allow the 120 m span crossing of the Slough. The need for the 120m span is similar to that of the previous GMTR project.

South approach bridge Option 2, shown on drawing BR012 and in Figure 9 below, includes a 380 m cable stayed bridge used to clear span Deas Slough. This span length was selected to prevent any in-water work; all structural works, including ground improvement, are located above the high-water level and outside of Deas Slough. Although more costly than south approach Option 1, this option is expected to have significant environmental benefits.

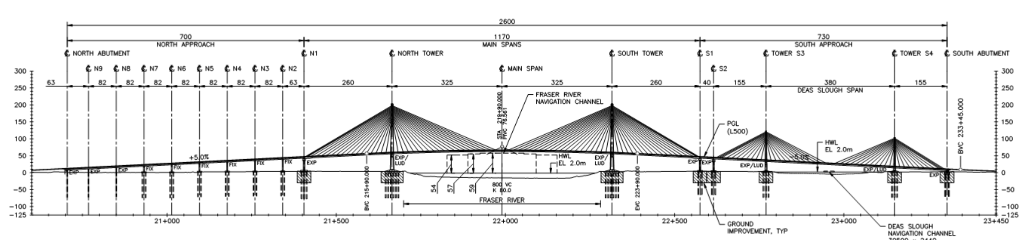


Figure 9 – Bridge Option 2 with Cable-stayed Bridge over Deas Slough

- MUP Width

  All options have 3.5 m wide MUP’s placed in board of the cables. If a wider MUP is preferred, the bridge width can be increased to accommodate this, with no significant impacts to the conclusions in this memo. Additionally, the MUP's can be placed outboard of the cables and integrated into the wind fairings, which is expected to improve the aerodynamic performance of the bridge.

4.2 Seismic and Geotechnical Considerations

Seismic and geotechnical considerations played an important role in the concept selected for the bridge options. The key considerations are summarized below.

- Foundation Type

  The concept presented includes large-diameter drilled shaft foundations for the main span and approach bridges. In addition to supporting the vertical load of the bridge, the drilled shafts resist significant lateral loads that occur during a seismic and wind event. During a seismic event, when liquefaction occurs, the drilled shafts are effectively unsupported over the depth of liquefied soil at the surface.

  Experience has shown that large diameter drilled shafts, in the order of 2.5 m diameter, represent an efficient foundation type for this bridge location.

- Ground Improvement

  The ground at the project site is prone to liquefaction during an earthquake. During a seismic event when the soil liquefies and loses its shear strength, soil near the banks of the Fraser River and Deas Slough will laterally spread towards the watercourses. Ground improvement is provided around the bridge foundations to arrest the lateral spread and stabilize and control the demands on the foundation. Further, ground improvement around all the pier and abutment foundations is required to provide axial resistance during and after soil liquefaction associated with all three levels of design earthquake motions (475, 975 and 2,475-year events) and their associated performance requirements.

- Seismic Devices

  Experience has shown that the careful selection and use of seismic devices which connect the main span superstructure to the towers can significantly reduce seismic demands on the main bridge and its foundations. The proposed bridge option would utilize seismic dampers connecting the superstructure to the towers to control seismic demands.

4.3 Bridge Superstructure Considerations

The following additional key considerations have significantly influenced the concepts presented for the six-lane and eight-lane bridge options.

› No cables above roadway and MUPs

Due to concerns associated with snow and ice falling from cables onto traffic below, and as noted on previous design criteria for cable-supported bridges in the province of BC, both the six-lane and eight-lane bridge concepts do not include stay-cables in the envelope above the roadway and multi-use paths. Figure 10 below shows the proposed arrangement of the main towers, deck and cables.

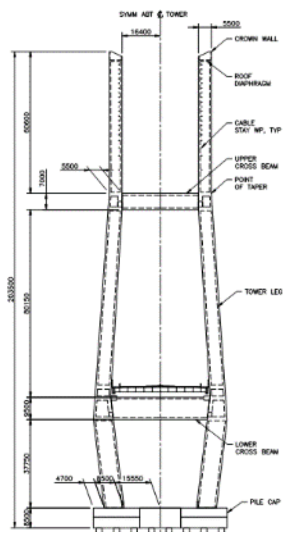


Figure 10- Main Towers

The tower arrangement shown permits the use of vertical cable planes which are located vertically outside of the travelled portion of the deck.

