MEMO

TO:	Mr. Bill Szto, P.Eng., Structural Liaison Manager, BC MOTI
FROM:	Michael Farnden, EIT, Designer, WSP Charles Chataway, P.Eng., Senior Project Engineer, WSP
SUBJECT	01287 Agassiz-Rosedale Bridge Steel and Concrete Repairs 12595-2020 Viaduct Column Encapsulation
DATE	January 29, 2021

The BC Ministry of Transportation and Infrastructure (the Ministry) has retained WSP to complete a design package for the rehabilitation of select components of the Agassiz-Rosedale Bridge. To determine the extents of the rehabilitation and assess the overall condition of the bridge, WSP performed a bridge inspection between April 22nd and 24th, 2020, to identify areas of deterioration to support development of a comprehensive rehabilitation program intended to address target elements. Based on the results of this inspection and communication with the Ministry, the major components of the rehabilitation will include:

- Replacement of all compression seals to address leaking joints;
- Concrete encapsulation of the approach expansion bent caps to repair and arrest ongoing deterioration;
- Repair of deteriorated steel truss members to restore structural integrity;
- Installation of drain troughs below finger joints to control runoff;
- Modifications to the truss deck drains to convey deck runoff to below superstructure elements, and;
- Select recoating of deteriorated steel elements located below expansion joints to restore the protective coating on these elements.

Another minor component of work initially considered for inclusion in the rehabilitation program was repair of select North Viaduct bent piles which were exhibiting significant cracking of the concrete jacketing. The North Viaduct bents consist of a concrete reinforced pile cap supported on six piles. The viaduct piles comprise steel H-piles surrounded by 635mm outside diameter pre-cast concrete pipe sections having a thickness of 64mm. Following installation, the annulus of the pipe section containing the H-pile was filled with concrete. Based on the as-built information, as shown in Figure 1, the concrete encasing the steel H-pile is unreinforced. The concrete pipe sections are similarly believed to be unreinforced. No details of the pipes are available.

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Figure 1: Viaduct Column As-built Information

The viaduct columns which where identified as having more extensive cracking in the precast concrete pipes are listed in Table 1. The piles located within the Cheam slough had the widest and most extensive cracking which is likely due to increased exposure to standing water and prolonged moist conditions.

Fiber Reinforced Polymer (FRP) wrapping and a corrugated steel pipe enclosure with grout infill were identified as possible repair options to prevent further damage and potential spalling of the precast concrete pipes. Crack injection is not deemed possible as the injected resin would likely flow in-between the precast concrete pipe and cast in place concrete surface which would prevent the crack from ever filling completely.

Table 1: North Viaduct Columns with Significant Cracking

NORTH VIADUCT BENT #	COLUMN # (1)	PHOTOS (2)
BENT 30 (CHEAM SLOUGH)	6	Figure 2
BENT 31 (CHEAM SLOUGH)	4, 5, 6	Figure 3
BENT 32 (CHEAM SLOUGH)	6	-
BENT 33 (CHEAM SLOUGH)	5	-
BENT 35 (CHEAM SLOUGH)	1, 2	Figure 4 & 5
BENT 55	1	Figure 6
BENT 70	1	Figure 7

(1) Columns are numbered east to west

(2) Figures attached to end of memo

With the progression of the design for the rehabilitation program, WSP has further reviewed the viaduct pile conditions and possible repair options and concluded that the columns do not need to be repaired. The consequences of the precast concrete pipes failing and spalling off are low risk as they do not contribute to the structural capacity of the pile and there is little risk to the public were a spall to occur - and a very low risk of the precast concrete pipes spalling to begin with. The cracks may lead to accelerated corrosion as they provide a pathway for moisture to reach the steel H-piles, however the cast-in-place concrete still provides varying degrees of cover and there was no evidence of the cracks having propagated to depth of the H-piles and similarly, no evidence of excessive corrosion of the H-piles.

The majority of the viaduct columns with significant cracks are located in Cheam Slough. To complete repair work within the wetted perimeter of the slough a Water Act permit would be required. The approval process for this permit is expected to take up to a year and would delay the delivery of the rehabilitation program.

Based on expected results of leaving the cracks as they currently are and the potential delay to the delivery of the project, WSP is recommending to not complete any repairs to address the cracking the viaduct column pre-cast encapsulation.

We trust that this memo provides the Ministry with the information required to determine if repairs to the North Viaduct columns should be included as part of the Agassiz-Rosedale Bridge rehabilitation program. If you have any questions regarding this memo, please contact the undersigned.

Yours truly,

WSP Canada Group Limited

Prepared By:	Reviewed By:
M. Farnden	
Michael Farnden, EIT Designer, Bridges	Charles Chataway, P.Eng. Senior Project Engineer, Bridges

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To:	Charles Chataway, WSP Canada Keith Holmes, WSP Canada	**Date:**	October 27, 2021
From:	Ben Park, Senior Estimator Ed Green, Director	**Memo No.:**	Agassiz-Rosedale Bridge 002

Subject: **Independent Engineer's Estimate Review - Agassiz-Rosedale Bridge No. 1287 Steel and Concrete Repairs Project – Highway 9, between Agassiz and Rosedale, BC.**

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Sincerely,

Ben Park, GSC

Senior Estimator

Charter Project Delivery Inc.

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Province of British Columbia

TOTAL TENDER PRICE AND ASSOCIATED MINISTRY COST ESTIMATES

Schedule of Approximate Quantities and Unit Prices

Project No: 12595-2021

Project Name: Agassiz - Rosedale Bridge No. 1287 Steel and Concrete Repairs

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TOTAL TENDER PRICE AND ASSOCIATED MINISTRY COST ESTIMATES

Schedule of Approximate Quantities and Unit Prices

Project No: 12595-2021

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To:	Charles Chataway, WSP Canada Keith Holmes, WSP Canada	**Date:**	March 24, 2021
From:	Ed Green, Director Ben Park, Senior Estimator Arturo Brosig, Cost Estimator	**Memo No.:**	Agassiz-Rosedale Bridge 001

Subject: **Independent Construction Cost Estimate - Agassiz-Rosedale Bridge No. 1287 Steel and Concrete Repairs Project – Highway 9, between Agassiz and Rosedale, BC.**

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REPORT

AGASSIZ-ROSEDALE BRIDGE

AGASSIZ, BRITISH COLUMBIA

WIND CLIMATE AND SITE EXPOSURE REPORT

RWDI #2200919

October 8, 2021

SUBMITTED TO

Keith Holmes, P.Eng.
Manager, Bridges (BC/Yukon)
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MEMO

TO: BC Ministry of Transportation and Infrastructure

FROM: WSP Canada Inc.