› Aerodynamic stability

For a long-span bridge of this magnitude, aerodynamic stability is an important consideration. Long-span bridges can be susceptible to flutter, especially if the bridge deck is narrow relative to its span length and the structure is relatively flexible torsionally.

For the eight-lane bridge option main span, preliminary estimates of aerodynamic performance show that it is likely that an open composite steel concrete superstructure can be utilized, provided that wind fairings and/or baffle plates are used to improve the aerodynamic performance. For the six-lane bridge option however, the reduced bridge width compared to the eight-lane option means that it is likely that a box girder superstructure will be required to provide the required torsional properties to maintain aerodynamic stability.

4.4 Environmental and Aesthetic Considerations

The following considerations represent important design parameters that have the potential to be included in the bridge option to provide environmental and aesthetic benefit.

› Inclusion of aesthetic features

Cable-stayed bridges are generally regarded as aesthetically pleasing structures that contribute positively to the appearance of a city or landscape. The simple, clear structural form and slender superstructure are often complemented by impressive bridge towers. However, additional aesthetic considerations may be warranted, especially to increase the visual appeal of the approach bridges and structural details. A 10% premium on the construction cost provides a reasonable estimate of the costs associated with incorporating features that will increase the visual appeal of the bridge.

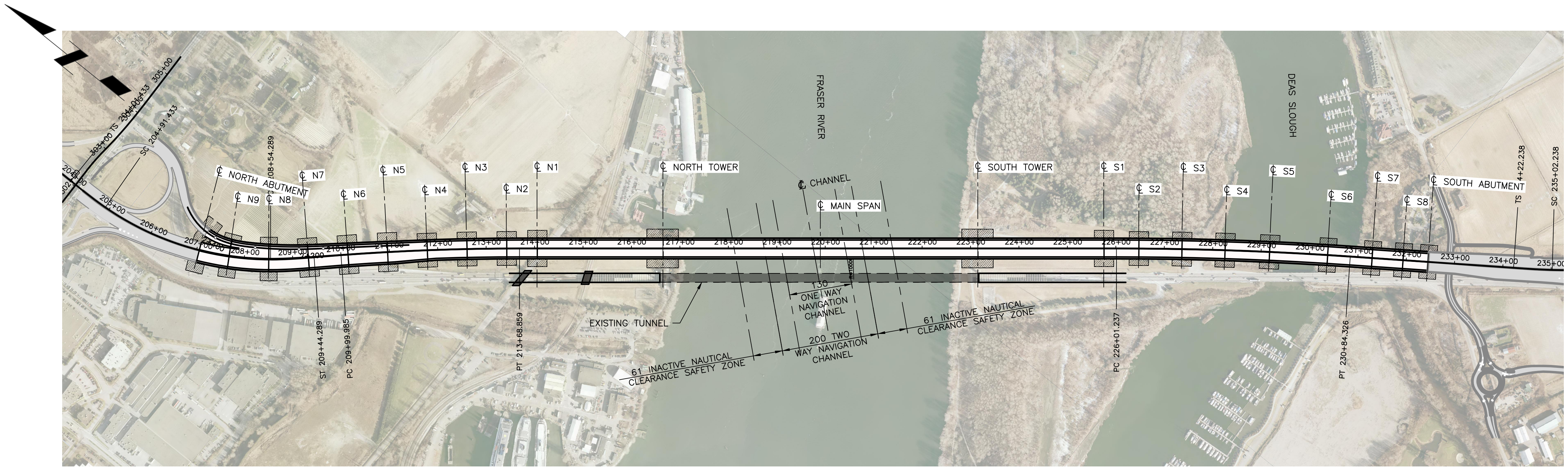
- Reducing shade from bridge on Deas Slough

For the bridge superstructure passing over Deas Slough with limited clearance, the shade provided by the wide bridge superstructure has the potential to limit fish movement under the bridge due to behavioural avoidance. If this is a concern, the continuous width of shaded bridge may be reduced by either incorporating discrete openings in the bridge deck at its centerline or splitting the northbound and southbound lanes into separate bridge decks with a gap between them.

5 Conclusions

The eight-lane cable stayed bridge option outlined above is a feasible and cost-effective solution for the crossing. The selected bridge type comprising an eight-lane composite deck cable stayed bridge is a very competitive bridge solution. The span arrangement keeps the works completely out of the Fraser River. Two options have been presented for the Deas Slough Crossing, a conventional haunched girder span option with piers in the Slough near the shoreline and a longer span cable stayed option which would keeps all the works completely out of the Slough.

Appendix A – Bridge Drawings



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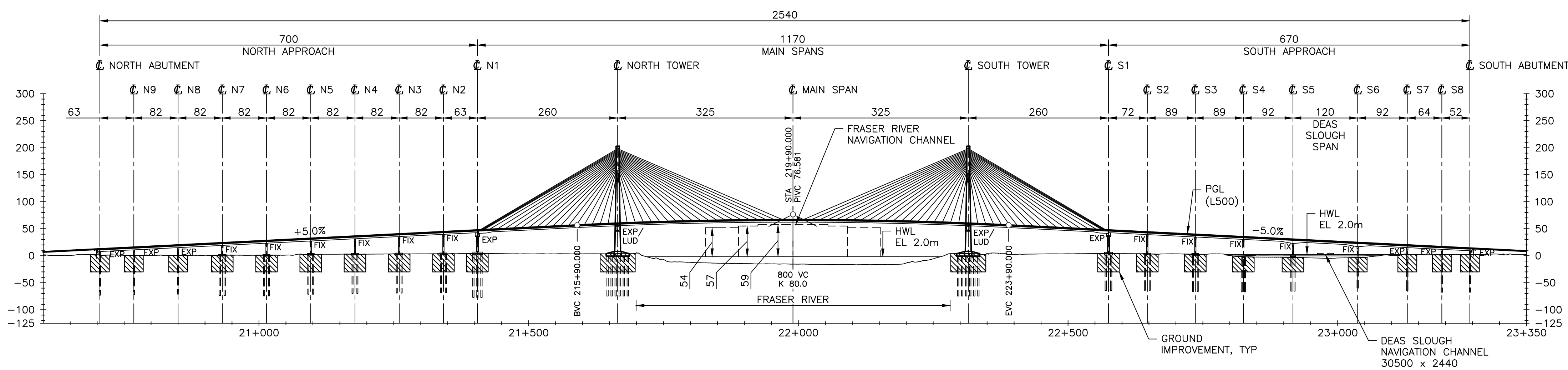

ELEVATION
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NOTES:

1. FOR TOWER AND PIER DETAILS, REFER TO SHEET STR-BR-102.
2. FOR TYPICAL MAIN SPAN AND APPROACH CROSS-SECTION, REFER TO SHEET STR-BR-103.
3. EXISTING DEAS SLOUGH RIVER BED LEVELS AND NAVIGATION CLEARANCE ENVELOPE BASED ON ORIGINAL BRIDGE DESIGN DRAWINGS. RIVER BED LEVELS AND REQUIRED NAVIGATION CLEARANCE TO BE CONFIRMED AT LATER PROJECT STAGES.

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BRITISH COLUMBIA
Ministry of Transportation & Infrastructure
South Coast Region

LOWER MAINLAND HIGHWAY DISTRICT
HIGHWAY 99

MASSEY CROSSING – BRIDGE OPTION 1 GENERAL ARRANGEMENT

PREPARED UNDER THE DIRECTION OF

ENGINEER OF RECORD

DATE

DESIGNED DWB DATE 2019-11-15
CHECKED DATE
DRAWN JNML/CRLS DATE 2019-11-15
SCALE AS SHOWN
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
1070-20	153CS1036	1	BR011	B