SUBJECT: **Agassiz-Rosedale Bridge – Deck Drainage**

DATE: **March 5, 2020**

INTRODUCTION

A deck drainage assessment was completed for the Agassiz-Rosedale bridge. The performance of the drainage system was assessed against the ponding width criterion of 1.2 m at the inlets as prescribed by the BC supplement to the CHBDC S6-14, plus 0.3 m to account for the shoulder width for a total of 1.5 m. The design storm event included increases in rainfall intensity to account for climate change effects for different scenarios as described herein. Clogging was not considered in the analysis as there has been no recorded issues of clogging at the bridge and the risk is considered to be low. The drainage study is limited to the river spans of the bridge.

GENERAL ANALYSIS PROCEDURE

Deck hydrology and inlet spacing analyses were based on the procedure outlined for bridges on a vertical curve in the Federal Highway Association's HEC-21, Design of Deck Drainage. The HEC-21 procedure solves for the optimal inlet spacings as a function of given allowable ponding width. For this project, the procedure was modified to solve for the ponding widths as a function of inlet locations.

CLIMAGE CHANGE

Broadly speaking, the local climate projections are divided into two different commonly used 'scenarios', or 'Representative Concentration Pathways (RCP)': the active scenario (RCP 4.5) and the passive scenario (RCP 8.5). The active scenario is modelled assuming that there is a significant decrease in global greenhouse gas (GHG) emissions from the 2040s, while the passive scenario has been designed by assuming the worst case 'business-as-usual' approach without any mitigation measures implemented at global scale and a constant increase in GHG emission until the depletion of fossil fuel stocks. For this study the RCP 8.5 projections scenario was used to generate conservative results. These projections were compared to the RCP 4.5 projections scenario as a check to ensure the more conservative of the two were taken. Climate science is still in development and the effects of climate change are highly regionalized, as such, it is important to consider available information in the context of the project location.

In terms of surface drainage design for the Agassiz-Rosedale bridge, climate change is anticipated to increase the frequency and intensity of rainfall events, especially in the winter. Additionally, the 2010 BCMoTI Coquihalla Climate Change Vulnerability Assessment in collaboration with the Pacific Climate Impacts Consortium (PCIC) identified that atmospheric river events like the "Pineapple Express" events have increased in intensity and frequency and are projected to moderately increase, with medium level of confidence. However, due to the lack of directly applicable storm-duration rainfall projections of climate change, a number of information sources were used to arrive at the recommended percentage increases. Reports for climate studies for nearby areas such as Metro Vancouver and the Coquihalla Highway were reviewed, as well as rainfall and projection information from PCIC, Western University and ECCC to produce a range of estimates. These were evaluated against EGBC and CSA guidelines to estimate the following recommended climate change percent increases to be applied to 5-minute 10-year return period design rainfall:

- Projection to 2040's (roughly 20 years) – 30%
- Projection to 2070's (roughly 50 years) – 60%

Refer to the attached "Design Criteria Sheet for Climate Change Resilience" for additional climate change and risk analysis information.

EXISTING INLET TYPE

The existing inlets are 0.18 m x 0.25 m (7” x 10”) undepressed rectangular inlets with parallel evenly spaced 38 mm (1-1/2”) bars for the grate. The down drain is 0.10 m x 0.10 m (4” x 4“) square which is assumed to not limit the inlet capacity. The locations of the existing inlets were taken from the record drawing. There are 3, 4 or 5 drains per span, with a drain immediately upstream of each finger joint.

DESIGN PARAMETERS

Design parameters used to assess the ponding width of the existing inlets are tabulated Table 1.

Table 1. Analysis parameters for computing ponding width at various inlet locations

PARAMETER	VALUE	COMMENT	SCOURCE
Allowable ponding width	1.5 m	0.3 m shoulder + 1.2 m onto traffic lane	BC Supplement to CHBDC S6-14 (Section 1.8.2.3.1)
Cross slope	0.01 m/m		Record drawing
Deck draining width	4.724 m		Record drawing
Deck Profile	Varies	Crest curve and grade	Record drawing
Design storm return period	1 in 10-years		BC Supplement to CHBDC S6-14 (Section 1.8.2.3.1)
Runoff coefficient	0.9		HEC-21 (Section 8.1)
Manning roughness for pavement	0.016 $s/m^{1/3}$	Roughness for asphalt surface	HEC-21 (Section 8.1)

DESIGN SCENARIOS

When considering deck drainage design several factors need to be taken into account including current conditions, climate change impacts, and future planning. It is understood that there is a plan to complete deck improvements in roughly 20 years, and that the expected remaining bridge life is in the range of 50 years. The bridge deck improvements, if completed, would include widening of the lanes on the bridge and potentially re-grading/increasing the cross slope of the deck to 2%. Both would have significant impacts to the deck drainage which would need to be reassessed and designed for at that time. Looking at the possibility of drainage improvements as part of the current rehabilitation project presents two possible scenarios, depending if the future deck rehabilitation is done:

Scenario 1 – Deck drainage will be improved in conjunction with future deck rehabilitation in roughly 20 years and the current deck drainage will be in place until that time. Climate change increases for that relatively short-term projection are estimated to be no more than 30%.

Scenario 2 – The future deck rehabilitation is not done in which case deck drainage improvements done now may need to serve the remaining 50-year life of the bridge. Climate change increases for the 2070s are estimated to be 60%.

INLET LOCATIONS AND PERFORMANCE

Performance of the existing inlet spacing/location on the bridge deck was assessed for scenarios 1 and 2 as described above, based on the corresponding ponding width at the inlets. Results of the analysis are visualized in Figure 1.

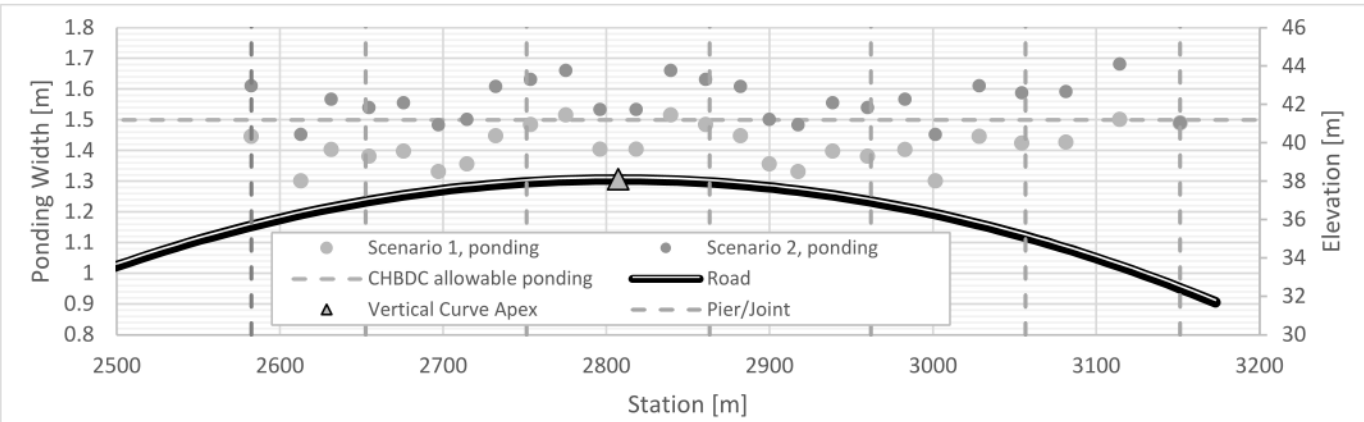

Figure 1. Computed ponding width at inlets

CONCLUSION

The following conclusions have been drawn from the analysis:

Scenario 1 – Deck drainage improvements in conjunction with future deck rehabilitation in roughly 20 years and 30% climate change factor.