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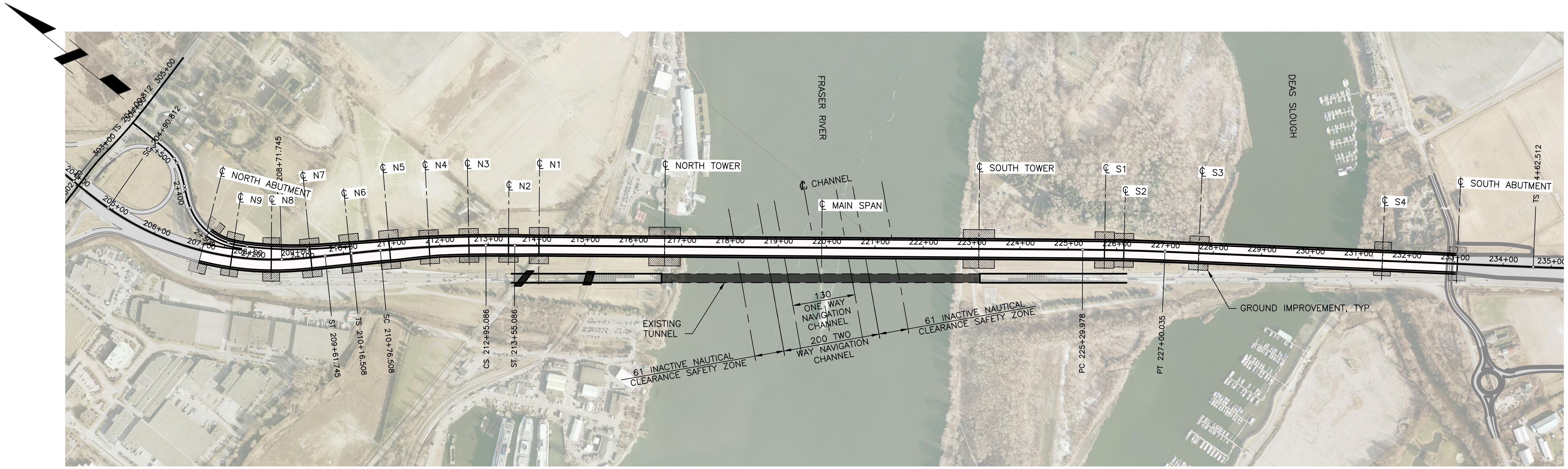

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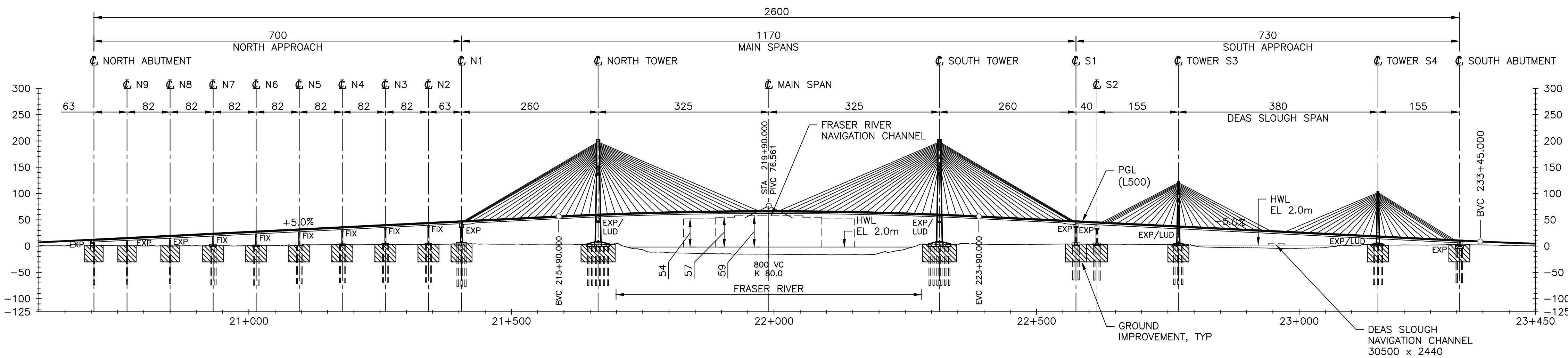

ELEVATION

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2. FOR TYPICAL MAIN SPAN AND APPROACH CROSS–SECTION, REFER TO SHEET STR–BR–103.
3. EXISTING DEAS SLOUGH RIVER BED LEVELS AND NAVIGATION CLEARANCE ENVELOPE BASED ON ORIGINAL BRIDGE DESIGN DRAWINGS. RIVER BED LEVELS AND REQUIRED NAVIGATION CLEARANCE TO BE CONFIRMED AT LATER PROJECT STAGES.

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REVISIONS

BRITISH COLUMBIA — Ministry of Transportation & Infrastructure, South Coast Region