- The existing drains are adequate to limit the inlet ponding effectively within the 1.5 m criterion.
- There is low risk of ponding significantly exceeding the criterion in this case if there are no deck drainage improvements done at this time.

Scenario 2 – No deck drainage improvement with deck remaining service life of 50-years and 60% climate change factor.

- The existing drains are not adequate to limit ponding within the 1.5 m criterion. The resulting ponding along the bridge deck ranges from 1.30 m to 1.68 m with 28 of the 60 inlets underperforming at the projected flows in 50 years. The maximum ponding width over the length of the bridge is 0.18 m over the 1.5 m criterion.
- Risk to public safety associated with this scenario is considered to be low for the following reasons:
  - Moderate traffic speed on the bridge (80 km/h) makes ponding less hazardous in terms of potential hydroplaning compared to major highways using the same design criteria.
  - The climate change factor of 60% is considered to be on the high side of projected values.

Improving drainage at this time may not be justified given that Scenario 1 effectively meets the design criteria and that the occurrence of the worse-case scenario (Scenario 2) is associated with relatively low risks including climatic uncertainties. For these reasons additional inlets have not been included in the current design.

At this stage it may be most economical to employ proper and regular inspection and maintenance of the inlets during the service life of the bridge. The Observational Method design approach as described in EGBC's professional practice guidelines for climate-resilient highway infrastructure (2020) may also be used to reduce risk. This involves a monitoring program to determine the drainage performance of the bridge deck, and implementation of a plan to modify the design in response to observed climate changes in the future. The overall objective of this approach is to achieve greater economy without compromising safety.

Prepared by: Reviewed by:

Sho Harada, E.I.T.
Hydrotechnical E.I.T.

Kevin Henshaw
Senior Hydrotechnical Engineer

CLIMATE CHANGE RISK ASSESSMENT ASSURANCE STATEMENT

Note: This statement is to be read and completed in conjunction with the Highway Infrastructure Climate Change-Resilient Design Report outlined in the *Professional Practice Guidelines – Developing Climate Change-Resilient Designs for Highway Infrastructure in British Columbia* ("the guidelines").

This Assurance Statement is to be provided when a Climate Change Risk Assessment has been completed for the purpose of retrofitting existing Highway Infrastructure or informing the design process for new infrastructure, as required by the British Columbia (BC) Ministry of Transportation and Infrastructure (BCMoTI). Defined terms are capitalized and underlined; see the **Defined Terms** section in the guidelines for definitions.

Note that this Assurance Statement provides assurance that the professional has followed the guidelines, and does not guarantee that a specific design will perform without any issues under future climate conditions.

To: BC Ministry of Transportation and Infrastructure
(or other BC Municipality)

Date: March 10, 2021

Suite 310-1500 Woolridge Street

Coquitlam, BC V3K 0B8

Jurisdiction and address

With reference to (CHECK ONE):

- ☐ New design
- ☒ Retrofit
- ☐ Other (specify) ___________________________

For the Highway Infrastructure:

MOTI Structure ID: 1287, Coordinates: 589,099m E, 5,451,051m N (10U)

Legal description and GPS coordinates of the infrastructure

The undersigned hereby gives assurance that the attached Climate Change Risk Assessment reporting on the above-mentioned infrastructure substantially complies with the intent of the guidelines. The Highway Infrastructure Climate Change Resilient Design Report and the BCMoTI Design Criteria Sheet for Climate Change Resilience[1] must be read in conjunction with this statement.

[1] Technical Circular T-04/19, Climate Change and Extreme Weather Event Preparedness and Resilience in Engineering Infrastructure Design (BCMoTI 2019), identifies implications of climate change and extreme weather events for engineering project infrastructure components. The Design Criteria Sheet for Climate Change Resilience, which is part of the Technical Circular, lists infrastructure components impacted by climate change and extreme weather events and provides the Adaptation Measures included in the infrastructure design.

(Items in **BOLD** below indicate the minimum level of effort to be expended by the Qualified Professional in conducting the Climate Change Risk Assessment.)

In preparing the Highway Infrastructure Climate Change Resilient Design Report I have:

(CHECK TO THE LEFT OF APPLICABLE ITEMS)

X 1. **Collected and reviewed appropriate background information, including service life of the infrastructure**

X 2. **Reviewed the proposed or existing infrastructure development on the project**

___3. Conducted field work and reported on the results of the field work on and, if required, beyond the project

X 4. **Assembled a qualified team in collaboration with the Owner**

___5. Considered any changed conditions on and, if required, beyond the project

6. For the Climate Change Risk Assessment, I have:
   - X 6.1 **Reviewed and characterized, if appropriate, future climate and extreme weather event projections and analyses**
   - ___6.2 Worked with a climate data provider to obtain relevant future climate and extreme weather event projections
   - X 6.3 **Estimated the risk to the infrastructure using a BCMoTI/other Owner-acceptable risk screening analysis (such as the PIEVC Protocol)**
   - X 6.4 Included (if appropriate) the effects of climate change and land-use change
   - X 6.5 Identified existing and anticipated future components at risk on and, if required, beyond the project
   - ___6.6 Estimated the potential consequences to those components at risk

7. Where the BCMoTI has specified a specific level of Climate Risk Tolerance that is different from the standard design criteria, I have:
   - X 7.1 Compared the level of Climate Risk Tolerance adopted by the BCMoTI/other Owner with the findings of my investigation
   - ___7.2 Made a finding on the level of Climate Risk Tolerance on the infrastructure based on the comparison
   - X 7.3 Made recommendations to reduce the risk on the infrastructure

8. Where the BCMoTI has not specified a level of Climate Risk Tolerance, I have:
   - ___8.1 Described the method of risk assessment used
   - ___8.2 Described the assumptions used in arriving at climate projections
   - ___8.3 Where available, referred to an appropriate and identified provincial or national resource for level of risk
   - ___8.4 Compared the guidelines with the findings of my investigation
   - ___8.5 Made a finding on the level of Climate Risk Tolerance for the infrastructure based on the comparison
   - ___8.6 Made recommendations to reduce risks

X 9. Reported on the requirements for future inspections of the infrastructure and recommended who should conduct those inspections

___10. Suggested an operations and maintenance schedule to ensure that climate resilience and operational liability are addressed

Based on my comparison between:

(CHECK ONE):

- [X] The findings from the investigation and the adopted level of Climate Risk Tolerance (item 7 above); or
- ☐ The appropriate and identified provincial or national guideline for level of Climate Risk Tolerance (item 8 above)

I hereby give my assurance that the standard of practice established in the guidelines has been applied in conducting the Climate Change Risk Assessment, documenting the results in the Highway infrastructure Climate Change Resilient Design Report, and informing the design of the Highway Infrastructure.

I certify that I am a Qualified Professional as defined in the guidelines.

s.22

Name (print)

March 16, 2021

Date

s.22

Signature

s.22

Address

s.22

Telephone

s.22

Email

(Affix PROFESSIONAL SEAL here)

If the Qualified Professional is a member of a firm, complete the following:

I am a member of the firm s.22

(Name of firm)

and I sign this letter on behalf of the firm.

Design Criteria Sheet for Climate Change Resilience

Highway Infrastructure Engineering Design and Climate Change Adaptation
BC Ministry of Transportation and Infrastructure
(Separate Criteria Sheet per Discipline)
(Submit all sheets to the Chief Engineers Office at:
BCMoTI-ChiefEngineersOffice@gov.bc.ca)

Project: *Agassiz-Rosedale Bridge No. 1287*
Type of work: *Highway Surface Drainage*
Location: Agassiz-Rosedale Bridge on Highway 3 in Manning Park
Discipline: *Hydrotechnical*

Design Component	Design Life or Return Period	Design Criteria + (Units)	Design Value Without Climate Change	Change in Design Value from Future Climate	Design Value Including Climate Change	Adaptation Cost Estimate ($)	Comments / Notes / Deviations / Variances
Roadway Surface Drainage	10 yr. RP	5-Minute Short-Duration Rainfall Intensity (mm/h)	48	2040's: +30%	63	$0	Projections applied to Agassiz, BC short-duration rainfall data. Two scenarios are listed: the 2040's to represent potential deck upgrade timeline, and the 2070's to represent a performance-based monitoring scenario.
				2070's: +60%	77	-	
	-	Temperature	-	-	-	-	Temperature increase is anticipated to be the driver for more frequent, more intense rainfall. Projected temperature changes are generally warming, but may lead to increased freeze-thaw cycles.
	-	Snowfall	-	-	-	-	Projected precipitation as snowfall is not anticipated to directly affect highway surface drainage design, as it is somewhat accounted for by warming temps and increased rainfall.
	-	Wind	-	-	-	-	Wind is not anticipated to directly affect highway surface drainage design.
	-	Sea Level	-	-	-	-	Due to the Project's high elevation, sea level rise is not a design consideration.

Explanatory Notes / Discussion:

Design Criteria

This Design Criteria Sheet is limited to bridge surface drainage design, only applying to pavement drainage and its associated design. The information below provides a summary of the climate change study, which follows the professional practice guidance from EGBC on climate change-resilient highway infrastructure (2020).

The drainage design criteria for the project are based on the principles outlined in the British Columbia Ministry of Transportation and Infrastructure (BCMoTI) Supplement to TAC Geometrics Design Guide – 1000 Hydraulics Chapter. The highway surface drainage design methodology was assessed by comparing the 1.2 m criteria prescribed by the BC supplement to the CHBDC S6-14, plus 0.3 m to account for the shoulder width for a total of 1.5 m. This information is detailed in the WSP Deck Drainage memo (2021). The bridge deck design was assessed using guidance from the Federal Highway Association's HEC-21, Design of Deck Drainage, which derives its results from input IDF rainfall data.

The Environment and Climate Change Canada (ECCC) meteorological station at Agassiz, BC was used as the baseline data to characterize the design rainfall intensity in this study. The Agassiz CS (ID: 1113540) IDF curves draw from 23 years of data between 1955-1994. The meteorological station is located at 19 masl, which is directly applicable to the Project.

Projection Timelines

The bridge is aging, having been built in 1956 and there is a tentative plan for deck rehabilitation within the approximate 50 year remaining life of the bridge. It is understood that there is the potential for overall bridge deck improvements in roughly 20 years (the 2040's). The bridge deck improvements, if completed, would include widening of the lanes on the bridge and also potentially re-grading/improving the cross slope of the deck. There are therefore two scenarios to projection periods and risk to consider in this analysis:

- 2040's (2031-2060): Deck drainage will be improved in conjunction with future deck rehabilitation within the next roughly 20 years, and the current deck drainage system will be in place until that time. The deck drainage rehabilitation would require a reassessment for the service life of the new design. The 2040's may also bring better consensus on climate change projections.
- 2070's (2061-2090): This scenario assumed future deck rehabilitation is not completed, in which case bridge deck drainage may not be addressed again for the remaining life of the bridge.

Climate Parameters and Projections

In accordance with BCMoTI Climate Change Technical Circular T-04/19, the potential impacts of future climate change need to be considered on all Ministry projects. Broadly speaking, the local climate projections are divided into two different commonly used 'scenarios', or 'Representative Concentration Pathways (RCP)': the active scenario (RCP 4.5) and the passive scenario (RCP 8.5). The active scenario is modelled assuming that there is a significant decrease in global greenhouse gas (GHG) emissions from the 2040s, while the passive scenario has been designed by assuming the worst case 'business-as-usual' approach without any mitigation measures implemented at global scale and a constant increase in GHG emission until the depletion of fossil fuel stocks. For this study the RCP 8.5 projections scenario was used to generate conservative results. These projections were compared to the RCP 4.5 projections scenario as a check to ensure the more conservative of the two were taken. Climate science is still in development and the effects of climate change are highly regionalized, as such, it is important to consider available information in the context of the project location.

In terms of surface drainage design for the Agassiz-Rosedale bridge, climate change is anticipated to increase the frequency and intensity of rainfall events, especially in the winter. Additionally, the 2010 BCMoTI Coquihalla Climate Change Vulnerability Assessment in collaboration with the Pacific Climate Impacts Consortium (PCIC) identified that atmospheric river events like the "Pineapple Express" events have increased in intensity and frequency and are projected to moderately increase, with medium level of confidence, however, due to the lack of directly applicable storm-duration rainfall projections of climate change, a number of information sources were used to arrive at the prescribed percentage increases.

With respect to the 2070's (2061-2090 Scenario):

- Engineers and Geoscientists of British Columbia (EGBC) Professional Practice Guidelines: Legislated Flood Assessments in a Changing Climate in BC (August 2018) recommends an increase in event magnitude by 20% for small drainages for which available information is inadequate to provide reliable guidance.