LOWER MAINLAND HIGHWAY DISTRICT
HIGHWAY 99

MASSEY CROSSING – BRIDGE OPTION 2 GENERAL ARRANGEMENT

PREPARED UNDER THE DIRECTION OF

ENGINEER OF RECORD

DATE

DESIGNED DWB DATE 2019–11–15
CHECKED DATE
DRAWN JNML/CRLS DATE 2019–11–15
SCALE AS SHOWN
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
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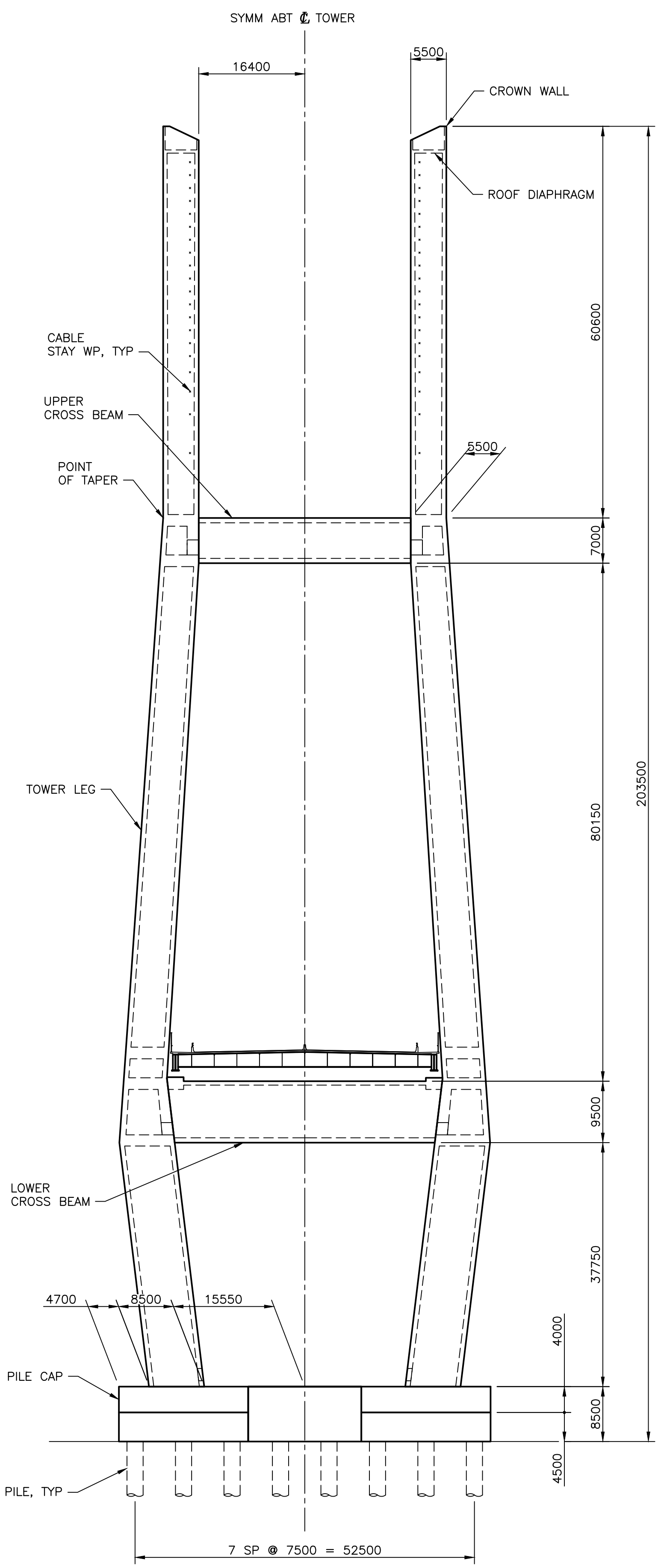

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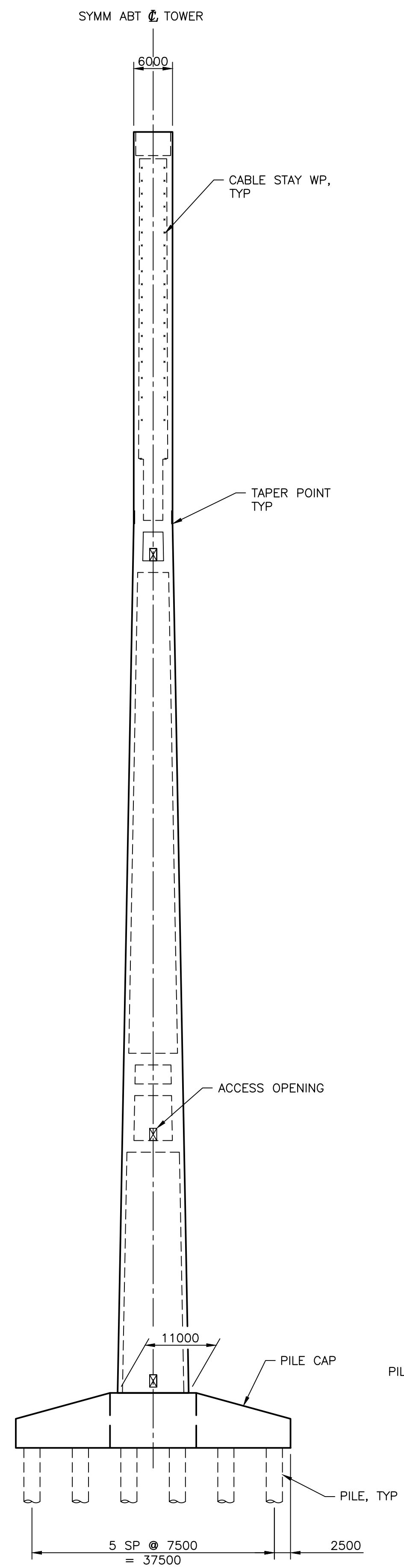