- BCMoTI Coquihalla climate change vulnerability assessment (2010) identified that atmospheric river events like the "Pineapple Express" events have increased in intensity and frequency, and are projected to moderately increase, with medium level of confidence from PCIC.

- The PCIC report (2018) projects that in Metro Vancouver wetter winters and drier summers will be more common (i.e. more extreme weather). The wettest single day of the year may see 32% more rainfall by the 2080s in Metro Vancouver. The 1 in 20 wettest day is expected to be 60% more than baseline at "high" elevations like Pitt Lake. The Metro Vancouver report does not extend up to Agassiz, BC where the impact may be less pronounced as storms lose their energy moving up the Fraser Valley. The report additionally does not prescribe increases for sub-hourly storm durations.

- The GHD report (2018) also projects wetter winters and drier summers in Metro Vancouver. **Rainfall Zone 2: Langley Township projections indicate a percent increase between 49% in 2050 and 76% in 2100 for 10-year return period, 5-minute duration rainfall under "large change" projections. The Langley Township is approximately 60 km from Agassiz, and storms generally track from the west coast toward Agassiz, losing energy as they go.**

- PCIC have developed regional projections on a seasonal basis, available through their Plan2Adapt tool (https://www.pacificclimate.org/analysis-tools/plan2adapt), which are presented in the screenshot below. Their seasonal values vary substantially, but PCIC projects that in the 2080s for the Fraser Valley, winter seasonal precipitation may increase 14% at the 90th percentile, and there may be much less precipitation as snow (up to 89% less, but these numbers can be deceptive if snowfall is already low). Seasonal projections do not translate well to short-duration projections, however, PCIC projects increased runoff and potential for flooding suggesting more intense short-duration precipitation. They also warn that stormwater design standards may no longer be adequate. The median results, showing much less summer precipitation and more winter precipitation, with an annual increase overall, do suggest that winter precipitation could become more intense.

Climate Variable	Season	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Temperature (°C)	Annual	+5.1 °C	+3.7 °C to +6.8 °C
Precipitation (%)	Annual	+3.1%	-5.5% to +9.0%
	Summer	-22%	-60% to -2.0%
	Winter	+3.8%	-4.5% to +14%
Precipitation as Snow* (%) *CAUTION: This variable may have a low baseline. See note 2 below.*	Annual	-69%	-75% to -55%
	Winter	-64%	-70% to -51%
	Spring	-82%	-89% to -64%
Growing Degree-Days* (degree-days)	Annual	+1110 degree-days	+749 to +1600 degree-days
Heating Degree-Days* (degree-days)	Annual	-1640 degree-days	-2050 to -1240 degree-days
Frost-Free Days* (days)	Annual	+92 days	+71 to +110 days

Notes:

1. Climate variables marked with * are derived from temperature and/or precipitation values, and are not direct outputs of the climate models.
2. CAUTION: Percent changes from a low baseline value can result in deceptively large percent change values. A small baseline can occur when the season and/or region together naturally make for zero or near-zero values. For example, snowfall in summer in low-lying southern areas.

Figure 1: 2080s Climate Change Projections for the Fraser Valley Region (PCIC)

- Canadian Standards Association (CSA) Plus 4013:19, Section 6.3.4.9 suggests the use of a simples increase factor using the Clausius-Clapeyron (CC) relation. Using Environment Canada temperature data available for Agassiz from ECCC (https://climatedata.ca/), a median temperature increase of 1.8 ºC was projected to 2060 and 3.9 ºC to 2100. It should be noted that the spread of temperatures given for 2100 is substantial. Median values were therefore chosen, rather than the 90th percentile results. The guideline recommends an increase of 7% rainfall intensity per 1 ºC in warming (i.e. CC = 1.07), but the GHD report

(2018) suggests a higher coefficient for sub-hourly rainfall (i.e. CC = 1.14 according to Figure 2 below for sub-daily rainfall intensity). **An increase of 27% in precipitation for the 2040s and 67% for the 2070s was projected using the CC Relation and the increased coefficient.** It was noted that the results are highly sensitive to the CC coefficient.

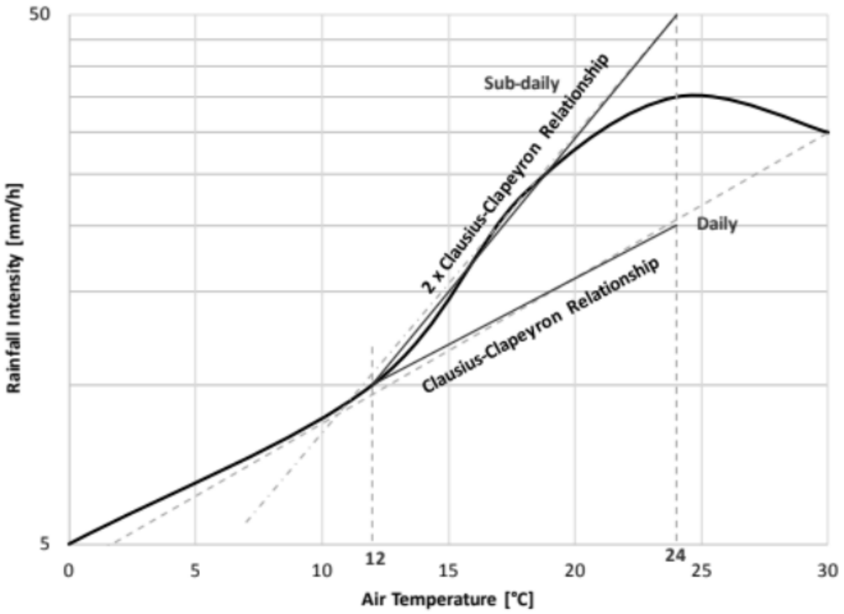

Figure 2: Calusius-Clapeyron Relationship between Rainfall Intensity and Air Temperature (GHD, 2018)