TOWER ELEVATION
FRASER RIVER BRIDGE
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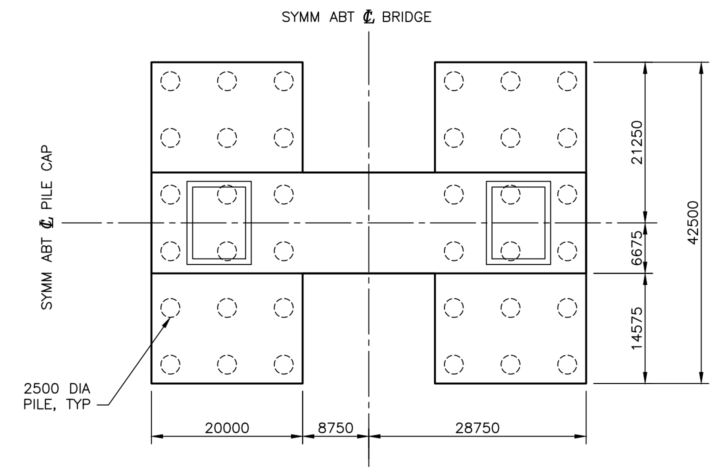

TOWER PILE CAP PLAN
FRASER RIVER BRIDGE
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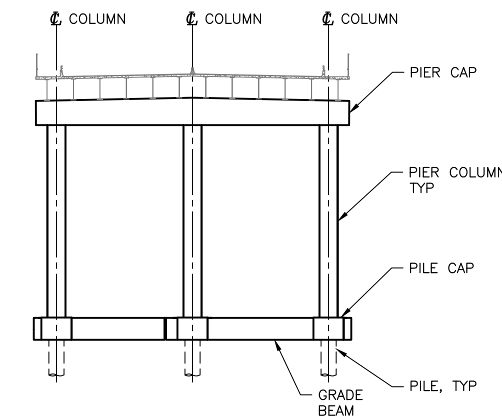

TYPICAL APPROACH PIER ELEVATION
MULTI-GIRDER APPROACH BRIDGES
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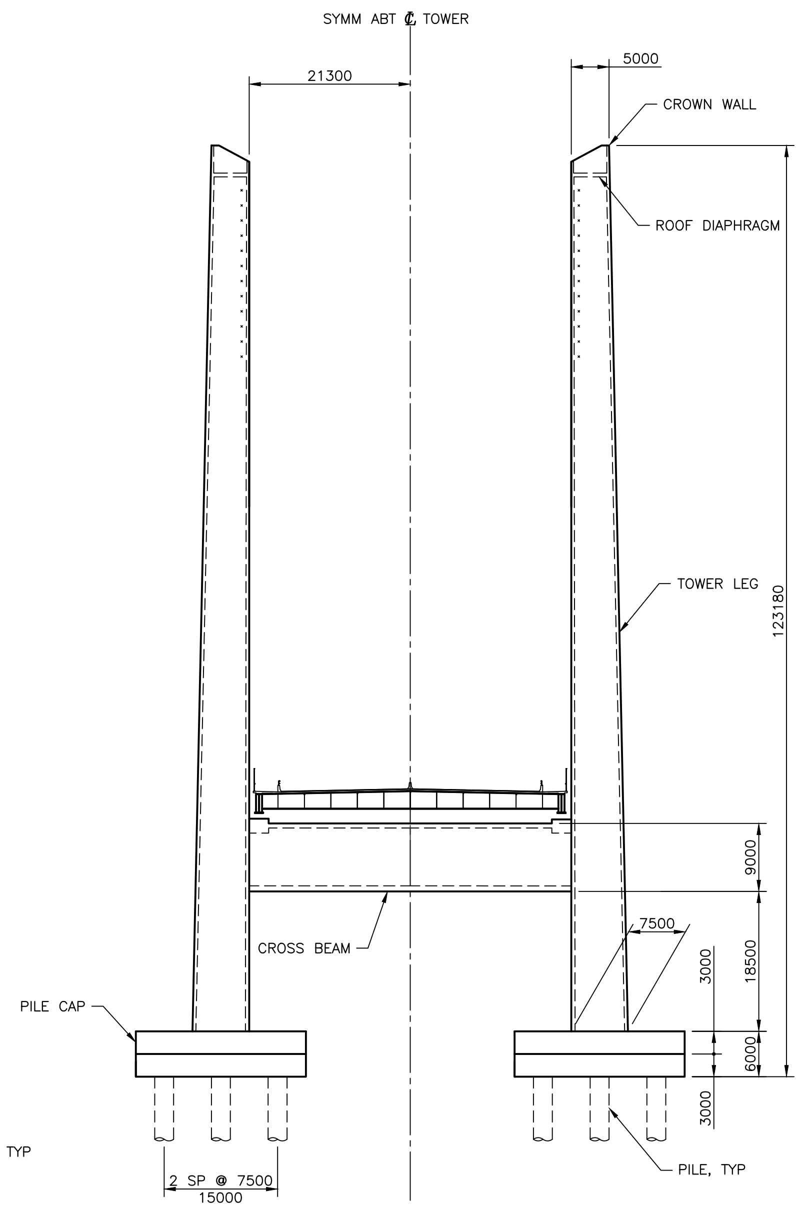