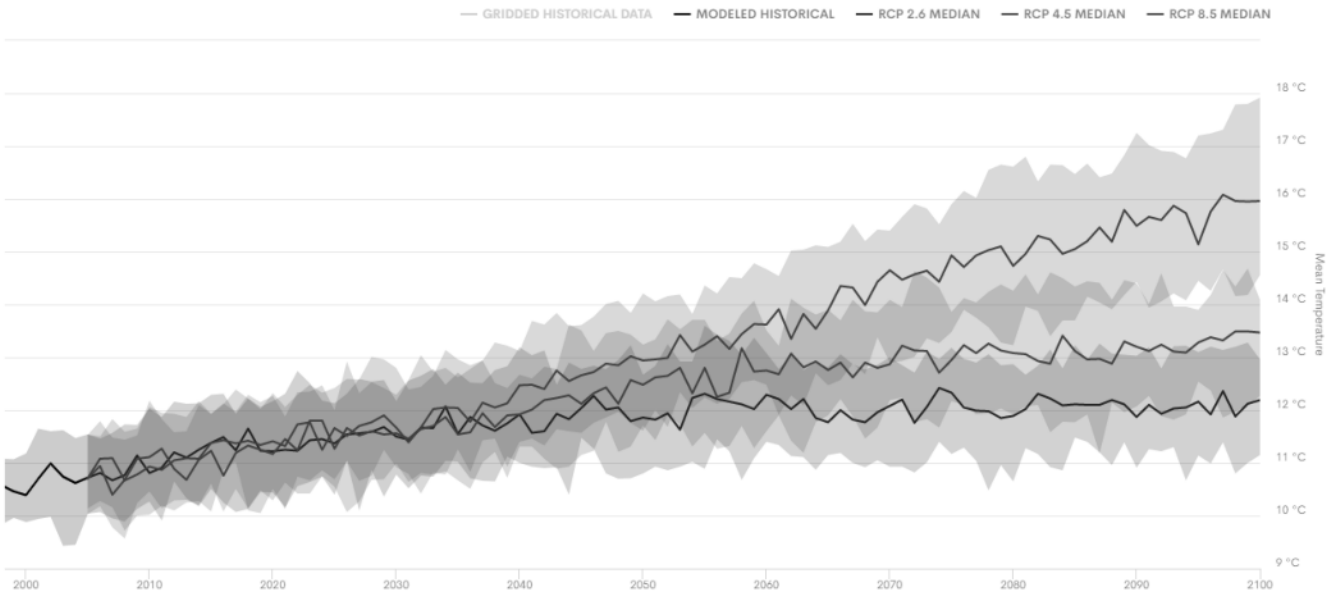

Figure 3: Projected Temperature for Agassiz, BC (ECCC)

- IDF_CC, a tool developed by Western University (https://www.idf-cc-uwo.ca/idfstation) generates historical and projected rainfall IDF summaries from ECCC meteorological stations. Using the Agassiz CS IDF station (ID: 1100119), the resulting climate change increases correspond to median values, and not extremes, as the IDF curves already present extreme rainfall. **According to IDF_CC, by the 2040s, 5-minute, 10-year return period rainfall may increase 8%, and 17% in the 2070s.**

T (years)	2	5	10	20	25	50	100
5 min	32.26	41.99	48.43	54.61	56.57	62.61	68.60
10 min	24.86	31.72	36.26	40.62	42.00	46.25	50.48
15 min	20.59	24.99	27.90	30.70	31.58	34.31	37.02
30 min	14.57	17.62	19.63	21.56	22.17	24.06	25.93
1 h	10.89	13.20	14.72	16.18	16.65	18.08	19.49
2 h	8.29	9.56	10.40	11.20	11.46	12.25	13.03
6 h	5.46	6.25	6.77	7.27	7.43	7.92	8.41
12 h	4.22	4.95	5.42	5.88	6.03	6.48	6.92
24 h	3.10	3.81	4.29	4.75	4.89	5.34	5.78

Figure 4: Historical IDF for Agassiz CS (IDF_CC)

T (years)	2	5	10	20	25	50	100
5 min	33.58	43.82	52.42	60.25	63.80	75.57	89.37
10 min	26.19	33.81	39.57	45.20	47.44	55.15	63.28
15 min	22.12	27.50	30.91	34.24	35.42	39.51	43.54
30 min	16.19	20.14	22.14	23.84	24.45	26.03	27.09
1 h	11.90	14.91	16.56	18.15	18.67	20.31	21.65
2 h	9.07	10.79	11.64	12.46	12.74	13.55	14.11
6 h	6.03	7.08	7.56	7.97	8.12	8.50	8.73
12 h	4.59	5.54	6.06	6.58	6.75	7.30	7.76
24 h	3.35	4.26	4.79	5.33	5.50	6.09	6.64

Figure 5: Projected IDF for Agassiz CS in the 2040s (IDF_CC)

T (years)	2	5	10	20	25	50	100
5 min	36.43	47.08	56.75	68.41	73.62	87.63	101.45
10 min	28.39	36.38	43.28	51.53	55.08	64.04	72.85
15 min	23.99	29.64	34.13	39.27	41.31	46.05	50.89
30 min	17.50	21.87	24.60	27.63	28.37	30.27	32.04
1 h	12.90	16.11	18.46	21.06	21.75	23.69	25.57
2 h	9.85	11.69	12.96	14.35	14.79	15.78	16.69
6 h	6.55	7.68	8.40	9.21	9.41	9.88	10.30
12 h	4.98	5.98	6.73	7.55	7.85	8.52	9.15
24 h	3.63	4.60	5.34	6.17	6.41	7.12	7.82

Figure 6: Projected IDF for Agassiz CS in the 2070s (IDF_CC)

Considering the information discussed above and their applicability to the location and scope of the study, prescribed increases to the 5-minute, 10-year return period rainfall were developed:

- **For the 2040's (2031-2060) projection window, a rainfall depth increase of 30%** is anticipated, which extrapolates the information presented for Langley Township in the year 2050 in the GHD Metro Van climate change report (2018), and also considers results from IDF_CC for the Agassiz climate station, and from the CC-Relationship using ECCC temperature projections for Agassiz.
- **For the 2070's (2061-2090) projection window, a rainfall depth increase of 60%** is recommended, which interpolates the information presented for Langley Township in the year 2050 and 2100 in the GHD Metro Van climate change report (2018), and also considers results from IDF_CC for the Agassiz climate station, and from the CC-Relationship using ECCC temperature projections for Agassiz.

Risk Assessment:

For the purposes of this assessment, risk is defined as "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity". The goal of the risk assessment is to identify climate- and weather-related risks that the project is likely to be vulnerable and considers the exposure of the design components to extreme weather and climate change. Each identified impact has been classified based on sensitivity and adaptive capacity, which measures the ability to mitigate risk through adaptive measures. Using the professional practice guidance for highway infrastructure design (EGBC, 2020), a vulnerability score was assigned for each impact based on a matrix which multiplies the sensitivity to each climate change impact with the adaptive capacity. These establish a risk profile and provide a structure for decision making after the assessment is complete. Climate change vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change. Vulnerability is the factor of sensitivity and adaptive capacity of each infrastructure component and/or system.

- **Sensitivity** is the degree to which a component is affected by climatic conditions or a specific climate change impact.
- **Adaptive capacity** is the ability of a system to adjust to climate change (including climate variability and extremes) to avoid potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptive capacity can reduce the vulnerability of infrastructure to a potential impact. This can be achieved by incorporating future climate projections into design criteria to enable infrastructure to adapt to a changing climate. Adaptive capacity can also be achieved by adjusting operations and maintenance procedures to adapt to a changing climate.

The ratings used to assess sensitivity and adaptive capacity have five distinct levels (very low, low, moderate, high, and very high), and correspond to the definitions detailed in the following table. As shown in the following table, adaptive capacity ratings are inversely proportional to the level of vulnerability.

Table 1: Probability and Severity Scoring Method (Adapted from EGBC, 2020)

Level	Sensitivity	Adaptive Capacity
1	Very Low: The likelihood that the system is affected remains minimal.	Very High: Adaptation measures are very easily implemented and effective.
2	Low: The likelihood that the main components of the system will be affected by the hazard is minimal. There is a low chance that the secondary components will be affected by the hazard.	High: Adaptation measures are very easily implemented and effective.
3	Moderate: There is a low chance that the main components of the system will be affected by the hazard. There is a good chance that the secondary components will be affected by the hazard.	Moderate: Adaptation measures exist, but their cost, time of implementation or efficiency makes their implementation questionable.
4	High: There is a high likelihood that the system will be directly affected by the hazard.	Low: The implementation of adaptation measures is long and inefficient and/or the cost of implementing accommodation measures is similar to the value of the system.
5	Very high: There is a high likelihood that the system will be directly affected by the hazard.	Very Low: Adaptation measures are non-existent or the cost of implementing adaptation measures exceeds the value of the system.

Table 2: Risk Matrix (Adapted from EGBC, 2020)

Vulnerability		Sensitivity Rating				
		Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Adaptive Capacity Rating	Very Low (1)	Very Low	Low	Moderate	High	Very High
	Low (2)	Very Low	Low	Moderate	High	High
	Moderate (3)	Very Low	Low	Low	Moderate	High
	High (4)	Very Low	Very Low	Low	Moderate	Moderate
	Very High (5)	Very Low	Very Low	Low	Low	Moderate

Based on the information and data reviewed, an initial probability scoring exercise was performed as shown in Table 3 below. The primary climate parameters and interactions were therefore limited to:

— Rainfall
— Temperature
— Snowfall

Table 3: Climate / Infrastructure Interaction Risk Profiles

Climate Parameter	Infrastructure Design Indicator	Will the Interaction Change Over Projected Horizon?	More / Same / or Less?	Magnitude of Projected Change	Frequency of Projected Change	Robustness of Forecast	Professional Judgement	Sensitivity Score
		Y / N	+ / -	H/M/L	H/M/L	H/M/L	Comments	0-5
		(A)	(B)	(C)	(D)	(E)	P =ƒ (A,B,C,D, & E)	**P**
5-Minute Short-Duration Rainfall	Drainage Outlet Spacing	Y	+	M	M	L	Low robustness due to statistical downscaling and interpretation of multiple sources of information.	**4**
Temperature	N/A	Y	+	H	M	M	Temperature Increase is likely and highly documented. Low robustness in winter temperature variation due to statistical downscaling.	**5**
Snowfall	N/A	Y	-	L	M	L	Low robustness due to statistical downscaling and interpretation of multiple sources of information.	**4**
Wind	N/A	Y	+	-	-	-	Not investigated; scope limited to roadway drainage design.	**-**
Sea Level	N/A	Y	+	-	-	-	Not investigated; scope limited to roadway drainage design.	**-**

Table 4: Climate / Infrastructure Interaction Risk Score

Design Component	Climate Parameter	Risk Assignment	Justification / Evidence
Bridge Surface Drainage	5-Minute Short-Duration Rainfall, 10 year return period	**2040s: Moderate**	The main input in drainage design is short-duration rainfall. There are potential plans in the future for a deck rehabilitation which suggests that this project would benefit from an adaptive approach with monitored performance. Due to the bridge's moderate posted speed at 80 km/h, and sufficient existing capacity to absorb climate change impacts in the short-term projection, the risk to the public is considered to be low. If deck rehabilitation is not completed in the 2040s, performance monitoring should be used to ensure continued proper drainage.
		2070s: Moderate	
	Temperature	**2040s: Moderate**	Warming is generally expected, but there could be a near-term increase in freeze-thaw cycles in the winter months, causing ice buildup if drainage is insufficient or if ice is not managed operationally. Since maintenance is likely to be the more economical and effective approach, it was given a low risk rating in terms of design, and excluded from the study.
		2070s: Low	
	Snowfall	**2040s: Low**	Precipitation as snowfall anticipated to decrease, however there is the potential for less frequent snow events to be larger in magnitude. Maintenance with respect to snow buildup is likely to be the more economical and effective approach, and it was therefore given a low risk rating in terms of design, to be excluded from the study.
		2070s: Low	
	Wind	**-**	Not investigated; scope limited to roadway drainage design.
	Sea Level	**-**	Not investigated as project is far from sea leve.

Conclusion

The existing bridge deck drainage arrangement has sufficient capacity to accommodate the 30% increase to design rainfall in the 2040's. It should be noted that the performance of the bridge drainage will only be assured with proper and regular inspection and maintenance during its service life. Regular inspection will detect any natural or unnatural debris that may block or partially block the conveyance of water, thus not allowing it to perform as designed. If a bridge deck rehabilitation is conducted in roughly 20 years, MoTI should revisit the vulnerability, risks and control measures considered in this assessment as new information becomes available, including climate projections, changes to operating parameters and local conditions.

Based on our assessment for the 2070's, roughly half of the bridge drains may not have sufficient capacity to accommodate the 60% increase to design rainfall. The maximum ponding is however limited to within 0.2 m of the 1.5 m criteria which, considering the relatively low 10% probability of occurrence (10 year return period), and moderate posted speed for traffic of 80 km/hr, would not impose a significant increase in risk to traffic safety in terms of hydroplaning compared to similar design criteria on major highways. Given that this scenario may not occur if drainage is improved, and given the relatively low risk it presents at the end of the project life of the bridge, improving drainage at this time may not be justified. . It is most economical to employ the Observational Method design approach to account for uncertainty in climate change projections, as described in EGBC's professional practice guidelines for climate-resilient highway infrastructure (2020).

At this stage it may be most economical to employ the Observational Method design approach as described in EGBC's professional practice guidelines for climate-resilient highway infrastructure (2020). This involves monitoring the drainage performance of the bridge deck, and implementation of a plan to modify the design in response to observed climate changes in the future. The overall objective of this approach is to achieve greater economy without compromising safety.

Recommended by: Engineer of Record:
(Print Name / Provide Seal & Signature)

Kevin Henshaw, P.Eng.