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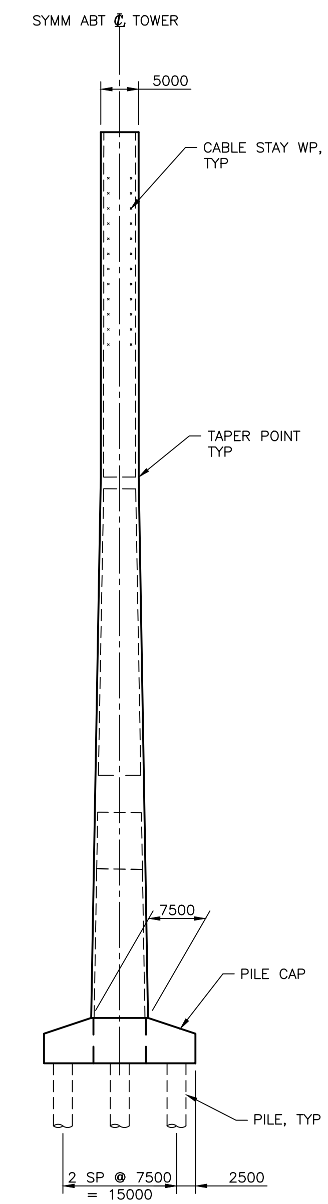

TOWER S3 ELEVATION
DEAS SLOUGH CABLE STAYED BRIDGE
SCALE 1:500

NOTES:

1. FRASER RIVER BRIDGE DETAILS AND TYPICAL APPROACH DETAILS ARE APPLICABLE TO BRIDGE OPTIONS 1 & 2. DEAS SLOUGH CABLE-STAYED BRIDGE DETAILS ARE APPLICABLE TO BRIDGE OPTION 2 ONLY.

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LOWER MAINLAND HIGHWAY DISTRICT
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MASSEY CROSSING – BRIDGE OPTION BRIDGE DETAILS