Date: ___March 17, 2021___

Engineering Firm: ___WSP Canada Inc.___

Accepted by BCMoTI Consultant Liaison: ____
(For External Design)

Deviations and Variances Approved by the Chief Engineer: ________________________________
Program Contact: Chief Engineer BCMoTI

Klohn Crippen Berger

October 7, 2021

WSP Limited
1045 Howe Street, Suite 700
Vancouver, BC, Canada V6Z 2A9

Keith Holmes, P.Eng.
Manager, Bridges

Dear Mr. Holmes:

Agassiz-Rosedale Bridge
Construction Wind Load Screening Study (DRAFT)

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Yours truly,

KLOHN CRIPPEN BERGER

Kristin Greinacher, P. Eng.
Project Manager

Permit to Practice No. 1000171

NK:nk

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South Coast Region

LOWER MAINLAND DISTRICT
HIGHWAY NO. 9
AGASSIZ–ROSEDALE BRIDGE NO. 01287 – RIVER SPANS

WIND LOAD COMBINATION D/C VALUES 220' SPAN

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ENGINEER OF RECORD

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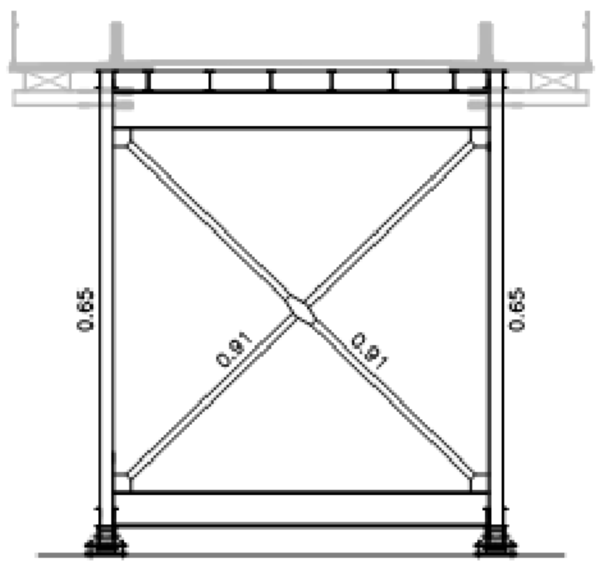

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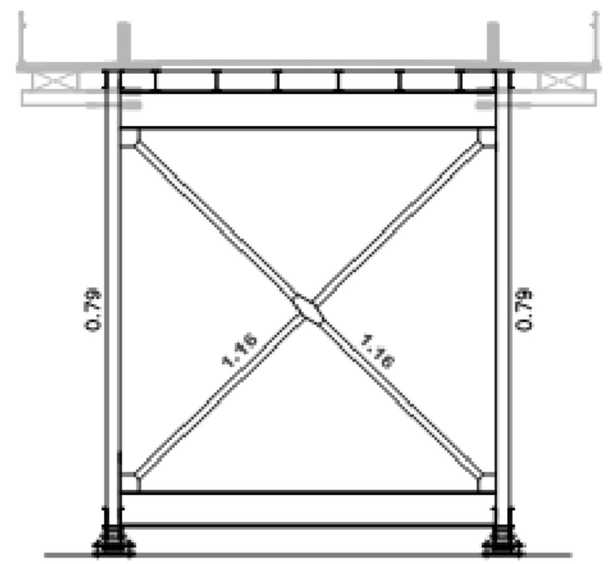

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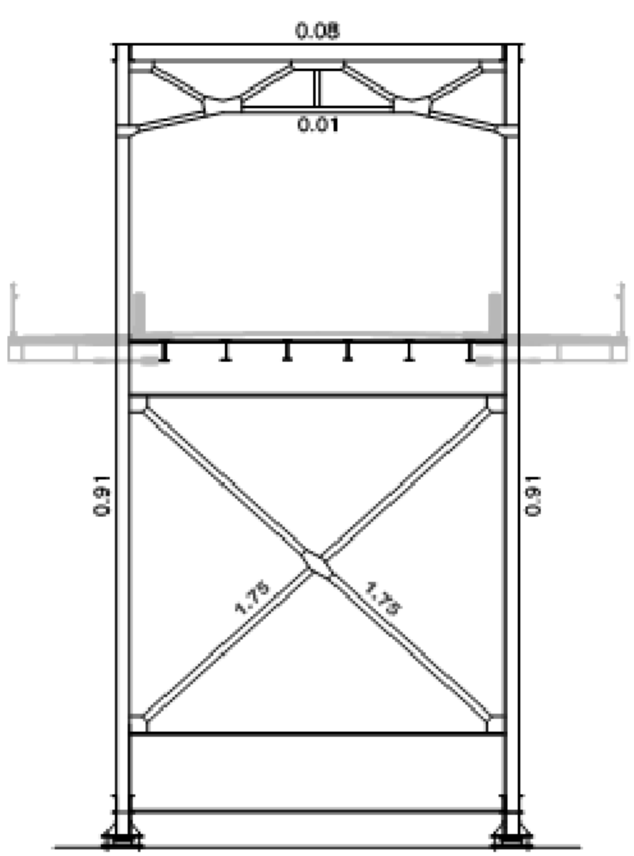

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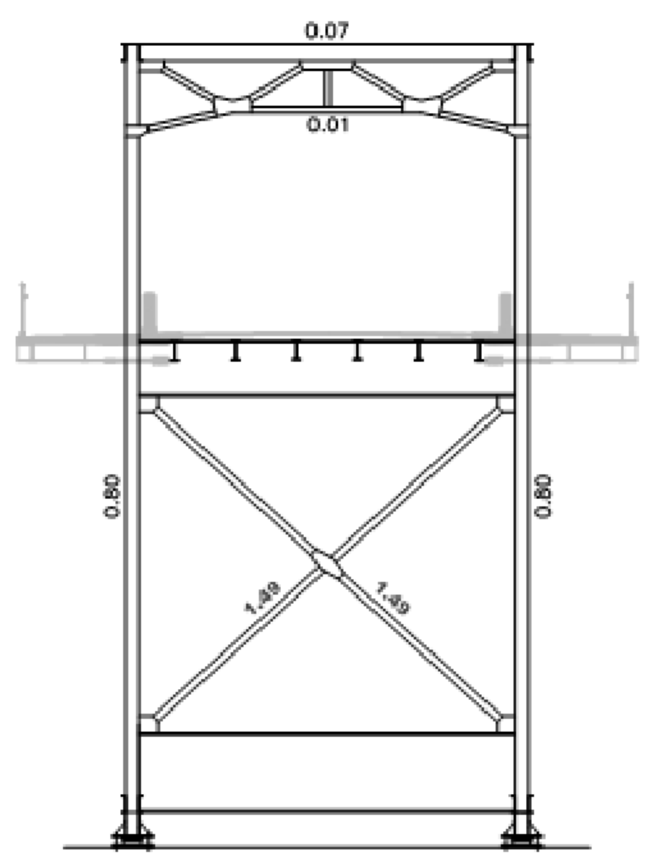

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