PREPARED UNDER THE DIRECTION OF
ENGINEER OF RECORD
DATE

DESIGNED DWB DATE 2019-11-15
CHECKED DATE
DRAWN JNML DATE 2019-11-15
SCALE AS SHOWN
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.	
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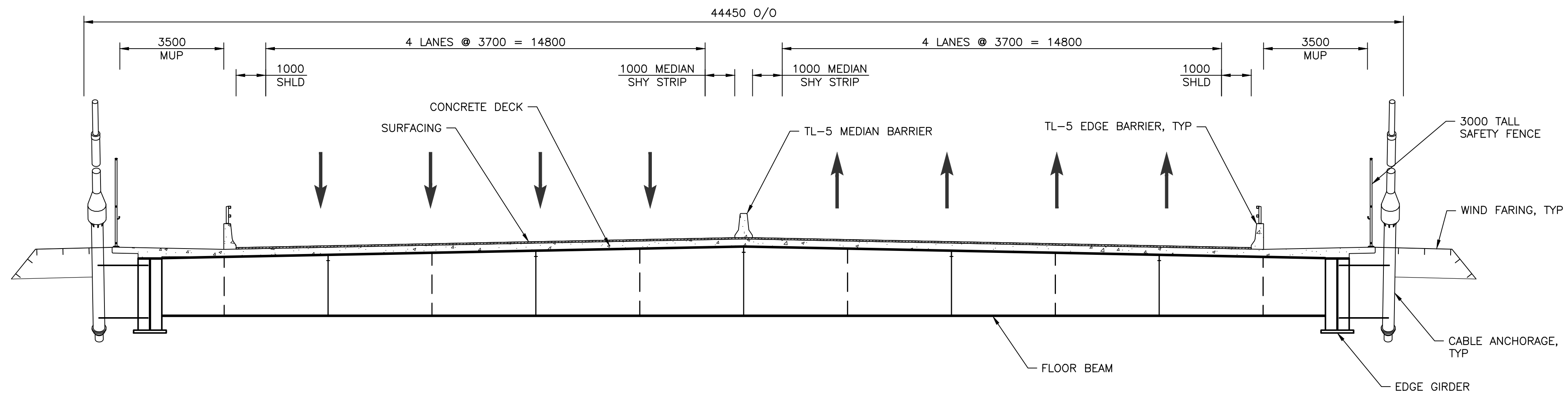

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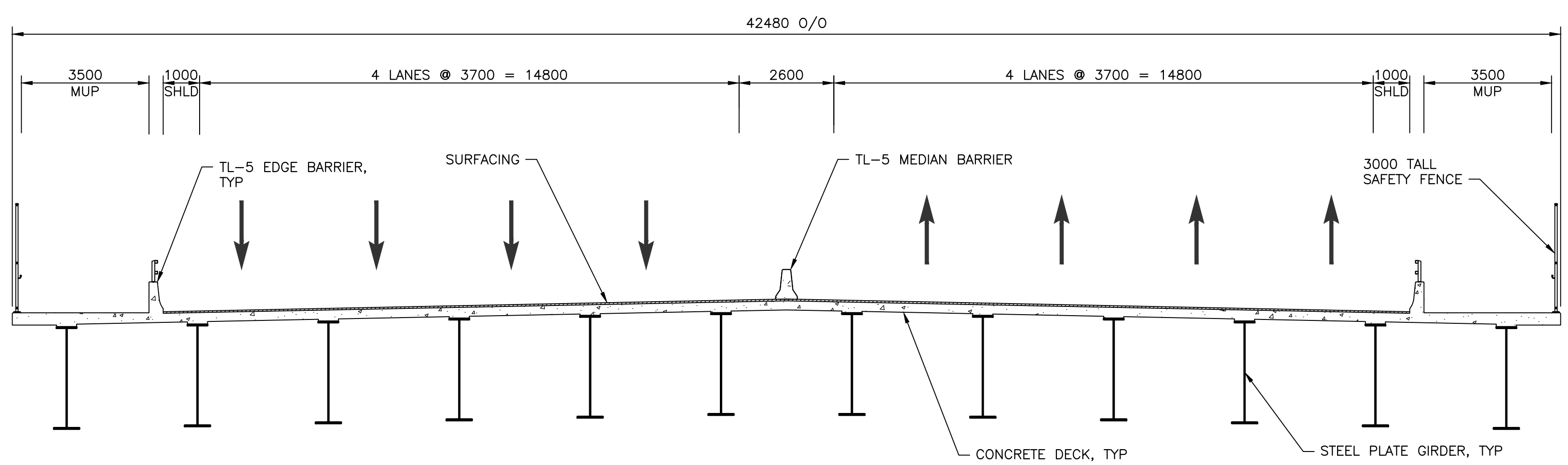

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BRITISH COLUMBIA | Ministry of Transportation & Infrastructure
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LOWER MAINLAND HIGHWAY DISTRICT
HIGHWAY 99

MASSEY CROSSING – BRIDGE OPTION
TYPICAL DECK CROSS SECTIONS

PREPARED UNDER THE DIRECTION OF

ENGINEER OF RECORD

DATE

DESIGNED DWB DATE 2019–11–15
CHECKED DATE
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SCALE AS SHOWN
NEGATIVE No.

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1070–20	153CS1036	1	BR103	A

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